Drawers of water for life, but not for health.
How water carriage is associated with the health of water carriers.

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Abstract

Introduction

For many people, water carriage is a regular chore which is essential for life. However, the relationship between water carriage and health of the water carriers is not clear. The aim of this thesis is to answer the research question 'How is water carriage associated with the water carrier's health?'

Methods

A systematic review of literature, analysis of data from 49 Multiple Indicator Cluster Surveys, and a cross sectional survey conducted in South Africa, Ghana and Vietnam were used to investigate the relationship between water carriage and the health of water carriers. Water carriers are most often women and girls of child bearing age, therefore, maternal, early childhood and physical health outcomes were investigated.

Results

It was found that water carriage is associated with pain location and increased pain severity, but slightly better self-reported general health. Water carriage is also associated with reduced likelihood of a woman giving birth in a health care facility, reduced uptake of antenatal care, increased risk of child deaths, and increased risk of a child under five years of age having diarrhoea, and being left at home alone. The systematic review additionally highlights that water carriage is associated with fatigue and discrimination or abuse of vulnerable people and revealed plausible mechanisms by which water carriage may lead to psychological distress.

Conclusion

Water carriage is associated with a range of negative health outcomes and indicators, suggesting that it is not good for the water carrier's health. Water carriage is a potential barrier to achieving targets of the United Nations Sustainable Development Goals 6 'Ensure availability and sustainable management of water and sanitation for all' and 3 'Ensure healthy lives and promote well-being for all at all ages'. Overall the data support a conclusion that action should be taken now to reduce the need for water carriage, and to increase the number of people who can access water for household use in their own home or yard.

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List of acronyms and abbreviations

DFID	Department for International Development
WHO	World Health Organization
JMP	Joint Monitoring Programme of WHO and UNICEF
UN	United Nations
UNICEF	United Nations Children's Fund
MICS	Multiple Indicator Cluster Surveys
SIWI	Stockholm International Water Institute
ILO	International Labour Organization
LSHTM	London School of Hygiene and Tropical Medicine
UEA	University of East Anglia
UL	University of Leeds
UNC	University of North Carolina at Chapel Hill
TUT	Tshwane University of Technology
KNUST	Kwame Nkrumah University of Science and Technology
HSPH	Hanoi School of Public Health
WaSH	Water, Sanitation and Hygiene

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Statement of the candidate's contribution to jointly authored publications

Chapter 2, Chapter 3 and Chapter 4 include material that has previously appeared in jointly authored publications (Geere et al., 2018a, Geere and Cortobius, 2017, Geere and Hunter, 2019, Evans et al., 2013, Geere et al., 2018b) (Appendix 1, 2, 3, 4 and 5 respectively). The candidate's (JLG) contribution to the work reported in Chapter 2 was to identify the topic focus for the review, devise the search strategy and criteria for studies to be included in the review, complete the electronic data base searches, select papers to include in the review against the inclusion and exclusion criteria, extract data, and appraise articles reporting qualitative and quantitative data. JLG wrote the first draft of the journal article, reviewed and amended subsequent drafts, and reviewed and approved the final draft of the paper. To write Chapter 2, JLG edited, reformatted and added further information to the text of the paper. Moa Cortobius assisted with identification of the topic focus for the review, contacted experts in the field of water and health, provided translation of Swedish papers retrieved from the electronic data base searches, reviewed drafts of the published paper and reviewed and approved the final draft of the published paper. Jonathan H Geere (JHG) appraised articles reporting quantitative data, reviewed drafts of the published paper and reviewed and approved the final draft of the paper. Charlotte Hammer (CH) appraised articles reporting qualitative data, reviewed drafts of the published paper and reviewed and approved the final draft of the paper. Paul R Hunter (PRH) randomly selected a subset of retrieved papers and identified papers to include in the review against selection criteria, provided translation of French papers, appraised articles requiring consensus on quality rating, reviewed drafts of the published paper and reviewed and approved the final draft of the paper. Hazel Marsh provided translation of articles published in Spanish, Eneida Moshi of articles in Portugese and Umut Yukaruc of articles in Turkish. Jack Morris assisted with data extraction during scoping searches conducted in preparation for the published review.

The candidate's (JLG) contribution to the work reported in Chapter 3 was to design the study and propose the initial hypotheses to be tested, download and merge Multiple Indicator Cluster Survey (MICS) data files, generate descriptive statistics, propose the initial analysis plan and undertake all analyses personally with the support of Professor Paul R Hunter (PRH). JLG wrote the first draft of the two papers related to Chapter 3 (Geere and Cortobius, 2017; Geere and Hunter, 2019); amended and reviewed subsequent drafts of the papers and tables within them; responded to reviewer's comments; reviewed, amended and approved the final versions of the papers. To write Chapter 3, JLG edited, reformatted and added further information to the text and tables. PRH revised and developed the analysis plan, supported refinement of the hypotheses to be tested and supported the data analysis reported in Chapter 3. PRH also amended and reviewed drafts of the Geere and Hunter, 2019 paper text and tables; responded to reviewer's comments; reviewed, amended and approved the final version of the paper. Moa Cortobius contributed to the initial hypothesis generation as part of the study design, amended and reviewed drafts of the Geere and Cortobius, 2017 paper text and tables; responded to reviewer's comments; reviewed, amended and approved the final version of the paper.

The candidate's contribution to the work reported in Chapter 4 was to lead on the water carriage and physical health component of the Department for International Development (DfID) funded study titled 'Public Health and Social Benefits of at-house Water Supplies'. This included selecting questions from existing questionnaires, and creating additional survey questions, to indicate exposure to the work of water carriage and capture the physical health of water carriers, for incorporation into the overall DfID study questionnaire and survey. The candidate also developed a fieldworker training programme for use across all three countries, trained the fieldworkers in South Africa on data collection and advised the fieldwork supervisors of each country on how to administer the water carriage and physical health aspect of the survey and collect the data reported in Chapter 4. JLG generated descriptive statistics and undertook all analyses personally with the support of PRH; wrote the first draft of the published paper and tables; amended and reviewed subsequent drafts of the paper and tables; responded to reviewer's comments; reviewed, and amended and approved the final version of the paper. To write Chapter 4, JLG edited and reformatted the paper and added further information to the text and tables. PRH contributed to the overall design of the broader study, completed sample size calculations, developed the analysis plan for the overall DfID study, supported the data analysis reported in Chapter 4 and reviewed and approved the final version of the published paper. Jamie Bartram, Barbara Evans, Nora Groce and Wolf-Peter Schmidt contributed to the overall design of the broader study, and reviewed and approved the final version of the published paper. Laura Bates, Leslie Danquah, Michael B Fisher, Batsirai Majuru and Ashley Rhoderick Williams contributed to the design of the overall study, supervised data collection, and reviewed and approved the final version of the published paper. Michael M Mokoena, Murembiwa, S Mukhola, Hung Nguyen-Viet, and Phuc Pham Duc supervised data collection, and reviewed and approved the final version of the published paper.

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Chapter 1. Introduction and background to the thesis

1.1 Introduction

This thesis addresses the question of whether carrying water for household use is significantly associated with the heath of water carriers. The reported projects investigate how the physical work of drawing water from a source located away from the home, and then carrying water filled containers back to the home, is related to the health of the people performing these tasks.

Considering the biopsychosocial model of health (Engel, 1977) and the World Health Organization's definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (WHO, 2018), it is clear that water carriage may affect the health of water carriers in various ways and through physical, psychological or social mechanisms. For example, the health effects of water carriage work will be mediated by the physical characteristics of the water carrier, such as their strength, age and sex (Bonita et al., 2006). In many cultures, water carriage has long been a task allocated to women and children, with descriptions of women and girls collecting water incorporated into ancient stories of the bible (Genesis 24: 11, 13; 1 Samuel 9: 11; John 4: 7) and other spiritual traditions (Rinpoche, 2010). Health effects will also be mediated by psychological factors, including the water carrier's perception of the task and its characteristics, such as whether the work is perceived as stressful, considered a fair workload and within the water carrier's locus of control, or appropriately timed and paced (Davis et al., 2002, Geere et al., 2010b). Even though water is essential for life, the work of drawing and carrying water has often been afforded low social status (Vuorinen et al., 2007) and connected with other labour intensive tasks according to social norms of behaviour, interactions between social or cultural groups and social organisation of labour. For example in the biblical story of Joshua, the Gibbeonites were forced into permanent servitude as 'drawers of water and hewers of wood' in exchange for their lives (Joshua 9: 17, 21, 23).

In modern times, water carriage is common in low or middle income regions or countries where public or private water supply services are absent or limited, for example where they are provided to water points shared by a number of households (Sorenson et al., 2011, Pickering and Davis, 2012). Water is carried home from water sources in a variety of ways. Women in Africa have been observed to commonly carry twenty litre containers filled with water on their head, referred to as 'head loading' (Porter et al., 2012). Men, women or children might carry one or two buckets by the side of the body, or use simple equipment such as a wheelbarrow or cart, into which a number of containers are loaded and pushed or pulled home by human effort. Children have also been observed to roll large, sealed containers of water along the ground (Geere et al., 2010b). The volume of water carried per container varies between households and settings, but is commonly twenty to thirty litres (Geere et al., 2010a). In this thesis, transporting water with motorised vehicles or animal drawn carts is not considered ‘water carriage’, as the load is not carried or transported over distance by human effort. ‘Water carriage’ is synonymous with ‘water fetching’, and people who regularly engage with water carriage are referred to as ‘water carriers’.

The thesis begins with a global perspective, gained through a systematic review of peer reviewed and grey literature (Chapter 2), followed by analysis of data derived from forty nine Multiple Indicator Cluster Surveys (MICs) conducted in forty one countries (Chapter 3). It then becomes focused on data collected from a cross sectional survey conducted in three countries; South Africa, Ghana and Vietnam (Chapter 4). It concludes with a summary of the findings in this thesis, policy implications, acknowledgement of the limitations of the thesis, and suggested directions for future research.

A predominantly quantitative research approach is taken. An illustrative conceptual model to aid understanding of the relationship between the various factors and potential apriori confounders, as well as variables on the causal pathway between water carriage work and health outcomes was not developed prior to commencing the thesis. This was because very little was known about the relationship between water carriage and health at that time and it was not clear that any association actually existed. However, prior to commencement of the PhD programme, the author had conducted a mixed methods pilot study and scoping review of literature on the work of water carriage in South Africa (Geere et al., 2010a, Geere et al., 2010b) (Appendix 6 and 7) and collected qualitative data on how people reported water access to affect older adults and people living with disability or caring for people with disability in rural South Africa (Wrisdale et al., 2017) (Appendix 8). The scoping review indicated that most published reports were qualitative, based on opinion or small cross sectional studies. The pilot study, scoping review and further qualitative research indicated that people experienced a range of health related symptoms which they attributed to water carriage, and held a range of views about the reasons they struggled with limited water access and how water carriage affected their own health. Therefore, the findings of the pilot study, scoping review and further qualitative research generated the rationale supporting the overall aim of this thesis, which is to test the hypothesis that the human work of water carriage is significantly associated with the health of water carriers. Establishing whether a statistically significant association exists between water carriage and health was considered a necessary step prior to developing a conceptual model, which would otherwise be mainly speculative. A very sensitive literature review, incorporating analysis of existing qualitative data to identify the types of health conditions water carriers attributed to water carriage and symptoms that they experienced during water carriage, was deemed most useful to identify variables for analysis in an empirical study. Therefore, understanding of ways in which health might be affected, and consequently the choice of health outcomes to assess in relation to the hypothesis, were informed by the findings of the pilot study and also by the findings of the systematic literature review (Chapter 2), which included both quantitative and qualitative research. Thus the health outcomes investigated in relation to the overall hypothesis of the thesis, through more specific hypotheses tested and reported in Chapter 3 and Chapter 4, are derived from the findings of empirical research and the lived experiences of people engaged in the work of water carriage.

1.2 Background

1.2.1 Past research focus: Bradley classification

Most research into water and health has focussed on water related hazards and routes of infectious disease transmission, as described in the 1972 'Bradley Classification' (Bartram and Hunter, 2015). The classification includes four categories of water related disease; water borne, described as diseases in which water is the vehicle for the infective agent, for example by ingestion of pathogens present in drinking water; water washed, described as infections which can be reduced by having more water available, to prevent disease transmission with better hygiene; water based, in which the infecting organism has part of its life cycle in water and infection occurs during water contact, such as schistosomiasis; and diseases with a water related insect vector, such as malaria (Bartram and Hunter, 2015). Research has clearly shown that better access to safe water supplies can reduce the global burden of water related disease transmitted through these mechanisms and due to conditions such as infectious diarrhoea, malnutrition (as a consequence of repeated diarrhoea), trachoma and schistosomiasis (Bartram et al., 2005, Prüss-Üstün et al., 2008, Bartram and Cairncross, 2010). However, with the focus of water and health research on infectious disease, little attention has been paid to health problems associated with water collection when water is accessed or supplied away from home. Recognising this as a potentially important public health issue, Bartram and Hunter incorporated 'injury and violence associated with water collection' into their proposed modifications to the Bradley Classification (Bartram and Hunter, 2015).

1.2.2 Current global situation of water access: definitions of water access and the burden of water collection on women

The Joint Monitoring Programme (JMP) of the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) have also recognised the burden of water collection as an important issue, with the responsibility of water collection most commonly falling to women and girls. They reported that when water is accessed away from home or 'off plot', women and girls are responsible for water collection in eight out of ten households (WHO and UNICEF, 2017b). JMP data from 2015 also indicated that 263 million people spent over 30 minutes per round trip to collect water from an improved water source. Improved water sources are those which are less likely to be contaminated by pollutants or faeces because of how they are constructed, and include piped water, boreholes or tube-wells, protected dug wells, protected springs, and packaged or delivered water (WHO and UNICEF, 2017a). In 2015, an estimated 663 million people were using unimproved water sources or surface water. Surface water sources include rivers, dams, lakes, ponds, streams, canals or irrigation channels, and people using unimproved or surface waters are more likely to take over 30 minutes to collect water (WHO and UNICEF, 2017a). In 24 countries of sub-Saharan Africa, when water collection took more than 30 minutes, it was most often reported to be a woman's role, with 13.54 million women and 3.36 million children estimated to be responsible for household water collection taking more than 30 minutes per return trip in the region (Graham et al., 2016).

The JMP recently described levels of water supply service which incorporate water collection times in their water service 'ladder'. The highest level of service is 'safely managed water supply', which by definition is 1) accessible on premises, 2) available when needed and 3) free from contamination. A basic level of service is defined as drinking water obtained from an 'improved source', but lacking one or more of the three criteria above for safely managed services, and with a round trip collection time, including queueing, of not more than 30 minutes. In 2015, it was estimated that 6.5 billion people utilised at least a basic level of service, and 844 million people had a lower level of drinking water service (WHO and UNICEF, 2017a). People who lacked a basic level of service either used a 'limited' service (263 million people), which would involve a round trip water collection time of more than 30 minutes from an improved water source, or used unimproved water sources or surface water, both of which as mentioned above, are likely to involve round trip collection times of more than 30 minutes (WHO and UNICEF, 2017b). These estimates suggest that many more than 844 million people must regularly carry water, because many of those with a basic level of service will access water from off-plot sources as well as most of those living without a basic level of service.

The rationale for the 30 minute cut point between a basic and limited water supply service is derived from research in the 1970's and 1980's in sub-Saharan Africa, which found that distances to water source points which created a round trip collection time of 30 minutes or more greatly reduced the quantity of water accessed for household use, potentially increasing the incidence of water washed diseases (Cairncross, 1987). The 30 minute cut point is, therefore, not based on an understanding of how the work of water carriage affects the health or wellbeing of the water carrier, but based solely on the effect that a reduced quantity of water available in the household is proposed to have on risk of water washed diseases. Better understanding of how the work of water carriage is associated with the health of water carriers could provide a stronger rationale to justify and/or refine the definitions related to each rung of the JMP's water service ladder, and generate social and political will to support progress along them. It might also help to identify ways to make water carriage safer and easier for people who will continue to access water away from their home. To investigate the relationship, variables related to how water is collected and carried, as well as potential mechanisms by which water carriage might directly or indirectly affect different health outcomes, should be considered.

1.2.3 Method of water collection and exposure to water carriage work

Water collection is often done by physically carrying containers filled with 20 to 25 litres of water on the head, carrying buckets or jerry cans by the side or with a yoke across the shoulders, or by loading containers into simple equipment such as a wheelbarrow (Geere et al., 2010a, Evans et al., 2013). Analysis of 29 Multiple Indicator Cluster Surveys (MICS) completed in 23 countries from eight global regions revealed an overall average time of 28 minutes to collect water and return (Geere and Cortobius, 2017), similar to the average return trip time reported for sub-Saharan African countries (UNICEF and WHO, 2015). However, average water fetching trip times vary considerably between countries within regions, and for different settings within countries. A study by Sorenson et al., in 44 different countries, reported that the mean time taken for single trips to the main water source and back per country ranged from seven to 67 minutes (Sorenson et al., 2011), and Geere and Cortobius (2017) reported statistically significant differences in rural versus urban water fetching trip times, which could be either increased or decreased in rural compared to urban areas within different countries. Furthermore, single trip times do not indicate the total time spent fetching water, as the number of trips completed by an individual per day will vary depending on household needs, number of household members engaged in fetching water, and the method of carrying water containers (Geere et al., 2010a, Geere and Cortobius, 2017).

The years of exposure to the work of water carriage may begin in childhood (Geere et al., 2010b, Porter et al., 2012) and continue into older age (Schatz and Gilbert, 2014, Wrisdale et al., 2017). Therefore, the stresses induced by the physical work required for water carriage, due to differences in the total volume of water carried per trip and per day and the method of water carriage, compared to the physical capacity or fitness of the water carrier, are likely to influence how easy or difficult water carriage work is for each person. Such factors, as well as any challenges of the physical and social environment, will also influence the potential for water carriage to affect the water carrier's health positively or negatively, through direct or indirect mechanisms.

1.2.4 Direct health impacts

Direct health impacts of water carriage might occur through a variety of mechanisms, such as acute or chronic tissue strain from carrying heavy water filled containers, or interpersonal violence or accidental injury from collecting water in unsafe environments. Psychological distress may also be caused by the challenges of negotiating access to sufficient water to survive and maintain personal and household health and dignity. Energy expenditure required for the work of water carriage may also affect the water carrier's health. For example water carriage may have adverse health outcomes if the physical energy required for it exacerbates undernutrition or malnutrition in areas where people are affected by hunger or food insecurity, or have beneficial outcomes if it contributes to a regular and healthy dose of physical activity. If the work of water carriage is well suited to an individual's physical and energetic capacity to do the work, it may also lead to healthy adaptations, such as strengthening of the musculoskeletal system, improved endurance of the cardiovascular system, and reduced risk of being overweight or obese.

1.2.5 Indirect health impacts

Through time costs, or as a secondary consequence of direct health impacts such as fatigue, water carriage may indirectly affect the health of water carriers. It may take up time needed to travel to and access health services, such as antenatal care, or influence decisions on whether to give birth in a health care facility or at home. It may also restrict opportunities to engage in better livelihoods, meaningful occupations and activities involving social participation that foster good health (Jepson et al., 2017, Wrisdale et al., 2017). For example, water carriage may limit the quantity of water available for growing food at home for family consumption or sale, consume time for other domestic or paid occupations, or limit a parent's capacity to care for or spend time with their children. It may also detrimentally affect children's attention and engagement at school, with homework or in sport if they are tasked with water carriage. Ability to participate in meaningful occupations and education are both associated with, and can be considered integral to, good health and wellbeing (Cieza et al., 2008). More positively, water carriage might be the meaningful occupation which enables individuals to meet cultural, social and familial obligations or demonstrate reciprocity. It may also be an activity which leads to additional productive or income generating activities, such as brewing beer, or washing laundry for payment.

1.2.6 Health outcome measurement and health indicators

Because of the potential direct and indirect impacts on health, water carriage may be associated with a range of positive and negative consequences and health outcomes. It will disproportionately affect women and girls because they most commonly perform the work (Graham et al., 2016, Geere and Cortobius, 2017, WHO and UNICEF, 2017b). Collection and analysis of data to establish whether water carriage is independently associated with either poorer or better health outcomes, is an important step prior to further research into which causal pathways operate in specific contexts. Many women and children who carry water also contend with a complete lack of, or use unimproved sanitation facilities. Even households with improved access to water and in which water carriage is not required, may lack toilet facilities or use unhygienic and poorly maintained facilities. Health problems associated with poor sanitation may therefore mask or undermine any health benefits from easier access to improved water supplies, and so where possible, data on sanitation use should be included in analyses as a confounding factor.

Health outcomes potentially associated with water carriage could be captured in a variety of ways, for example by using questionnaires to gather self-reported symptoms such as pain or fatigue, observational surveys which collect anthropometric measures, such as measuring weight and height to calculate body mass index (BMI), or by indirect indicators such as increased incidence of child deaths and childhood stunting (short height for age) or wasting (low weight for height or weight for age) in households where the children's mothers collect and carry water. For example, the energetic cost of water carriage might exacerbate the effects of undernutrition or malnutrition on women and girls who are pregnant or lactating, and subsequently affect the health of their very young children. Adequate nutrition during a child's first one thousand days, from inception to age two, is critical for childhood growth and development, and breastfeeding is highlighted by Save the Children as the 'single most important nutrition intervention for saving lives', as well as being key to reducing the short and long term effects of childhood malnutrition (Agnew et al., 2012). If the energetic cost of a mother's water carriage work is sufficient to affect her health during pregnancy and impair her ability to breastfeed, an association between water carriage performed by adult women and their children's health, as indicated by deaths of children under five years of age, under five weight for age or under five height for age, might exist. Therefore, a relationship between women's water fetching and childhood health indicators may occur in countries subject to food scarcity, such as South Sudan, Democratic Republic of Congo, Somalia and Ukraine (Alam et al., 2014, OCHA, 2018) or in poor urban areas (Amaditz et al., 2015).

1.2.7 Water carriage and the Sustainable Development Goals

In September 2015, Heads of State and Government and High Representatives, met at the United Nations (UN) Headquarters in New York to agree a new set of Sustainable Development Goals to be achieved by 2030 (UN, 2015c). Sustainable Development Goal 6, to 'ensure availability and sustainable management of water and sanitation for all' includes target 6.1; 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all' (UN, 2015b). 'Equitable access' implies that there should not be any disadvantage for individuals or households because of different methods of accessing safe drinking water, due to different levels of water supply service. Yet it is hard to see how people who must expend time and energy, and perhaps risk their personal health and safety to obtain drinking water, are not disadvantaged compared to those who have water available in their house or yard. This is implicitly recognised within the indicator for target 6.1, currently proposed to be 'the proportion of population using safely managed drinking water services' (UN, 2015b). 'Safely managed' drinking water is defined by the World Health Organization (WHO) and United Nations Children's Fund (UNICEF) Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) as 'drinking water from an improved water source that is *located on premises* (author's emphasis), available when needed and free from faecal and priority chemical contamination' (WHO and UNICEF, 2017b).

If water carriage is associated with detrimental health outcomes for the water carrier, then the rationale supporting the indicator for SDG target 6.1 will be strengthened further through its connection to SDG 3; 'Ensure healthy lives and promote well-being for all at all ages'

(UN, 2015c). Environmental factors such as inadequate water, sanitation and hygiene (WaSH) are highlighted as major contributors to the global burden of illness and death, however, whether water carriage as a specific aspect of inadequate water access is associated with poorer health outcomes is not clear. Given the emphasis in SDG 3 on improving maternal and child health, and the fact that it is most often women and children who collect and carry water home, the relationship between health outcomes pertinent to this population and water carriage is worthy of investigation. Evidence of an association between the work of water carriage and poorer health outcomes could be used in efforts to enhance national and local political will to increase the proportion of people using safely managed water supplies on premises or at home. It will also confirm that the different levels of water supply service below the optimum of 'safely managed' supply, which require millions of women and children to collect and carry water filled containers, are not only a potential barrier to achievement of SDG 6, target 6.1, (UN, 2015b) but also to SDG 3; good health and wellbeing, secured for all people, across the whole lifespan (UN, 2015c).

For people obtaining water from off-plot sources, any adverse health impacts associated with water carriage would be likely to make bringing safe drinking water into the home more difficult, and therefore make water access more 'inequitable' for them as compared to people with safe water piped into their homes. In relation to SDG 3, water carriage could also be identified as a potential mechanism which increases health inequalities between water carriers and people who do not have to carry water, if water carriage is associated with poorer health outcomes. Water carriage is also likely to have implications for the feasibility of achieving SDG 5 (gender equality) because women and girls mainly collect water (Graham et al., 2016), SDG 4 (quality education) because it may lead to absence from school or lack of engagement during school and with homework (Porter et al., 2012), and SDGs 1 (end poverty in all its forms), 8 (decent work and economic growth) and 10 (reduced inequalities) because the time costs of water carriage may reduce opportunities to engage in other meaningful and productive activities (Wrisdale et al., 2017). As a factor contributing to increasing inequalities, and as a consequence of power struggles and abuses linked to water access (Zeitoun, 2012), the work of water carriage may also be a barrier to SDG 16 (promote peaceful and inclusive societies) (UN, 2015c).

1.3 Research aim and specific hypotheses

The aim of the PhD thesis is to answer the research question 'How is water carriage associated with the water carrier's health?' which was derived from the general hypothesis that the human work of water carriage is significantly associated with the health of water carriers. Four specific hypotheses are tested in relation to this question.

1.3.1 Hypothesis 1: Household water carriage is associated with increased risk of adverse maternal and child health consequences

Women and girls are most often the household water carriers (WHO and UNICEF, 2017b), therefore, it is predicted that maternal health, and as a consequence, the health of their very young children (those five years of age or younger) will be adversely affected by water carriage work, depending on the age and sex of the person usually responsible for collecting water in the household. Indicators used to identify an association between water carriage and increased risk of adverse maternal and child health outcomes at the household level are a woman's place of giving birth and up-take of antenatal care, childhood deaths, diarrhoea, WHO weight for age and height for age z-scores, and whether a child under five years of age is left completely alone for an hour or more on one or more days per week.

1.3.2 Hypothesis 2. Carrying water is associated with water carriers experiencing bodily pain

A mixed methods pilot study indicated that water carriers attribute pain and problems with movement to water carriage, key symptoms of musculoskeletal disorders (Geere et al., 2010a, Geere et al., 2010b). Manual labour which involves regular or repeated lifting and carrying, as occurs during water carriage, is associated with musculoskeletal disorders (Kilbom et al., 1996). It is therefore predicted that water carriage is associated with self-reported pain indicative of musculoskeletal disorders, and characterised by pain location, severity, duration and constancy of pain.

1.3.3 Hypothesis 3. Carrying water is associated with increased disability affecting the water carrier

Musculoskeletal disorders are a common cause of years lived with disability in low and middle income countries (Hoy et al., 2014) and likely to affect a person's ability to use their limbs or body and engage with functional activities of daily living. It is predicted that as a consequence of increased pain or physical injury, water carriage will be associated with impaired physical function, indicated by self-reported problems with walking, or using the upper limb, lower limb or body.

1.3.4 Hypothesis 4. Carrying water is associated with general health of the water carrier

A pilot study indicated that people variably attribute either better general health or poorer general health to the physical activity of water carriage (Geere et al., 2010b). The relationship between physical activity and general health is likely to vary according to the level of physical activity an individual typically engages with, or which is required for a specific activity. It is therefore predicted that water carriage is associated with general health, but not whether water carriers will report better or worse general health compared to people who do not carry water.

1.4 Summary

The work of water carriage is clearly relevant to SDG 6 and if it is associated with health outcomes, is also relevant to SDG 3. It is also likely to be relevant to multiple other SDGs, and therefore, to the current UN agenda to 'transform the world' by 2030 (UN, 2015c). If either direct or indirect health outcomes are associated with water carriage, when water is supplied or accessed away from home, it has potential to challenge achievement of the SDGs and increase inequalities in human health and wellbeing nationally, regionally and globally. Any detrimental health outcomes associated with water carriage are most likely to affect women and children, because they are most often allocated the tasks of collecting and carrying water. It is therefore timely to review existing evidence and further investigate water access, with a clear focus on trying to better understand whether, and how, the work of water carriage is associated with the health of water carriers.

Chapter 2. A systematic review of the relationship between water carriage and the health of water carriers

2.1 Introduction

Historically, the focus of water and health research has been on management of water quality and risk or prevalence of infectious disease. More recently, interest in the work of carrying water from sources located away from the home, or 'off-plot', has been raised by the World Health Organization, UNICEF (Chan, 2007, WHO and UNICEF, 2017b) and the International Labour Organization (ICLS, 2013). Understanding how water carriage impacts upon water access and is related to health is relevant to the UN Sustainable Development Goal (SDG) 6, target 1 'universal and equitable access to safe and affordable drinking water for all' (UN, 2015b), and SDG 3, which aims to ensure 'healthy lives and promote well-being for all at all ages' (UN, 2015a). If, as noted in 1.2.7, the work of water carriage is in fact a barrier to SDG 6 and 3, then it is also potentially a barrier to other SDGs which are dependent on or interdependent with access to sufficient water and good health, such as SDG 1 (end poverty in all its forms), SDG 4 (quality education), SDG 5 (gender equality), SDG 8 (decent work and economic growth), SDG 10 (reducing inequalities) and SDG 16 (peaceful and inclusive societies).

Previous research has demonstrated an association between distance or time to water source and health of children in the home, as indicated by diarrhoeal disease, and child anthropometrics and mortality (Hunter et al., 2010, Wang and Hunter, 2010, Pickering and Davis, 2012). Stelmach and Clasen (2015) reviewed the association between water quantity and health. In low income countries, incidence of trachoma and gastro-intestinal related disease improved with increased quantity of water in the home, and in high income countries, higher levels of water consumption were associated with renal and bladder cancer, but not type II diabetes. What is absent from these studies of distance to water source and increased household water quantity, is investigation of how these factors affect the health of the person who brings water into the home.

It is clear that women and children most commonly collect and carry water home for household use (Graham et al., 2016, Geere and Cortobius, 2017, WHO and UNICEF, 2017b), often by carrying 20 to 25 litre containers on their head or by other methods such as loading a number of containers into a wheelbarrow (Geere et al., 2010a, Evans et al., 2013, Geere, 2015). What is not clear, is whether the work of water carriage, independent of other forms of manual labour and load carriage, has an impact on the health of water carriers. Whilst typical volumes and therefore weights of water may be less than typical loads carried for paid work, water carriage may be repeated multiple times within a day to obtain enough water for household use, or to store water and mitigate against unreliable water supplies. Water carriage may start at a young age and continue into older age. This is because water is essential for survival and basic hygiene, yet in many areas where water must be carried home from an off-plot source, the middle age cohort of healthy adults are absent due to economic migration, illness or death (Schatz and Gilbert, 2014). The task may also be delegated to children as part of their normal household chores and contribution to family life (Hemson, 2007). This means that the burden of this work may often fall on those with reduced physical capacity to perform it, that is, children and older adults rather than working age adults (Geere, 2015).

The method of carrying water from off-plot sources varies depending on whether equipment, such as wheelbarrows suitable for use in the local environment, is affordable and available, and cultural or social norms, which influence decisions around who should perform the work of water carriage and how people carry containers (Geere et al., 2010a). Environmental and social challenges to safely completing the work of water carriage will also vary greatly in different regions, for example traffic may pose a greater danger in urban compared to rural areas (Mohan, 2008), and areas affected by war and conflict may pose significant threats to personal safety (Zeitoun, 2012). Therefore, the health impact of water carriage is likely to be variable depending on the characteristics of the individual who performs the work, and social and environmental factors that differ between settings. Differences in health impact may exacerbate existing inequalities which variably affect access to safe water within and between regions and may also exacerbate household water insecurity (Jepson et al., 2017).

With more attention focussed on this issue in recent years, and it’s relevance to the UN’s global agenda for change, a review of the published literature to summarise what is currently known about the health impacts of water carriage and to identify gaps in the existing knowledge base is timely. Therefore a systematic review of published and grey literature was conducted with the aim of answering the review question: ‘Is the work of water carriage associated with the health of individuals who fetch and carry water for household use?’

2.2 Methods

A systematic review of literature published in peer reviewed academic journals was undertaken to identify research investigating the relationship between water carriage and health. The peer review process is intended to support the publication of findings from good quality research which has used valid measurement and analysis methods (Elsevier, 2017). Therefore, electronic searching was conducted in data bases containing journals which utilise a peer review process, include relevant disciplines and have an appropriate scope of content. Relevant research may also be conducted for government or non-government organisations with the findings published in non-commercial reports as 'grey literature'. Therefore, the review also included searches of relevant grey literature electronic data bases.

2.2.1 Search strategy

A search of electronic data bases was conducted 8th November 2017 by one reviewer (JLG). Seven electronic databases were accessed; Embase; Medline; Web of Science Social Sciences Citation Index (1956 - present) selecting public, occupational and environmental health themes; Web of Science Arts and Humanities Citation Index (1975 - present), and grey literature databases provided by the International Initiative for Impact Evaluation (http://www.3ieimpact.org/), the WHO Virtual Health Sciences Library (www.emro.who.int/information-resources/vhsl/), and the WHO African index medicus. The use of Medline and Embase has been recommended to enhance search sensitivity, as there is minimal overlap of journal content between the two data bases (Furlan et al., 2009). The Social Sciences and Arts and Humanities Indexes were used to broaden the search and retrieve research reports on sociological, environmental and psychological aspects of household access to water and which might also include information about the work water fetching and health impacts on water carriers. The grey literature was searched to capture research reports published in non-commercial form. All databases were searched from inception to 8th November 2017. Experts in the field of water access and health were also contacted to identify relevant literature, particularly on the topic of safety and gender based violence in relation to WaSH access, because few papers were initially identified on the topic through the electronic searching of peer reviewed literature.

Advanced search strategies were conducted using key terms combined with boolean operators to maximise search sensitivity. Terms were also mapped to medical subject headings in Medline (MeSH) and Embase (Emtree). Truncation terms and searches in all fields ('.af') were used to maximise search sensitivity in each data base.

Combination of terms and Medical Subject Headings used in Medline (OVID platform):

1. Exp Water Wells/ or exp Fresh Water/ or water.mp. or exp Water/ or exp Water Resources/ or exp Water Quality/ or exp Water Supply/ or exp Drinking Water
2. Water.af.
3. 1 or 2
4. (Household$ or house$ or home$ or homestead$ or family or domestic or domicile or dwelling$ or dwelling-place$ or yard$ or plot or plots or off-plot or on-plot or residence$ or residential).af
5. Household.mp. or exp Family Characteristics/
6. 4 or 5
7. (fetch$ or carry or carriage or carrying or carrie$ or courier$ or bear or bear$ or convey$ or transport$ or porter$ or haul$ or cart$ or deliver$)af.
8. 3 and 6 and 7
9. Limit 8 to humans

Combination of terms and Emtree headings used in Embase (OVID platform)

1. exp water/ or exp tap water/ or exp drinking water/ or exp lake water/ or exp water supply/ or exp river water/ or exp fresh water/ or Water.mp. or exp water quality/ or exp well water/ or exp surface water/ or exp water availability/ or exp ground water/
2. water.af.
3. 1 or 2
4. household.mp. or exp household/
5. (Household$ or house$ or home$ or homestead$ or family or domestic or domicile or dwelling$ or dwelling-place$ or yard$ or plot or plots or off-plot or on-plot or residence$ or residential).af.
6. 4 or 5
7. (fetch$ or carry or carriage or carrying or carrie$ or courier$ or collect$ or bear or bear$ or convey$ or transport$ or porter$ or haul$ or cart$ or deliver$).af.
8. 3 and 6 and 7
9. limit 8 to human

Combination of terms used in Social Science Citation Index:

1. Water
2. house* OR home* OR family OR domestic OR domicile OR dwelling*OR yard* OR plot* OR off-plot OR on-plot OR residence OR residential
3. Fetch* OR carry OR carriage OR carrying OR carrie* OR courier OR collect* OR bear* OR convey* OR transport* OR porter* OR haul* OR cart* OR deliver*

4. 1 and 2 and 3
5. and document types: (article)

Grey Literature:

Combination of terms used in WHO data bases with advanced search tool searching all fields

1. water
2. Household or house or home or homestead or family or domestic or domicile or dwelling or dwelling-place or yard or plot or plots or off-plot or on-plot or residence or residential
3. fetch or carry or carriage or carrying or carries or courier or bear or bear or convey or transport or porter or haul or cart or deliver

WHO African Index Medicus: The search terms for Medline were entered without use of the truncation symbols, using the advanced search tool in all fields.

International Initiative for Impact Evaluation: The terms water and health were entered within the areas of impact evaluations, and systematic reviews, using their advanced search tool.

2.2.2 Selection criteria

Articles and reports of research were included in the review according to predetermined selection criteria, described below. Studies reporting health outcomes of children under the age of five years were excluded because a mixed methods pilot study reported previously (Geere et al., 2010a; Geere et al, 2010b) did not observe any children under five carrying water for household use, even though they frequently accompanied their mothers on water fetching trips. The scoping review also indicated that published reports of the health of children under five years of age focussed on health outcomes related to infectious diseases and nutrition, and did not report whether a child under five carried any water. Whilst water carriage performed by children under five is likely to cause health problems if it occurs, for example due to axial loading of the developing spine, a decision was made to exclude studies which only focussed on the health of children under five because they were very unlikely to include such cases.

2.2.2.1 Inclusion criteria

- Quantitative research reporting the relationship between variables related to the physical work of carrying filled water containers and variables related to the health of the water carrier

- Qualitative research where people who carry water report their views of how and/or why they believe water carriage has some effect or influence on their own health, or the health of others who carry water
- Studies reported in English, French, Spanish, Portuguese, Swedish or Turkish

2.2.2.2 Exclusion criteria

- Studies reporting health only of children aged 5 or less and without information on water carriage practices of their mothers, because children of this age are not likely to carry substantial water for household use (see 2.2.2)
- Studies reporting variables related to water access and water carrying, but not reporting health of the water carrier other than prevalence or indicators of infectious or vector borne diseases
- Studies reporting the relationship between the exposure variable of water contact due to water fetching and health outcomes related to prevalence or incidence of infectious disease, and not reporting variables related to the physical work of carrying water containers and health outcomes other than those related to infectious disease
- No report of empirical data of health related variables or health impacts of water carriage on people who carry water (only includes secondary reporting of analysis findings)
- Qualitative studies which do not explore how people report or explain their views on the relationship between the work of water carriage and the health of people who perform water carriage
- Article with a topic focus on sanitation, hygiene, water source type, and water source or household water contamination or treatment, without data on the work of water carriage and health of water carriers
- Article with information on 'water insecurity' and health, without any data about the impact of physically carrying water containers (as an aspect of water security) on health, disaggregated from other aspects of water insecurity (such as limited water quantity or quality)

2.2.3 Data extraction

Where studies separately presented analyses of multiple risk factors or independent variables, and multiple outcomes or dependent variables, only findings which reported the relationship between variables related to the work of water fetching and health outcomes of the water carrier were extracted. For example if type (piped, spring or well) or location (piped to house, to yard or public tap) of water source was an independent variable analysed for its relationship with health, this data was extracted as an indicator of the health impact of water fetching activity if it also distinguished between people who would need to fetch and carry water from those who would not, or indicated the extent of water carriage work required for different source types, and no other analysis of the relationship between variables related to water fetching work and health was provided. However, where more detailed and specific data on water fetching work was provided, such as time spent fetching water, distance to water source or method of water carriage, and its relationship to health of the person performing the work was analysed, water source type and location data was not extracted. Where variables related to water fetching were included in analyses together with other variables, for example in regression analyses, the findings of the models were extracted. No studies were excluded on the basis of methodological quality, however methodological quality was appraised to aid evaluation of the strength of available evidence for answering the review question.

2.2.4 Analysis

Summary measures, statistics and qualitative themes reported in the studies were diverse, and findings are presented as reported in each study. Meta-analysis was planned. However, the studies included in the review were too heterogeneous to perform a meta-analysis, because of differences in the characteristics of study samples, and exposure variables or outcomes measured. Therefore a narrative synthesis was completed.

2.2.5 Assessment of methodological quality

No studies were excluded on the basis of methodological quality, which was appraised independently by two reviewers; JLG and CH for qualitative aspects of studies, and JLG and JHG for quantitative aspects of studies. Where differences in quality scores could not be agreed a third reviewer (PRH) was consulted to achieve consensus.

The U.S. Department of Health and Human Services, National Institutes of Health Quality Assessment tool for observational cohort and cross-sectional studies (NIH, 2014) was used for quality appraisal of 26 studies which reported quantitative data (Buor, 2004, McCray, 2004, Foggin et al., 2006, Gibson and Mace, 2006, Rao et al., 2007, Hemson, 2007, BeLue et al., 2008, Borah et al., 2010, Geere et al., 2010a, Rauniyar et al., 2011, Devoto et al., 2012, Singh et al., 2012, Stevenson et al., 2012, Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, Ono et al., 2013, Henley et al., 2014, Mugambe et al., 2014, Berrian et al., 2016, Cook et al., 2016, Hennegan et al., 2016, Krumdieck et al., 2016, Dapaah and Harris, 2017, Geere et al., 2018a, Thomas and Godfrey, 2018). The NIH critical appraisal tool is useful to guide evaluation of the internal validity of cohort and cross sectional studies, and whether the reported associations could be explained by systematic error due to bias or measurement error (Appendix 9). The tool also supports evaluation of whether confounding factors may have influenced the results, by considering whether variables with a potential association with both the risk factor and outcome under investigation have been incorporated into the analyses (Beaglehole et al., 1993, Bonita et al., 2006). The likelihood of the study outcome being due to chance can be evaluated considering reported p values and confidence intervals, and the risk of incorrectly rejecting a null hypothesis ('false positive' or type 1 error) or failing to reject a false null hypothesis ('false negative' or type 2 error) by considering sample size and whether a sample size calculation was reported (NIH, 2014). To be consistent with the NIH guidance for determining the overall quality rating of the studies (p 9, Appendix 9) the reviewers independently judged the risk of bias for each study and provided a rating of poor quality (high risk of bias), fair quality (medium risk of bias) or good quality (low risk of bias). Agreement was reached through discussion of the study design and responses to the appraisal tool questions, and on one occasion when consensus was not reached, a third reviewer (PRH) was consulted.

The rigour of qualitative research can be evaluated with the use of a critical appraisal tool such as the checklist developed by the Critical Appraisal Skills Programme (CASP) (CASP, 2017). The Critical Appraisal Skills Programme (CASP) tool (CASP, 2017) was used for quality appraisal of 21 studies (Foggin et al., 2006, Hemson, 2007, Geere et al., 2010b, Domenech et al., 2012, Stevenson et al., 2012, Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, House et al., 2014, Isoke and Van Dijk, 2014, Mukuhlani and Nyamupingidza, 2014, Schatz and Gilbert, 2014, Bisung et al., 2015, Sarkar et al., 2015, Subbaraman et al., 2015, Ghosh et al., 2016, Mbereko et al., 2016, Zolnikov and Blodgett Salafia, 2016, Ayoade et al., 2017, Mercer and Hanrahan, 2017, Thomas and Godfrey, 2018) which were qualitative or of mixed methods and reporting a qualitative component to the study. The CASP tool (Appendix 10) assists evaluation of whether qualitative data was collected appropriately, analysed with sufficient rigour and interpreted and reported with enough explanation to provide trustworthy results (Creswell, 1998). Rigorous qualitative research can provide additional lines of evidence to that derived from quantitative research, particularly when the aim of research is to better understand how or why activities impact on the health, wellbeing or quality of life of individuals or communities (Creswell, 1998, Mason, 2002b). The tenth and final CASP tool question ‘How valuable is the research?’ was replaced with a quality score rating studies as ‘poor’, ‘fair’ or ‘good’. Studies with three or fewer of the first nine CASP questions scoring a ‘yes’ response, were deemed to have provided insufficient information to have confidence in the study quality, therefore they were rated as ‘poor’. Studies were rated as ‘fair’ if four or five questions had yes responses, because this allows for descriptive information of the study’s aim and findings, and at least some detail about how the study was conducted, to be included. Studies were rated ‘good’ if six or more of the appraisal criteria scored a ‘yes’ response, because this allows for most study design issues of importance to be reported sufficiently to provide evidence of rigour.

A wide variety of systems to grade the strength of evidence gathered in systematic reviews have been reported, however most place emphasis on a hierarchy of research design considered most robust for determining the effectiveness of a clinical intervention (West et al., 2002). This results in systematic reviews of randomised controlled trials, followed by randomised controlled trials, being considered in these systems as the highest form of evidence which can support a cause and effect relationship between exposure and outcome variables. However, many variables of relevance to public health research cannot be randomly allocated to experimental groups for practical and ethical reasons, and so data is more often derived from observational studies. Randomised controlled trials also do not draw on the diversity of subjective data which can be derived qualitative research, by allowing participants to express their experience in personally meaningful and unique ways. Therefore a system reported by Hoogendoorn et al., (1999) was used to rate the strength of evidence from observational cohort and case-referent studies, considering study quality, number of studies, and consistency of findings across studies. Hoogendoorn et al’s., approach was modified by applying it to the synthesis of cross-sectional and qualitative studies and incorporating the NIH and CASP ratings of study quality. This was done because the aim of the review was to use quantitative data to identify whether water carriage is associated with reported health problems, and qualitative data to gain insight into how and why the association may be real, even if it were not possible to establish a cause and effect relationship. There was no funding source for this study.

2.3 Results

2.3.1 Results of the search strategy

A total of 19,758 titles were retrieved through the electronic data base searches (Figure 2.1). A further 37 papers were flagged electronically whilst retrieving full text papers from the data bases, identified in references lists of retrieved papers or obtained from contacting WaSH experts. Once duplicates were removed, 12,131 articles remained for further screening of abstracts and titles against the inclusion and exclusion criteria. Of these, 11,789 articles were excluded, because the title and abstract clearly indicated that the content was irrelevant to the purpose of this review; or because health outcomes were reported only for children aged five or less or for cases of infectious disease; or they reported only sanitation and hygiene practices or household water supply type without information about water source location (i.e. does not indicate need for water fetching work).

In total, the full text of 342 articles was obtained for review against the inclusion and exclusion criteria. Of these, 300 were excluded because they did not include data on either the work of water fetching or health of water carriers or both. Articles which focused on the health impact of physical contact with water at the point of collection, for example reporting prevalence of schistosomiasis infection and observed or reported water contact time during water fetching activities, were also excluded because such studies do not provide information on the association between health and the work of carrying water containers home. Initially 42 articles and research reports were included in the review, however one report found in the grey literature searches was subsequently excluded as it reported the same data as a published journal article, and one article (Porter et al., 2012) was subsequently excluded because data on water carriage was not fully disaggregated from carriage of other types of loads, and fully disaggregated data focussing on water carriage from the same study was provided in another report (Robson et al., 2013). One study was reported in two papers (Geere et al., 2010a, Geere et al., 2010b), both of which were included because different data was provided in each report. In total 40 articles reporting 39 studies were included in the review, which reported associations between the health of water carriers and the work of water carriage.

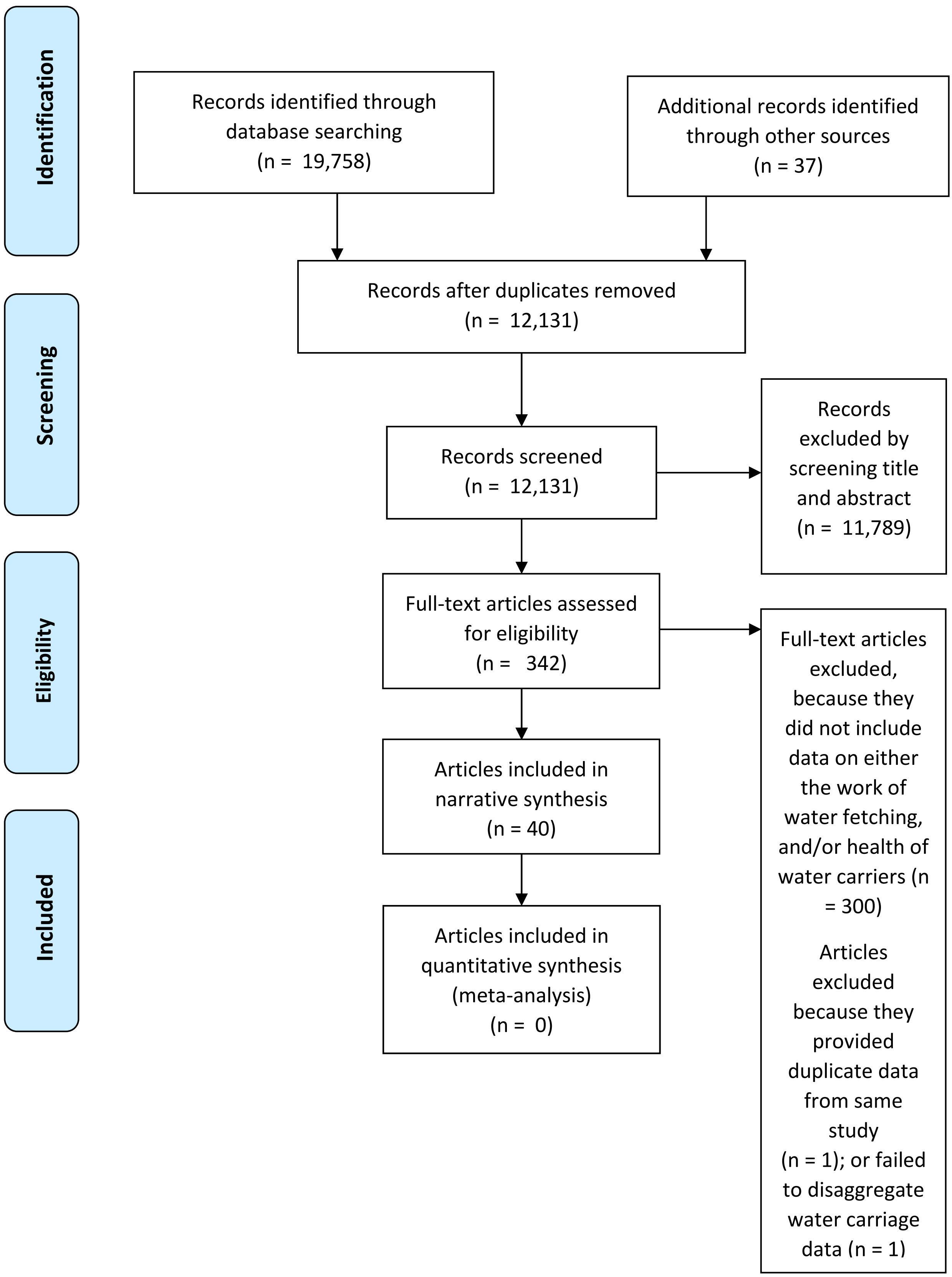

Figure 2.1 Study selection (PRISMA 2009 Flow Diagram)

2.3.2 Description of studies

2.3.2.1 Study characteristics

Of the 40 articles and reports included in this review, 17 reported quantitative studies, comprised of 15 cross sectional surveys or observational studies, and two cohort studies, 13 reported mixed methods studies collecting quantitative and qualitative data and ten reported qualitative studies. Of the mixed methods studies, one contained only relevant quantitative data, four contained only relevant qualitative data and eight contained relevant quantitative and qualitative data.

2.3.2.2 Participants

Most studies were conducted in a single African country (Table 2.1). Six studies (producing seven reports) were conducted in South Africa; six were conducted in Kenya; four in Uganda; four in Ethiopia; two in Ghana; two in Zimbabwe; and one each in Malawi, Morocco and Nigeria. One study reported findings from data collected in South Africa, Ghana, and Vietnam. Five studies were conducted in India, two in Canada, and one each in Nepal, Pakistan and Tibet. One further report incorporated qualitative data from 31 low or middle income countries (Table 2.1).

Data was collected from men, women, children and key informants (Table 2.1). Eighteen studies described their participants as ‘household’ respondents or adult men and women. Six studies included adults (men and women) and children. Ten studies included only women in their samples, with five of these describing participants simply as women, four focusing on mothers, one on pregnant women and one on older women. Two study samples included women and children and four studies included only children.

2.3.2.3 Independent variables

The work of water carriage was represented by a wide range of independent variables or risk factors summarized below, with some studies measuring or capturing more than one aspect of fetching water (Table 2.1).

- Nine studies investigated water carriage as an activity, without focusing on a specific measurable aspect or attribute of water carriage as a task, such as distance walked or carriage method (Geere et al., 2010b, Singh et al., 2012, Asaba et al., 2013, Robson et al., 2013, Mukuhlani and Nyamupingidza, 2014, Bisung et al., 2015, Sarkar et al., 2015, Ayoade et al., 2017, Geere et al., 2018a).

- Twelve studies captured some indication, either quantitatively or qualitatively, of time spent or distance travelled to collect water (Buor, 2004, Foggin et al., 2006, Gibson and Mace, 2006, Hemson, 2007, Geere et al., 2010a, Devoto et al., 2012, Stevenson et al., 2012, Yallew et al., 2012, Mugambe et al., 2014, Ghosh et al., 2016, Zolnikov and Blodgett Salafia, 2016, Thomas and Godfrey, 2018).
- Thirteen studies included description of the type or location of water source, with sufficient information to provide an indicator of the need for water carriage, or the level of work effort involved (Rao et al., 2007, BeLue et al., 2008, Borah et al., 2010, Rauniyar et al., 2011, Domenech et al., 2012, House et al., 2014, Isoke and Van Dijk, 2014, Subbaraman et al., 2015, Berrian et al., 2016, Cook et al., 2016, Krumdieck et al., 2016, Dapaah and Harris, 2017, Mercer and Hanrahan, 2017).
- Six studies investigated water carriage linked to social vulnerability or gender of the water carrier as a risk factor associated with poorer health outcomes (McCray, 2004, Ono et al., 2013, Henley et al., 2014, Schatz and Gilbert, 2014, Hennegan et al., 2016, Mbereko et al., 2016).

2.3.2.4 Dependent or health outcome variables

The studies also reported a range of health and social outcomes, summarized below and in Table 2.1. The studies reporting outcomes of gender based violence and social vulnerability were included because of the clear and likely impact on the water carrier’s physical or psychological health.

- Sixteen reports of 15 studies reported pain or injury (Hemson, 2007, Borah et al., 2010, Geere et al., 2010a, Geere et al., 2010b, Rauniyar et al., 2011, Domenech et al., 2012, Singh et al., 2012, Asaba et al., 2013, Robson et al., 2013, Bisung et al., 2015, Sarkar et al., 2015, Subbaraman et al., 2015, Berrian et al., 2016, Ayoade et al., 2017, Mercer and Hanrahan, 2017, Geere et al., 2018a),
- Twelve of 11 studies reported tiredness, fatigue or energetic costs (Gibson and Mace, 2006, Hemson, 2007, Rao et al., 2007, Borah et al., 2010, Geere et al., 2010a, Geere et al., 2010b, Domenech et al., 2012, Asaba et al., 2013, Robson et al., 2013, Bisung et al., 2015, Zolnikov and Blodgett Salafia, 2016, Ayoade et al., 2017),

- Six reported on stress, mental health or well-being (BeLue et al., 2008, Devoto et al., 2012, Stevenson et al., 2012, Henley et al., 2014, Zolnikov and Blodgett Salafia, 2016, Thomas and Godfrey, 2018),
- Six reported impacts on perinatal health (McCray, 2004, Gibson and Mace, 2006, Ono et al., 2013, Mukuhlani and Nyamupingidza, 2014, Bisung et al., 2015, Ghosh et al., 2016),
- Nineteen reported gender based violence or other health outcomes related to social vulnerability (Devoto et al., 2012, Domenech et al., 2012, Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, House et al., 2014, Isoke and Van Dijk, 2014, Mukuhlani and Nyamupingidza, 2014, Mugambe et al., 2014, Schatz and Gilbert, 2014, Subbaraman et al., 2015, Cook et al., 2016, Ghosh et al., 2016, Hennegan et al., 2016, Krumdieck et al., 2016, Mbereko et al., 2016, Zolnikov and Blodgett Salafia, 2016, Ayoade et al., 2017, Dapaah and Harris, 2017),
- Five reports of four studies reported general health (Buor, 2004, Foggin et al., 2006, Hemson, 2007, Geere et al., 2010b, Geere et al., 2018a).

Table 2.1 Included studies n = 40 (40 reports of 39 studies)

First author and year of publication	Study design	Data extracted	Year of data collection	Sample characteristics and size	Independent/ predictor variables	Health related dependent/ outcome variables
Buor 2004	Cross sectional survey	Quantitative	2001	Ghana: 210 females aged 12+ in Kumasi; 90 from urban 'core', 120 form urban 'periphery'	Time spent fetching water (continuous variable in hours), sources of water supply	Health status: ranked on self-reported frequency of sickness; "1" for once in 2 weeks; "2" for once a month; "3" for once in 3 months; "4" for rarely.
McCray 2004	Cross sectional survey	Quantitative	1998	South Africa: 327hh surveys: Mothers of child aged 12-23 months in randomly selected households of Kwazulu Natal	Daily activity of fetching water affected by prenatal visit (Yes/No)	Level of prenatal care utilization categorized as high, average or low
Foggin 2006	Mixed methods: Cross sectional survey and qualitative	Quantitative and qualitative	2002	Tibet: herders in the Sanjiangyuan region of the Tibetan Plateau, in southwest Qinghai Province; 50 families in Suojia Township and 49 families in Zhahe Township	Time collecting water, categorised as ≤ or > 15 minutes	Sick over last month: general morbidity which includes all cases of illness
Gibson 2006	Cohort study retrospective	Quantitative	2003	Ethiopia: Agropastoralist community, 1,548 women of reproductive age (15–49 y) within households of demographic survey of 1,976 HHs; subsample of 682 children (<15 y) and 264 women (15–49 y) in anthropometric survey across four of the study villages	Water collection time, access to taps	Fertility analyses derived from full retrospective birth histories and anthropometric measures of women and children

Hemson 2007	Mixed methods: Cross sectional survey and qualitative	Quantitative and qualitative	NR	South Africa: 1052 children aged 5-17 from 366 households, in 3 villages with no piped water supply; 2 dry flat villages in Limpopo and 1 hilly village with natural springs in Kwazulu Natal	Time collecting water, number of trips per day	Health conditions mentioned by children, and for which treatment was sought. Self-reported change to 'state of health', self-reported sore neck or back, fatigue
Rao 2007	Cross sectional survey	Quantitative	NR	India: 22 rural women aged 18–45 from villages about 30–40km from Pune city, Maharashtra	Drawing water from a well, and carrying water containers on the head	Energy costs (by indirect calorimetry); PARw (BMR predicted for individual women from FAO/WHO/UNU equation); PARm (BMR estimated from measured RMR). Physical activity level as index of total energy expenditure adjusted for BMR.
BeLue 2008	Cross sectional survey	Quantitative	1999-2000	South Africa: Mothers, 9 months postpartum aged 17-30 from Khayelitsha, Western Cape	Main source of drinking water	Perceived Stress Scale
Borah 2010	Observational study	Quantitative	NR	India: 30 rural women with normal blood pressure and temperature aged 21-40 years in Jorhat district of upper Brahmaputra Valley Zone of Assam	Household water fetching cycle including drawing water and carrying it home	Pain location
Geere 2010a	Mixed methods: Cross sectional	Quantitative	2008	South Africa: Subgroup of 29 people interviewed (semi-structured interview), drawn from convenience sample of 39	Distance walked to fetch water and return, weight of water	Prevalence of neck, back or spinal pain,

	survey and qualitative			adults and children fetching water in 6 rural villages of Limpopo Province	carried, water carriage method, rating of perceived exertion	rating of perceived exertion (RPE)
Geere 2010b	Mixed methods: Qualitative report	Qualitative	2008	South Africa: 39 adults and children observed to fetch water in 6 rural villages of Limpopo Province	Work of water fetching	Perceptions of ‘health’ reported by children in interviews or focus groups
Rauniyar 2011	Cross sectional survey	Quantitative	2008	Pakistan: 1301 ‘treatment’ households of rural water and sanitation project villages and 1301 matched comparison households in non-project villages	Households in a project village provided with improved access to water supply compared to households in non-project villages	‘Drudgery’ defined as pain from fetching water due to muscle strain, back ache or blisters
Devoto 2012	Cohort study	Quantitative	2007-2008	Morocco: 845 households in Tangiers, not connected to a city water network, comparing subgroup of households reporting above median baseline time fetching water	Households reporting above median baseline water fetching time	Mental well-being and life satisfaction
Domenech 2012	Mixed methods: Cross sectional survey and qualitative	Qualitative	2008-2009	Nepal: 120 households equally distributed among ten selected communities and with at least 2 years of experience with rainwater harvesting	Provision of roof top rain water harvesting for at home water supply	Perceived benefits of rainwater harvesting reported in free listing; Salience score of (global importance) of items from free listing

Singh 2012	Cross sectional survey	Quantitative	NR	India: 100 agricultural workers (50 male and 50 female) engaged in agricultural tasks over last 10 years, from villages of Udaipur district of Rajasthan	Water fetching for household purposes and animal husbandry; rating of work demand	Body part discomfort score, Overall discomfort rating score (RPE score)
Stevenson 2012	Mixed methods: Cross sectional survey and qualitative	Quantitative and qualitative	2009-2010	Ethiopia: women from cluster sample of 104 households for free listing, convenience sample of 39 women from 3 kebeles for ranking exercise, 3 focus group discussions totaling 30 women from 3 kebeles, cluster sample of 324 women	Water insecurity, including water collection time, quantity of water collected	Psychosocial distress
Yallew 2012	Mixed methods: Cross sectional survey and qualitative data	Quantitative and qualitative	2009	Ethiopia: 296 home based care clients living with HIV/AIDS, drawn from two NGOs in Gondar city .	Being forced to walk far to fetch water, needing assistance with walking	Water status, which included main access from water source types typically requiring water fetching or > 200m away from home
Asaba 2013	Mixed methods: cross sectional survey and in-depth interviews, focus group, participant observation	Quantitative and qualitative	2011-2012	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in 4 villages	Water carriage for household use	Reports of injury, pain location and death

Ono 2013	Cross sectional survey	Quantitative	2011	Kenya: 303 (99%) mothers aged 18 to 49, who brought their babies to Sosiot Health Center for immunization within their first year of life	Social support fetching water; respondents asked if, and from whom, they had support for fetching water	Place of delivery of the latest child, dichotomized as health facility or home
Robson 2013	Mixed methods: cross sectional survey and qualitative data	Quantitative and qualitative	2006-2009	Malawi: 1,504 children living in 12 urban and rural field sites in each of Malawi's three regions	Water carriage	Self-reported health problems and pain
Henley 2014	Cross sectional survey	Quantitative	2011	Kenya: Randomly selected subsample of ~ 200 men and women (out of 1000 participants) from settlements in Naivasha and Mogotio who participated in a health status survey	Survey that asked 'Do you feel safe' and 'Have you ever been assaulted' when collecting water and when going to the bathroom?	Chronic stress indicated by cortisol analysis of hair samples
House 2014	Qualitative case studies	Qualitative	NR	Various countries	Off plot access to water or sanitation facilities	Reports of gender based violence
Isoke 2014	Mixed methods: Cross sectional survey and	Qualitative	NR	Uganda: 127 survey respondents from Bwaise II and Kisenyi III, informal settlements in Kampala; semi structured interviews with 10 experienced National Water and Sewerage	Water technology preference out of public water points (PWPs) with	Reasons cited for choice of tap by the respondents

	qualitative data			Corporation staff, 3 focus groups, 2 of 12 members representing leadership of the 2 parishes; 1 of 4 members of NGOs	conventional meters, PWPs with prepaid meters, house connections and yard taps	
Mugambe 2014	Cross sectional survey	Quantitative	NR	Uganda: 450 respondents with 222 from HIV/AIDS affected, 228 from HIV/AIDS non-affected households of rural districts Mpigi and Gomba	Perception that fetching water takes a lot of time and a lot of energy	Buying water from water vendors
Mukhulani 2014	Qualitative case study	Qualitative	NR	Zimbabwe: Key informants from City Council, Health department, residents' association and NGOs in 3 suburbs of Bulawayo	Women and children fetching water during water scarcity	Qualitative reports of health and social impacts of water fetching
Schatz 2014	Qualitative interviews	Qualitative	NR	South Africa: 30 women aged 60–75 and impacted by HIV in some way, from Phase I of a larger rural study	Social support for older women	Qualitative reports of experiences of water access
Bisung 2015	Qualitative (photovoice)	Qualitative	2013-2014	Kenya: 8 women living in Usoma, a lake shore community 15km from Kisumu	Water collection burden on women and children	Health and social impacts captured photographically and discussed in interview
Sarkar 2015	Mixed methods: Cross sectional survey and qualitative	Qualitative	2013	Canada: Convenience sample of key informants, recruited from residents of Black Tickle-Domino (population 138), a sub-Arctic Inuit community, Island of Ponds, Southern Labrador	Loading, moving and un-loading buckets of water on to all-terrain vehicles (ATVs), snow mobiles or sleds	Health impact reported during qualitative interviews

Subbaraman 2015	Mixed methods: qualitative and structured survey	Qualitative	2011-2012	India: 6 focus group discussions, 40 individual qualitative interviews, and a structured survey of 521 randomly selected households in Kuala Bandar, a Mumbai slum of 12,000 people	Water indicators - quantity, access, price, reliability, and equity	Reported adverse life impacts due to deficiencies of water service delivery
Berrian 2016	Cross sectional survey	Quantitative	2013	South Africa: stratified random sample of 262 household surveys within 4 purposively-selected villages (Athol, Gottenburg, Thlavekisa, and Utha) located in Mpumalanga Province	Interactions with wildlife, source of and satisfaction with water	Household's health history of diseases linked to animals, sanitation, and water; perceptions of conservation efforts in their community
Cook 2016	Cross sectional survey	Quantitative	2013	Kenya: 387 households near Kianjai, north-central Kenya	Type and location of water source	Whether using the source is likely to lead to conflict
Ghosh 2016	Qualitative (photovoice)	Qualitative	NR	India: 79 mothers of child aged 6 or younger living in three administrative blocks (average population of 125,000 each) of the Indian Sundarbans, purposively selected out of six blocks most vulnerable, in terms of climatic vulnerability and service delivery	Living in an area of drinking water scarcity and uneven distribution of boreholes, with need to fetch water from a distant source	Qualitative reports of health problems affecting mothers and young children
Hennegan 2016	Cross sectional survey	Quantitative	2012-2014	Uganda: 8 schools in Kamuli district; 205/435 girls who completed the final follow-up survey of the Menstruation and The Cycle of Poverty trial and had reached menarche at the time of survey	Fetching water during menstruation, with reusable sanitary pads compared to existing	Impact on social participation indicated from yes/ no response to the item: "are there any activities or settings that you avoid while on your menstrual

					menstrual management	period?", including water fetching
Krumdieck 2016	Cross sectional survey	Quantitative	2014-2015	Kenya: 323 women at <30 weeks gestation,1:1 ratio of HIV-infected to HIV-uninfected women, recruited from seven clinical sites in Nyanza province	Access to water: including participants with off plot access	Experiences of water insecurity and perceptions of health and safety during water fetching at ~ 33 weeks of pregnancy
Mbereko 2016	Qualitative interviews	Qualitative	NR	Zimbabwe: 8 focus groups and 3 key informants from 9 purposively selected villages in Hurungwe, Mashonaland	Water fetching in households directly affected by HIV AIDs and water scarcity	Perceptions, experience of stigma and challenges accessing sufficient water for household use
Zolnikov 2016	Qualitative interviews	Qualitative	NR	Kenya: 52 semi-structured interviews to examine relationship experiences among primary water gatherers and their families after receiving nearby access to water, in Kitui	Implemented community water interventions for nearby access	Response to questions: "Did personal time change after receiving access to water?"; "Did relationships change after receiving access to water?"
Ayoade 2017	Qualitative interview survey	Qualitative	2013-2014	Nigeria: 800 girls aged 5-15 in peri-urban areas of Abeokuta, Ogun State	Water collection for household use	Experiences of and emotions related to collecting water
Dapaah 2017	Mixed methods: cross sectional survey and qualitative	Quantitative	NR	Ghana: survey of 120 households sampled in Ga Mashie, 80 in Madina, Accra, and 3 key informant interviews and 2 focus groups in each community	Entitlements to water and methods of water access	Incidence of fights at water collection points
Mercer 2017	Mixed methods:	Qualitative	NR	Canada: 21 individuals of 7 households in southern Inuit community of Black Tickle-	Pilot of domestic	Perceived health effects of rainwater harvesting,

	survey and focus groups			Domino, Island of Ponds, South Coast of Labrador	rainwater harvesting units	as compared to usual water retrieval
Geere 2018	Cross sectional survey	Quantitative	2012-2013	South Africa, Ghana and Vietnam: 997 adults and children from 3 villages in Limpopo Province, South Africa; 4 communities near Kumasi, Ghana; rural hamlets of Lao Cai Province, Vietnam	History of water carriage (past, current or never) and method of water carriage (head loading versus other)	Self-reported pain (pain in previous 7 days, pain location, pain duration), self-reported disability and self-rating of general health
Thomas 2018	Mix methods: Cross sectional survey and focus groups	Quantitative and qualitative	NR	Ethiopia: survey and focus groups with 200 households in Welenchiti, Oromia region, and interviews with senior water utility staff	Total water collection time and experience of collecting water	Emotional distress and feeling ‘bothered’

2.3.3 Methodological quality

2.3.3.1 Quantitative studies

The overall methodological quality of the 26 studies collecting quantitative data, in terms of their capacity to demonstrate a cause and effect relationship between the work of water carriage and health was rated as fair (6 studies) or poor (19 studies), only one was rated as good (Table 2.2). The key reasons for low quality ratings were the use of cross sectional study design, lack of evidence to support the reliability and validity of exposure or outcome measures, lack of outcome assessor blinding and failure to include important confounding factors in the analyses.

2.3.3.1.1 Clearly specified research question or objective, and study population

Particularly in quantitative research, an explicitly defined research question may indicate higher scientific research quality (NIH, 2014). All studies except five (McCray, 2004, Hemson, 2007, Borah et al., 2010, Asaba et al., 2013, Mbereko et al., 2016) provided a clear statement of the research question or objectives being addressed. All studies described the group of people from which the study participants were selected or recruited, using demographics, location, and/or time period of the study. Most studies recruited participants from the same or similar populations, however nine (Buor, 2004, Foggin et al., 2006, Gibson and Mace, 2006, Hemson, 2007, Rao et al., 2007, Singh et al., 2012, Robson et al., 2013, Henley et al., 2014, Geere et al., 2018a) either did not recruit from the same population or did not provide enough information on participant selection and exclusion criteria to demonstrate that participants were recruited from the same population. This may introduce bias, and result in a sample which is not representative of the target population to which the study results were generalised.

2.3.3.1.2 Participation rate of eligible persons at least 50%

If fewer than 50% of eligible people participate in a study, the study sample may not be representative of the target population. This may introduce bias and reduce generalisability of the study, as the characteristics of the people in the sample may differ from those of the target population in important ways (NIH, 2014). The participation rate of eligible people could not be determined, or was not reported in nine studies (Gibson and Mace, 2006, Hemson, 2007, BeLue et al., 2008, Borah et al., 2010, Singh et al., 2012, Stevenson et al., 2012, Ono et al., 2013, Robson et al., 2013, Mugambe et al., 2014) and was less than 50% in 13 studies (Buor, 2004, McCray, 2004, Foggin et al., 2006, Rao et al., 2007, Geere et al., 2010a, Rauniyar et al., 2011, Yallew et al., 2012, Asaba et al., 2013, Henley et al., 2014, Mugambe et al., 2014, Hennegan et al., 2016, Dapaah and Harris, 2017, Thomas and Godfrey, 2018). Four studies reported a participation rate of at least 50% of eligible people (Devoto et al., 2012, Berrian et al., 2016, Krumdieck et al., 2016, Geere et al., 2018a).

2.3.3.1.3 Sample size justification, power calculation or variance and effect estimates provided

Justification of the sample size, supported by a power calculation, can indicate whether a study had enough participants in it to find an association between variables of interest if one truly exists in the population from which the sample was drawn (NIH, 2014). However, exploratory observational studies often do not report whether a power calculation was used to plan recruitment of a sample sufficiently large enough to answer a pre-specified question (NIH, 2014). Estimates of effect size or variance may be provided instead of a power calculation and may indicate the likelihood of a study being underpowered, and at risk of a type II error. A type II error is the failure to detect an effect or association that is present (Portney and Watkins, 2000, Fritz et al., 2012). Five studies reported conducting an appropriate sample size calculation and recruited the number of participants close to the required sample sizes (Devoto et al., 2012, Robson et al., 2013, Mugambe et al., 2014, Berrian et al., 2016, Geere et al., 2018a). Eleven other studies reported estimates of variance, which can simply indicate the spread of scores within the sample (standard deviation) and estimate the population variance, or together with confidence intervals or the standard error of an estimate, indicate whether a study sample was large enough to provide a precise estimate of the outcome of interest in the reference population, given the variation in sample scores and sample size. Three studies simply reported standard deviations along with mean values (Rao et al., 2007, BeLue et al., 2008, Henley et al., 2014), four provided confidence intervals (Geere et al., 2010a, Yallew et al., 2012, Ono et al., 2013, Hennegan et al., 2016) four provided standard errors (McCray, 2004, Foggin et al., 2006, Gibson and Mace, 2006, Stevenson et al., 2012), and two provided an R^2 value for regression analysis, which indicates the amount of variance in the data explained by the model covariates (Buor, 2004, Rauniyar et al., 2011).

2.3.3.1.4 Exposure measured prior to outcomes being measured

To determine whether an exposure causes an outcome, it is useful to confirm that the exposure came before the outcome. In cross sectional surveys, information is collected about the exposure and outcome variables at the same time and it may be impossible to confirm which came first (Bonita et al., 2006). Only two studies were cohort studies, one a retrospective cohort study (Gibson and Mace, 2006) and one a prospective cohort (Devoto et al., 2012) both with exposure clearly preceding the health outcomes being measured. All other studies included in this review were cross sectional surveys or collected observational data within one time period as part of a mixed methods design, which provide weaker evidence of a cause effect relationship (Bonita et al., 2006).

2.3.3.1.5 Time frame sufficient to see an association between exposure and outcome

The signs and symptoms which indicate the presence of a health condition or disease take variable lengths of time to develop after exposure to a risk factor for disease (Bonita et al., 2006). In five studies (McCray, 2004, Gibson and Mace, 2006, BeLue et al., 2008, Devoto et al., 2012, Hennegan et al., 2016), the time frame was sufficient, or appropriate to see an association between exposure and the outcomes. Gibson and Mace, and Devoto et al., were able to do this by utilising a cohort study design. Hennegan et al., reported a cross sectional study, however the survey was carried out in the final stage of a controlled trial. Similarly, BeLue et al., conducted a survey as part of a larger study, at a nine month follow up interview whilst McCray utilised a survey to ask mothers about prenatal care utilisation.

2.3.3.1.6 Different levels of exposure measured

Capturing different levels of exposure to the risk factors of interest enables investigators to assess trends or dose-response relationships between exposures and outcomes. For example, a person who walks four kilometres to collect water every day is exposed to a greater dose of water carriage work than someone who makes two trips to a community tap located just 200 meters away from home. Evidence of a dose-response relationship strengthens the credibility of a cause effect relationship being present and can support the hypothesis that exposure to the risk factor caused the outcome (Bonita et al., 2006, NIH, 2014). Different levels of exposure to the work of water carriage can be captured in a variety of ways, related to time or distance to water source, frequency of water fetching trips per day, weight of water carried or years of exposure to the work. However, in four studies (Gibson and Mace, 2006, Hemson, 2007, Singh et al., 2012, Hennegan et al., 2016) different levels of exposure were either not measured or not reported.

2.3.3.1.7 Exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across study participants

Obtaining accurate information about a study participant's exposure to the independent variable of interest is essential to produce valid results of analysis and observe an association if it exists. Accurate exposure information relies on the use of clearly defined, reliable and valid indicators of exposure applied consistently to all study participants (Portney and Watkins, 2000, NIH, 2014). Six studies (Foggin et al., 2006, Gibson and Mace, 2006, Geere et al., 2010a, Yallew et al., 2012, Robson et al., 2013, Hennegan et al., 2016) reported use of clearly defined, valid and reliable independent or exposure variables. In the remaining studies the exposure variables were not clearly defined, not clearly validated for use with the population sample, or may not have been reliable or implemented consistently across all study participants. Many studies used questions which relied on the respondent's recall. Subjective reports of past exposure to risk factors may not be reliable, and can lead to misclassification of exposure status or exposure levels to create a high risk of bias (NIH, 2014).

2.3.3.1.8 Exposure assessed more than once

If exposure to the independent variable or risk factors is assessed more than once, it can increase confidence that exposure status is correctly classified and reduce risk of misclassification bias (NIH, 2014). Devoto (2012) and Hennegan (2016) assessed exposure more than once over time. None of the other studies were designed to incorporate assessment of the exposure more than once.

2.3.3.1.9 Outcome measures (dependent variables) clearly defined, valid, reliable and implemented consistently across study participants

To accurately identify health outcomes and have confidence in the results of analyses of the association between exposure and health outcome, valid and reliable health outcome measures or indicators must be used and applied consistently to all study participants (Portney and Watkins, 2000, NIH, 2014). In only four studies (Gibson and Mace, 2006, Ono et al., 2013, Henley et al., 2014, Geere et al., 2018a), the outcome (dependent) variables were clearly defined, and reported as valid for use with the population sample, reliable and implemented consistently across all study participants. The use of recall and subjective reports of health status or outcomes may not be reliable, and may lead to misclassification of health outcomes and create a high risk of bias (NIH, 2014).

2.3.3.1.10 Outcome assessors blinded to exposure status of participants.

Lack of assessor blinding can lead to bias in the outcome measurement or classification of the participant if the outcome assessor either knew, or could work out, the exposure status of the participant (NIH, 2014, Portney and Watkins, 2000). Only two studies (Devoto et al., 2012, Geere et al., 2018a) reported that the outcome assessor was blinded to the exposure status of the participant.

2.3.3.1.11 Loss to follow up after baseline 20% or less

Minimising loss to follow up reduces the risk of bias affecting the observed associations between exposure and outcome, which may occur if the participants who drop out are different in exposure or outcome characteristics than those who remain in the study (Howe et al., 2013). One study reported a 94% follow up rate (Devoto et al., 2012) and one included all eligible girls (those who had reached menarche) who were included at baseline or subsequently recruited into the larger study in which their survey was nested (Hennegan et al., 2016). All other studies except one (Gibson and Mace, 2006) were cross sectional in nature, and so would not have a follow up measurement time point. The cohort study (Gibson and Mace, 2006) was retrospective and used known dates of tap installations to capture exposure to improved water supply and reduced water fetching time, and so also did not incorporate a follow up assessment.

2.3.3.1.12 Potential confounding variables measured

Confounding variables are those which are associated with both the exposure variable and the health outcome, and can therefore create an apparent association between the exposure variable and health outcome which does not exist, and is present due to the association between the variables of interest and the confounding factor (Bonita et al., 2006). For example, a study might find and association between water carriage and poorer general health. However, wealthier people are more likely to afford and have a water supply in their home and therefore wealth may be associated with reduced exposure to water carriage. Wealth may also be associated with better nutrition and ability to access health care services, and therefore improved actual health and subsequent ratings of general health through these mechanisms. If wealth were not measured in the study, the relationship between better general health and reduced exposure to water carriage may be apparent because prosperity is associated with better general health through good nutrition and health care access, and with water supply in the home. Similarly, an association between poorer general health and water carriage, may be apparent when it is poverty that is associated with poorer general health and with out of house water supply. Nine studies adjusted their analyses for the effect of key potential confounding factors (McCray, 2004, Rauniyar et al., 2011, Devoto et al., 2012, Stevenson et al., 2012, Ono et al., 2013, Henley et al., 2014, Mugambe et al., 2014, Geere et al., 2018a, Thomas and Godfrey, 2018). The remaining studies therefore had a greater risk that their results could be affected by or due to the effect of confounding factors which were either not measured or not incorporated into the analyses.

Table 2.2 Quality appraisal of observational cohort and cross sectional studies (National Institute of Health critical appraisal tool)

1st Author & date (listed in chronological, then alphabetical order)	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations	Was a sample size justification, power description, or variance and effect estimates provided?	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome?	Were exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Was the exposure(s) assessed more than once over time?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all	Were the outcome assessors blinded to the exposure status of participants?	Was loss to follow-up after baseline 20% or less?	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Overall rating of study quality for determining cause and effect relationship
Buor 2004	Y	Y	N	N	N	N	N	Y	N	NA	N	NR	NA	N	Poor
McCray 2004	N	Y	N	Y	N	N	Y	Y	CD	N	N	N	NA	Y	Fair
Foggin 2006	Y	Y	N	N	N	N	N	N	Y	NA	N	N	NA	N	Poor
Gibson 2006	Y	Y	NR	N	N	Y	Y	N	Y	N	Y	NR	NR	N	Fair
Hemson 2007	N	Y	CD	CD	N	N	N	Y	N	NA	N	N	NA	N	Poor
Rao 2007	Y	Y	N	CD	N	N	N	Y	N	NA	N	N	NA	N	Poor
BeLue 2008	Y	Y	CD	Y	N	N	Y	Y	N	NA	CD	CD	NA	N	Poor
Borah 2010	N	Y	NR	Y	N	N	N	N	N	N	N	N	N/A	N	Poor

Geere 2010a	Y	Y	N	Y	N	N	N	Y	Y	NA	N	N	NA	N	Poor
Rauniyar 2011	Y	Y	N	Y	N	N	N	N	N	N	N	CD	N/A	Y	Poor
Devoto 2012	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Good
Singh 2012	Y	Y	CD	N	N	N	N	N	N	NA	N	CD	NA	N	Poor
Stevenson 2012	Y	Y	NR	Y	N	N	N	N	N	N	N	NR	NR	Y	Poor
Yallew 2012	Y	Y	N	Y	N	N	N	Y	Y	NA	N	N	NA	N	Poor
Asaba 2013	N	Y	N	Y	N	N	N	N	N	N	N	N	N/A	N	Poor
Ono 2013	y	y	CD	y	N	N	N	Y	N	NA	Y	N	NA	Y	Fair
Robson 2013	Y	Y	CD	N	Y	N	N	Y	Y	N/A	N	N	N/A	N	Poor
Henley 2014	Y	Y	N	N	N	N	N	N	N	NA	Y	NR	NA	Y	Fair
Mugambe 2014	Y	Y	N	Y	Y	N	N	Y	N	NA	N	N	NA	Y	Fair
Berrian 2016	Y	Y	Y	Y	Y	N	N	Y	N	N/A	N	N/R	N/A	N	Poor
Cook 2016	Y	Y	CD	Y	N	N	N	Y	CD	N/A	N	CD	N/A	N	Poor
Hennegan 2016	Y	Y	N	Y	N	N	Y	NA	Y	Y	N	N	Y	N	Poor
Krumdieck 2016	Y	Y	Y	Y	N	N	N	N	N	N/A	N	N/R	N/A	N	Poor
Dapaah 2017	Y	Y	N	Y	N	N	N	N	N	N/A	N	N	N/A	N	Poor

Geere 2018	Y	Y	Y	N	Y	N	CD	Y	N	N/A	Y	Y	N/A	Y	Fair
Thomas 2018	Y	Y	N	Y	N	N	N	Y	N	N	N	N	N/A	Y	Poor

Y = yes, N = no, CD = can't determine, N/R = nor reported, N/A = not applicable.

2.3.3.2 Qualitative studies

Twenty one studies reported qualitative data (Table 2.3). Most studies provided a clear statement of their aims, which were suitable for investigation with a qualitative research method, and provided a clear statement of findings. However, these aspects of the CASP appraisal tool are mainly descriptive and do not indicate whether the study design was appropriate and well conducted. There was often insufficient information reported to determine whether recruitment, data collection and analysis were appropriate to achieve the aims of the study and sufficiently rigorous. The influence of the researcher and ethical issues were also not clearly reported in most of the studies. Therefore if studies only had three or fewer of the appraisal criteria scoring a ‘yes’ response, the study was rated poor as there was generally a description of the aim, appropriate choice of qualitative method and a clear summary of findings, but insufficient information to have confidence in the choice of study design and study quality. Studies were rated as fair if four or five criteria had yes responses, because generally these studies provided descriptive information and at least some information about how the study was conducted. Studies were rated ‘good’ if six or more of the appraisal criteria scored a ‘yes’ response, indicating that most study design issues of importance were reported and provided evidence of rigour. The scoring process resulted in twelve of the studies being rated as having good quality, five of fair quality, and four rated as having poor quality.

2.3.3.2.1 Research aim, qualitative methods and research design

In research investigating water access, a wide range of issues may be investigated with a qualitative method, through a variety of qualitative research designs (Wutich et al., 2017). To demonstrate that the methods used in a study were appropriate to the aims of the research, a clear statement of the aims, description of the research design and methods, and justification of how decisions about which study design to use were made should be provided in research reports (Mason, 2002b, CASP, 2017). Almost all reports provided a statement of aims and all seemed to have appropriately chosen to use a qualitative method, as they sought to shed light on the meanings people ascribed to their experiences of accessing water and to understand or interpret their actions and/or social interactions in relation to water access and water carriage (Mason, 2002b, Creswell, 2009b). However in five studies (Robson et al., 2013, House et al., 2014, Mbereko et al., 2016, Ayoade et al., 2017, Thomas and Godfrey, 2018) the choice of research design within the qualitative method was not clearly justified and so it was not possible to determine conclusively whether the research design used was appropriate to the stated research aim.

2.3.3.2.2 Recruitment strategy

A clearly described and well justified recruitment strategy can indicate that a sample of participants was chosen with a relevant and sufficient range of characteristics or experiences to support the intended analyses and illuminate or illustrate the phenomena of interest (Mason, 2002c). Nine studies (Foggin et al., 2006, Hemson, 2007, Domenech et al., 2012, Yallew et al., 2012, Robson et al., 2013, House et al., 2014, Mukuhlani and Nyamupingidza, 2014, Ayoade et al., 2017, Thomas and Godfrey, 2018) did not provide sufficient information about their recruitment processes or the theoretical basis supporting their recruitment strategy to determine whether an appropriate strategy was used. This reduces confidence that in these studies, recruitment of participants was appropriate to provide the relevant knowledge and information sought by the study, or that they provided a sufficient range of perspectives to fully explore the phenomena of interest (Mason, 2002c, CASP, 2017).

2.3.3.2.3 Data collection

The settings and methods of data collection should be made explicit and justified to demonstrate that data was collected in an appropriate way to address the research issue of interest and achieve the aims of the research (Mason, 2002a, Creswell, 2009a). In six studies (Hemson, 2007, Asaba et al., 2013, Robson et al., 2013, House et al., 2014, Mukuhlani and Nyamupingidza, 2014, Thomas and Godfrey, 2018), insufficient detail was provided to confirm that the type of data and way in which data was collected would sufficiently address the research issue.

2.3.3.2.4 Relationship between researcher and participants

The researcher's role and relationship to participants and events which occurred in the study should be critically examined and reported, to acknowledge the influence of the researcher(s') background, perspectives and involvement with the study procedures and participants, and to acknowledge potential bias which might shape the researcher's interpretation of the study findings (Creswell, 2009a). This was not sufficiently reported in most studies included in the review (Foggin et al., 2006, Hemson, 2007, Geere et al., 2010a, Geere et al., 2010b, Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, House et al., 2014, Isoke and Van Dijk, 2014, Mukuhlani and Nyamupingidza, 2014, Schatz and Gilbert, 2014, Ghosh et al., 2016, Zolnikov and Blodgett Salafia, 2016, Ayoade et al., 2017, Mercer and Hanrahan, 2017, Thomas and Godfrey, 2018), and so bias and/or the influence of the researchers investigating water carriage might have an important influence on the findings in individual studies, and the overall findings of this review.

2.3.3.2.5 *Ethical issues*

Assessment of whether ethical standards were maintained in a study is incorporated into the CASP qualitative study appraisal tool. Ethical issues arise in qualitative research in relation to all aspects of the research design and procedures, including the nature of the issues under investigation, the setting of the research, the characteristics and expectations of the participants, the role and responsibilities of the researcher, and the audiences for and potential uses of the research findings (Mason, 2002b). All of these issues can influence the behaviour and responses of people involved with providing or generating data, and so can influence the nature and robustness of data gathered and therefore the findings of the study. Evidence that the researchers have taken relevant ethical issues into account is therefore part of the judgement of whether the research has been conducted appropriately.

Ethical issues are multiple and complex in water research, and how they have been addressed throughout the research processes should be reported in sufficient detail to indicate whether relevant contextual issues were in fact considered and addressed adequately. For example, it is clear that individuals and populations who are vulnerable for a variety of reasons, such as poverty, conflict, migration and social discrimination, are most likely to suffer from inadequate access to safe drinking water (UN, 2016) and often contend with poor access to water in settings where the possibilities and likelihood for change are limited. If the researchers or the research processes intentionally or inadvertently raise expectations for change within a community with limited water access, such expectations could influence participant responses during data collection. Other factors may influence how individuals participate and respond in a qualitative research project, and therefore affect the nature of the data and information gathered. These factors include, but are not confined to, how the research was explained to participants, how consent for participation and use of data was obtained, whether and how participant anonymity, confidentiality and safety was maintained, and how researcher safety, issues arising and participants' expectations during the research was handled. For example, a participant who is unsure of the purpose of the research, or how data will be used and shared, may limit their responses to questions; a participant coerced to participate may respond in the manner they believe is expected; and the interaction between researchers and participants in an unsafe environment will likely differ to that occurring in safer circumstances, to shape the nature, quantity and quality of data collected. In four studies included in this review (Asaba et al., 2013, Robson et al., 2013, Ayoade et al., 2017, Thomas and Godfrey, 2018), how ethical issues were addressed was not reported in any detail. In nine studies, insufficient detail was provided to determine whether ethical issues had been sufficiently addressed to ensure relevant and robust data collection (Foggin et al., 2006, Hemson, 2007, Domenech et al., 2012, House et al., 2014, Isoke and Van Dijk, 2014, Mukuhlani and Nyamupingidza, 2014, Schatz and Gilbert, 2014, Mbereko et al., 2016, Zolnikov and Blodgett Salafia, 2016).

2.3.3.2.6 Data analysis and statement of findings

Data analysis processes should be described in depth with sufficient data presented to support the research findings and create confidence that analysis was sufficiently rigorous. For example a report should explain how data were managed, how categories and themes were derived from the data, how data presented in the report were selected, and how contradictory data were identified and incorporated into the study analysis or findings (Creswell, 1994, CASP, 2017). In thirteen studies of this review (Foggin et al., 2006, Hemson, 2007, Geere et al., 2010b, Domenech et al., 2012, Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, Isoke and Van Dijk, 2014, House et al., 2014, Mukuhlani and Nyamupingidza, 2014, Sarkar et al., 2015, Ayoade et al., 2017, Thomas and Godfrey, 2018) it was not possible to tell whether data analysis was sufficiently rigorous. Whilst the conclusions of all studies seemed reasonable, with most providing a clear statement of findings and only five (Foggin et al., 2006, Asaba et al., 2013, Ayoade et al., 2017, Mercer and Hanrahan, 2017, Thomas and Godfrey, 2018) lacking a clear statement of findings, the lack of detailed reporting on data analysis procedures reduces confidence in the rigour of the studies.

Table 2.3 Quality appraisal of studies reporting qualitative data (CASP tool)

1st Author & date (listed in chronological, then alphabetical order)	Was there a clear statement of aims?	Is a qualitative method appropriate?	Research design appropriate to research aims?	Recruitment strategy appropriate to research aims?	Data collected to address research issue?	Relationship between researcher and participants considered?	Have ethical issues been considered?	Was the data analysis sufficiently rigorous?	Clear statement of findings?	Quality rating; Poor ≤3 Fair = 4-5 Good ≥6
Foggin 2006	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Can't tell	Can't tell	No	Fair
Hemson 2007	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Can't tell	Can't tell	Yes	Fair
Geere 2010a & b[1]	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Yes	Good
Domenech 2012	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Can't tell	Can't tell	Yes	Fair
Stevenson 2012	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Yallew 2012	Yes	Yes	Yes	Can't tell	Yes	Can't tell	Yes	Can't tell	Yes	Good
Asaba 2013	Yes	Yes	Yes	Yes	Can't tell	Can't tell	No	Can't tell	No	Fair
Robson 2013	Yes	Yes	Can't tell	Can't tell	Can't tell	Can't tell	No	Can't tell	Yes	Poor
House 2014	Yes	Yes	Can't tell	Can't tell	Can't tell	Can't tell	Can't tell	Can't tell	Yes	Poor
Isoke 2014	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Yes	Good
Mukuhlani 2014	Yes	Yes	Yes	Can't tell	Can't tell	Can't tell	Can't tell	Can't tell	Yes	Fair
Schatz 2014	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Yes	Yes	Good
Bisung 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Sarkar 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Good
Subbaraman 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Ghosh 2016	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Yes	Good
Mbereko 2016	No	Yes	Can't tell	Yes	Yes	Yes	Can't tell	Yes	Yes	Good
Zolnikov 2016	Yes	Yes	Yes	Yes	Yes	Can't tell	Can't tell	Yes	Yes	Good
Ayoade 2017	Yes	Yes	Can't tell	Can't tell	Yes	Can't tell	No	Can't tell	No	Poor
Mercer 2017	Yes	Yes	Yes	Yes	Yes	Can't tell	Yes	Yes	Can't tell	Good
Thomas 2018	Yes	Yes	Can't tell	Can't tell	Can't tell	Can't tell	No	Can't tell	Can't tell	Poor

[1] qualitative data reported in Geere et al., 2010a and Geere et al., 2010b is derived from the same study.

2.3.4 Study findings

The studies are grouped for comparison under six key themes derived from the health outcomes reported;

1. Bodily pain or physical injury
2. Tiredness, fatigue or energy costs
3. Stress, mental health or wellbeing
4. Perinatal health care access and behaviour
5. Social Vulnerability
6. General health

There is moderate evidence from quantitative data that water carriage is associated with pain or injury; tiredness, fatigue or energy costs; reduced perinatal health care access; and increased social vulnerability. There is inconclusive quantitative evidence on the association between water carriage and stress or mental health and general health (Table 2.4).

Table 2.4 Strength of evidence from quantitative data

Health Domain	Quality[1]	Quantity[2]	Consistency[3]	Strength of evidence[4]
Pain and injury	1 fair, 8 poor	9	Consistent: 100% associate WC and pain	Moderate
Fatigue and energy expenditure	1 fair, 6 poor	7	Consistent: 100% associate WC and increased fatigue	Moderate
Stress, mental health and wellbeing	1 good, 1 fair, 3 poor	5	Inconsistent: 3 (60%) associate WC and increased stress; 2 (40%) found no significant effect of reduced water collection time on mental health or life satisfaction	Inconclusive
Perinatal health	3 fair	3	Consistent: 100% associate WC and reduced perinatal health care access	Moderate
Social vulnerability	1 good, 1 fair, 7 poor	9	Consistent: 100% associate WC and worsened social vulnerability or risks	Moderate
General health	1 fair, 3 poor	4	Inconsistent: 3 (75%) associate WC and poorer health, 1 (25%) WC and better health	Inconclusive

[1]Quality score based on NIH tools; [2]Number of studies; [3]Inconsistent: if ≤75% of the available studies reported the same conclusion; [4]Evidence based on quality, number, and the outcome of studies: Strong = provided by generally consistent findings in multiple high-quality studies, Moderate = generally consistent findings in 1 high-quality study and 1 low quality study, or in multiple low quality studies, Inconclusive evidence = only 1 study available or inconsistent findings in multiple studies (Hoogendoorn et al., 1999)

There is strong evidence from qualitative data that people experience pain and injury, and tiredness or fatigue during water carriage. There is also strong evidence from qualitative data that people report stress or poorer mental health and wellbeing, reduced perinatal health care access and increased social vulnerability as consequences of water carriage. There is inconclusive qualitative evidence about the association between water carriage and general health (Table 2.5).

Table 2.5 Strength of evidence from qualitative data

Health Domain	Quality[1]	Quantity[2]	Consistency[3]	Strength of evidence[4]
Pain and injury	5 good, 2 fair, 2 poor	9	Consistent: 100% associate WC and pain	Strong
Fatigue and energy expenditure	3 good, 2 fair, 2 poor	7	Consistent: 100% associate WC and increased fatigue	Strong
Stress, mental health and wellbeing	2 good, 1 poor	3	Inconsistent: 2 (66%) good quality studies associate WC and increased stress, one study found no effect	Strong
Perinatal health	2 good, 1 poor	3	Consistent: 100% associate WC and reduced perinatal health or care access	Strong
Social vulnerability	7 good, 3 fair, 3 poor	13	Consistent: 100% associate WC and worse social vulnerability	Strong
General health	2 good	2	Inconsistent: 1 (50%) associate WC and poorer health, 1 WC and better health	Inconclusive

[1]quality score based on CASP tool; [2]Number of studies; [3]Inconsistent: if ≤75% of the available studies reported the same conclusion; [4]Evidence based on quality, number, and the outcome of studies: Strong = provided by generally consistent findings in multiple high-quality qualitative studies, Moderate = generally consistent findings in 1 high-quality study and 1 low quality qualitative study, or in multiple low quality studies, Inconclusive evidence = only 1 study available or inconsistent findings in multiple studies (Hoogendoorn et al., 1999).

2.3.4.1 Pain and injury

There is moderate evidence from quantitative data and strong evidence from qualitative data of an association between water carriage and self-reported pain or injury (Table 2.4 and 2.5). Sixteen reports of 15 studies (Hemson, 2007, Borah et al., 2010, Geere et al., 2010a, Geere et al., 2010b, Rauniyar et al., 2011, Domenech et al., 2012, Singh et al., 2012, Asaba et al., 2013, Robson et al., 2013, Bisung et al., 2015, Sarkar et al., 2015, Subbaraman et al., 2015, Berrian et al., 2016, Ayoade et al., 2017, Mercer and Hanrahan, 2017, Geere et al., 2018a) included people within their study samples whose experience of water carriage was associated qualitatively, or through quantitative analysis, with pain, injury or risk of injury (Table 2.6).

The significantly reduced distance walked and time spent for water fetching among head loading water carriers who reported pain, compared to those who did not report pain, was interpreted by Geere at al., (2010a) as an indication of pain related disability. They suggested that people who experienced pain during water fetching may reduce the length of time they are exposed to the loading force, whilst those without pain or with lower levels of pain may be able to collect water from greater distances. Although their study was limited by a small sample size, their findings are supported by the studies including qualitative data derived from people who collect water. They are also supported by the findings of Rauniyar et al., (2011) who attributed a significant 5% reduction in the ‘drudgery’ of water fetching among the lowest socio-economic group to water supply projects, and the findings of Porter et al., (2012) who found high proportions of children reporting pain as a direct result of load-carrying, which particularly for girls, included water carriage by head loading. However, as highlighted by Porter et al., (2012) individuals in low and middle income countries carry diverse loads, and water may not be the heaviest load carried. Because none of the studies took this into account in their analyses, the effects of manual labour in addition to water carriage may confound the apparent associations between water carriage and pain.

In a recent study, Geere et al., (2018a) did not find an association between report of any type of pain in the previous seven days, unspecified in terms of location, duration, intensity or consistency, and history of water carriage. However, they did find that the areas of the body in which pain was experienced were associated with a history of water carriage. Ten studies (Hemson, 2007, Borah et al., 2010, Geere et al., 2010a, Rauniyar et al., 2011, Singh et al., 2012, Asaba et al., 2013, Robson et al., 2013, Sarkar et al., 2015, Ayoade et al., 2017, Geere et al., 2018a) included some indication of the areas of the body in which water carriers experienced pain, with back and neck pain commonly reported. Geere et al., (2018a) found that participants reported multiple areas of pain, and that pain areas were correlated. Principle components analysis explained 55% of the variance in pain locations and extracted two factors correlated with patterns of pain distribution. The factor ‘axial compression’ was correlated with head, upper back, chest/rib, hands and abdomen/stomach pain. The association was proposed to indicate detrimental impacts of axial spinal loading, because participants who had previously or currently carried water had a mean increase in axial compression factor score compared to people who had never carried water, and the association was stronger among head loaders compared to those using other methods of water carriage. The factor ‘soft tissue strain’ was correlated with neck, upper limb pain, lower back and lower limb pain, and was slightly negatively associated with current or past history of water carriage. Whilst these findings may seem to contradict earlier data reporting complaints of neck and back pain during water carriage, the 'axial compression' pain pattern associated with water carriage was interpreted as pain referral from an underlying neck disorder.

All studies relied on self-report of pain, which is appropriate and necessary as pain is a subjective and emotional experience (IASP, 2012). Self-reported pain intensity scales have been shown to be valid and reliable for use in clinical trials to evaluate pain severity caused by a range of medical conditions (Flaherty, 1996, DeLoach et al., 1998, Anderson, 2005), however, only one of the studies reported findings based on a pain intensity scale (Singh et al., 2012), and the scale was not clearly defined in the published report. No other studies qualified participants' reports of pain in terms of its quality, severity or effect on functioning. Qualification of pain is important because it is a common phenomenon, and can range from mild intensity which does not affect functioning or quality of life to severe pain which is disabling and/or reduces quality of life. Studies should focus on whether the work of water carriage is associated with pain which is of a quality or intensity sufficient to impair functioning or reduce quality of life (Turk et al., 2003).

Seven studies included qualitative reports from participants, in which they associated physical injury with water fetching (Geere et al., 2010b, Domenech et al., 2012, Asaba et al., 2013, Robson et al., 2013, Sarkar et al., 2015, Ayoade et al., 2017, Mercer and Hanrahan, 2017), and four described fear of injury due to water carriage along routes or from locations frequented by dangerous animals (Asaba et al., 2013, Robson et al., 2013, Berrian et al., 2016, Mercer and Hanrahan, 2017). One study reported three cases of a child drowning at open wells or ponds (Asaba et al., 2013), participants in another study reported fear or risk of being swept away or drowning during floods (Robson et al., 2013), and a further study included participants who had witnessed people struck by moving vehicles while fetching water (Ayoade et al., 2017).

Table 2.6 Water carriage and pain or injury (16 articles)

First author & date	Population	Study type	Dates	Key findings	Quality
Hemson 2007	South Africa: 1052 children aged 5-17 from 366 households, in 3 villages with no piped water supply.	Mixed methods	NR	96% of the children reporting that their health had worsened, reported that they had a sore neck or back.	Poor[1] Fair[2]
Borah 2010	India: 30 rural women with normal blood pressure and temperature aged 21-40 years in Jorhat district of upper Brahmaputra Valley Zone of Assam.	Observational study	NR	Incidence of pain during complete water fetching cycle, and with sub-activities, was mainly in low back region. Pain also reported in shoulder joints while drawing water and carrying it home.	Poor[1]
Geere 2010a	South Africa: Subgroup of 29 people interviewed, drawn from convenience sample of 39 adults and children fetching water in 6 rural villages of Limpopo Province.	Mixed methods[3]	2008	Prevalence of spinal (neck or back pain) among water carriers was 69% and back pain alone was 38%.	Poor[1]
Geere 2010b	South Africa: 39 adults and children observed to fetch water in 6 rural villages of Limpopo Province.	Qualitative[3]	2008	Children linked water fetching to pain, spinal mobility problems and injury.	Good[2]
Rauniyar 2011	Pakistan: 1301 ‘treatment’ households of rural water and sanitation project villages and 1301 matched comparison households in non-project villages.	Cross sectional survey	2008	A significant 5% (p<0.001) reduction in ‘Drudgery’ defined as pain from fetching water due to muscle strain, back ache or blisters, attributed to water and sanitation projects; remained highly significant for lowest socio-economic group in sub-group analyses.	Poor[1]
Domenech 2012	Nepal: 120 households of 10 communities (2 communities from each district) of Kaski, Syangja, Palpa, Gulmi and Doti districts.	Mixed methods[4]	2008-2009	Rain water harvesting at the house reported to reduce ‘numbers of accidents and injuries during water collection’.	Fair[2]

Singh 2012	India: 100 agricultural workers (50 male and 50 female) engaged in agricultural tasks in last 10 years, from villages of Udaipur district of Rajasthan.	Cross sectional survey	NR	Male and female respondents reported severe neck and shoulder pain during water fetching; severe lower back pain felt by female respondents during water fetching.	Poor[1]
Asaba 2013	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in 4 villages.	Mixed methods	2011-2012	3 cases of a child drowning at open wells or ponds reported; accidental injury due to slips and falls while water fetching and fear of animal attacks also reported; among men and women, and male and female youths and children, carrying water was perceived to cause chest pain (33.3-64.4%); headache (5.7-23.1%); nasal bleeding (0.8-4.0%); back pain (0.8-1.9%); spinal problems (0.3-0.8%) and no problem (11.1-32.9%).	Poor[1] Fair[2]
Robson 2013	Malawi: 1504 children aged 9-18 years from 12 field sites in each of 3 regions.	Mixed methods	2006-2009	35% of children reported pains and health problems as their biggest difficulty in carrying water; headaches and neck aches most frequently cited (26%). Of children citing water carrying as their heaviest load, 5% more girls than boys reported bodily aches and pain in the last week. Supported by qualitative evidence from adults and children. Children (22%) reported hazards or risks of water fetching, such as rough terrain, stream/river crossings, snake or dog attacks, vehicles, or risk of being swept away or drowning during floods.	Poor[1,2]
Bisung 2015	Kenya: convenience sample of 8 women living in Usoma, 15km from Kisumu.	Qualitative (photovoice)	2013	Photograph used to illustrate that children fetch water bare footed and are exposed to injuries.	Good[2]

Sarkar 2015	Canada: 37% of adults and 100% of high school students living in the sub-Arctic Inuit community Black Tickle-Domino, located on the remote Island of Ponds, off the coast of southern Labrador.	Mixed methods[4]	2013	Study participants attributed chronic back and shoulder injuries to carrying heavy water buckets every day. Some men required surgery, but indefinitely postponed surgery due to 'the unavailability of alternative persons to retrieve water for their families.'	Good[2]
Subbaraman 2015	India: interviews with 40 adults in Mumbai slum; 3 focus groups (FG) of 6-9 women; 3 FG of 6-9 men.	Qualitative	2011	Physical strain occurs from water fetching, particularly impacting negatively the elderly, women, and children.	Good[2]
Berrian 2016	South Africa: 256 surveys within 4 purposively selected villages of Mnisi study area, Bushbuckridge Local Municipality, Mpumalanga.	Cross sectional survey	2013	224 (85%) respondents believed that shared water sources among people, livestock, and wild animals could be a health risk. 118 (45%) reported household water collection from places shared with animals. 'Most' survey participants dislike wildlife around their community, perceived as a threat to personal safety.	Poor[1]
Ayoade 2017	Nigeria: 800 girls aged 5-15 in peri-urban areas of Abeokuta, Ogun State.	Qualitative	2013-2014	788 (95%) experienced neck and back pain from carrying an excessive load of water and most reported a belief that their back pains worsened during menstruation as a results of heavy water carrying; 90% have experienced some form of violence (fights or punishment) and injury (slips, stepping on nails/glass); 166 (21%) experienced injury from physical fights at water points; 345 (41%) witnessed friends or neighbours struck by moving vehicles while fetching water.	Poor[2]

Mercer 2017	Canadian sub-arctic: 7 purposively selected households (21 people) in Black Tickle-Domino Inuit community.	Mixed methods[5]	NR	40.92% reduction in water retrieval time with rain water harvesting, explained by participants to mean less lifting and carrying of heavy water containers and potentially fewer injuries. Reported fear and anxiety of polar bear attack during water retrieval.	Good[2]
Geere 2018	South Africa, Ghana, Vietnam: 1 adult and 1 child from 673 households with at-house and off-plot water supply.	Cross sectional survey	2012-2013	People who previously carried water had increased risk of pain in hands (RR 3.62, 95%CI 1.34-9.75) and upper back (RR 2.27, 95%CI 1.17-4.40), as did people who currently carry water (RR hand pain 3.11, 95%CI 1.34-7.23; RR upper back pain 2.16, 95%CI 1.25-3.73) compared to people who never carried water. Mean 'axial compression' factor score (correlated with pain in head, upper back, chest/ribs, hands, feet and abdomen/stomach) associated with current (0.30, 95%CI 0.17-0.43) or previous (0.21, 95%CI 0.01-0.42) water carriage. Mean 'soft tissue strain' factor score, (correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs), negatively associated with currently (-0.18, 95%CI -0.32 - -0.04) carrying water.	Fair[1]

[1]methodological quality rating of cohort study or cross sectional survey; [2]methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study; [3]small mount of qualitative data presented in Geere 2010a is drawn from study reported in Geere 2010b; [4]quantitative data reported by Sarkar et al., and Domenech et al., was water quality testing; [5]no quantitative health data was collected for analysis against water retrieval time

2.3.4.2 Fatigue and energy expenditure

There is moderate evidence of an association between fatigue or tiredness and water carriage from quantitative data (Table 2.4) and strong evidence from qualitative data (Table 2.5). Five of 11 studies (12 publications) reporting tiredness, fatigue or exhaustion affecting water carriers (Table 2.7), described associations between water carriage and worsened family relationships (Zolnikov and Blodgett Salafia, 2016), poorer health status (Gibson and Mace, 2006, Hemson, 2007) and reduced engagement with education (Robson et al., 2013, Ayoade et al., 2017). Two studies measured energy expenditure (Rao et al., 2007, Borah et al., 2010). As an index of total energy expenditure, Rao et al., (2007) described drawing water as moderate physical activity, and carrying two containers on the head as heavy physical activity, whilst Borah et al., (2010) categorised drawing and carrying water home as moderately to very heavy. However, the energy expenditure measurements were done on very small samples of women in India, and may not be generalizable to other populations. Together with other studies in this review, which found that rating of perceived exertion is correlated with weight of water carried and path incline (Geere et al., 2010a), that energy expenditure for water carriage may be most important in food scarce regions (Domenech et al., 2012), and that water points which reduce water fetching increase birth rates (Gibson and Mace, 2006), current evidence highlights that the energetic cost of water carriage has potentially detrimental effects on health and wellbeing, manifesting as tiredness or fatigue.

2.3.4.3 Stress, mental health and wellbeing

Inconclusive evidence that water carriage is associated with stress was found from quantitative data (Table 2.4) even though strong qualitative data was reported indicating that people experienced or attributed stress to water carriage (Table 2.5). Two rigorous qualitative studies (Stevenson et al., 2012, Zolnikov and Blodgett Salafia, 2016), and one fair quality (Henley et al., 2014) and two poor quality (BeLue et al., 2008, Stevenson et al., 2012) cross sectional surveys, reported water carriage to be associated with stress (Table 2.8). In these studies, psychosocial distress was identified as an effect of water carriage by thematic analysis, and measured using three different questionnaires and by quantification of hair cortisol content as a biomarker for chronic stress. Despite the different indicators of stress, all of the studies elucidated mechanisms by which water carriage might cause stress. These included feeling unsafe during water collection (Henley et al., 2014), having insufficient time for family members to spend with each other or discuss household issues (Zolnikov and Blodgett Salafia, 2016), the physical difficulty of water carriage with a young child (BeLue et al., 2008), risk of physical assault or rape, extremes of temperature, queueing times and inability to complete household tasks triggering arguments between married couples (Stevenson et al., 2012). Considering issues related to social vulnerability which are discussed below, it is plausible that water carriers experience stress related to fear of conflict or abuse (House et al., 2014). However, one good quality cohort study failed to find any significant association with respondents' mental wellbeing or life satisfaction and connection to a piped water supply, among participants with above median time spent fetching water at baseline (Devoto et al., 2012). One mixed methods study failed to find an association between emotional distress and water fetching time, even though participants found water collection to be 'bothersome' because of having to collect water at night (Thomas and Godfrey, 2018). The findings of these studies are inconsistent with the others, however, they should be considered with some caution. The outcome measurement of mental wellbeing in Devoto et al., (2012) was derived from a composite score and its validity and reliability for use with the study population was not reported, and whilst socio-economic status was included, other potential confounding factors which might affect mental health and life satisfaction were not included in the analyses. The average one way time to the water source in Thomas and Godfrey's (2018) case study was less than three minutes, therefore it is likely that there was insufficient total time and variation in time spent fetching water by participants to observe an association with emotional distress.

2.3.4.4 Perinatal health.

There is moderate quantitative evidence that perinatal health is associated with water carriage (Table 2.4) and strong qualitative evidence (Table 2.5). Six studies reported different aspects of perinatal health to be associated with water carriage (Table 2.9). Two qualitative papers reported physical strain and non-specific 'health complications' from carrying 20 litre water containers on the head during pregnancy (Mukuhlani and Nyamupingidza, 2014, Bisung et al., 2015) and one reported mothers' views that being forced to fetch water in late pregnancy led to malnourished children (Ghosh et al., 2016). Quantitative studies reported reduced uptake of prenatal care services (McCray, 2004), six times greater odds (author's calculation) of giving birth in a health facility when a husband provided help with water fetching (Ono et al., 2013) and almost four times greater odds of giving birth in any given month, among women with an improved water supply located closer to their home compared to those without improved water supply (Gibson and Mace, 2006). Gibson and Mace (2006) described the improved water access as an 'energy saving' intervention which reduced distance to water and women's time spent water fetching. They concluded that the energy saved by the technology did not translate into an improved nutritional status for women, because it supported an increase in birth rates. Whilst the study found a negative consequence of the increased birth rate to be increased childhood malnutrition, it nevertheless indicates a potentially detrimental impact of maternal health associated with water carriage; it suggests that prior to installation of taps the exertion of water carriage affected women's health enough to reduce birth rates, as compared to birth rates post tap installation. Whilst Gibson and Mace did not include nutritional interventions as possible confounding factors in their multivariable analysis, and McCray's (2004) outcome measure could have been affected by recall and therefore misclassification bias, the six studies provide evidence that water fetching could be significantly associated with perinatal health outcomes through behavioural and physiological mechanisms.

Table 2.7 Water carriage and energy expenditure or fatigue (12 articles)

First author & date	Population	Study type	Dates	Key finding	Quality
Gibson 2006	Ethiopia: Agropastoralist community, 1,548 women 15–49 in a demographic survey of 1,976 HHs and subsample of 682 children (<15y) and 264 women (15–49) in anthropometric survey in 4 villages.	Cohort study	2003	Odds of a woman with 'energy saving' water points closer to home giving birth in any given month was three times greater than a woman without an improved water supply (OR 3.78, p=0.009).	Fair[1]
Hemson 2007	South Africa: 1052 children aged 5-17 from 366 households, in 3 villages with no piped water supply; 2 dry flat villages in Limpopo and 1 hilly village with natural springs in Kwazulu Natal.	Mixed methods	NR	17% of children surveyed on recent illness reported fatigue for which 4% had sought treatment. Of children reporting worsened health, 96% described water carrying as tiring, 75% reported fatigue.	Poor[1] Fair[2]
Rao 2007	India: 22 rural women aged 18–45 from villages about 30–40km from Pune city, Maharashtra.	Cross sectional survey	NR	PAL[3] of drawing water from a well and using hand pump were categorized as moderate; carrying 2 containers on the head was categorized as heavy.	Poor[1]

Borah 2010	India: 30 rural women with normal blood pressure and temperature aged 21-40 years in Jorhat district of upper Brahmaputra Valley Zone of Assam.	Observational study	NR	Compared to walking to water point and drawing water, the return journey with water filled containers had maximum heart rate (HR) and energy expenditure (EE) for 21-30 age group (115 bpm and 9.56kJ/min) and for 31-40 age group (113bpm and 9.24kJ/min); on basis of average HR and EE, workload for drawing water and return journey classified as moderately heavy; on basis of peak HR and EE, workload for drawing water and return was classified as heavy or very heavy; rating of perceived exertion was highest with the return journey while carrying water, and highly correlated with HR (r value 0.84-0.92) for both age groups at all parts of the water fetching cycle.	Poor[1]
Geere 2010a	South Africa: Subgroup of 29 people interviewed, drawn from convenience sample of 39 adults and children fetching water in 6 rural villages of Limpopo Province.	Mixed methods	2008	Rating of Perceived Exertion significantly correlated with container weight ($r = 0.52$; $p = 0.011$) and path incline ($r = 0.459$; $p = 0.018$) during water carriage.	Poor[1]
Geere 2010 b	South Africa: 39 adults and children observed to fetch water in 6 rural villages of Limpopo Province.	Qualitative	2008	Children link water carriage to tiredness in qualitative interviews.	Good[2]
Domenech 2012	Nepal: 120 households equally distributed among ten selected communities and with at least 2 years of experience with rainwater harvesting.	Mixed methods[4]	2008-2009	Rainwater harvesting reduced water fetching (6.4 hrs/day less in the rainy season; 4 hrs/day less in the dry season) and allowed energy (calorie) savings.	Fair[2]

Asaba 2013	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in 4 villages.	Mixed methods	2011-2012	Over 70% of survey respondents highlighted 'tiresome' nature of water fetching. Many added that carrying water required 'a lot of physical energy'. Among men (22.9%) and women (13.6%), male youths (18.1%), female youths (19.1%), male children (23.7%) and female children (23.1%) carrying water was perceived to cause fatigue.	Poor[1] Fair[2]
Robson 2013	Malawi: 1504 children aged 9-18 years from 12 field sites in each of 3 regions.	Mixed methods	2006-2009	Of children citing water carrying as their heaviest load, 5% more girls than boys reported experiencing tiredness in the last week. Supported by qualitative data from adults and children, indicating that children suffer from tiredness and inability to concentrate at school, particularly from being woken at night or very early morning to fetch water.	Poor[1,2]
Bisung 2015	Kenya: convenience sample of 8 women living in Usoma, 15km from Kisumu.	Qualitative	2013	Children need a lot of energy to push wheelbarrows and carts used for carrying water.	Good[2]
Zolnikov 2016	Kenya: 52 semi-structured interviews to examine relationships among primary water gatherers and their families after receiving nearby access to water, in Kitui.	Qualitative	NR	Primary water gatherer 'very tired and easily annoyed' prior to the implementation of interventions providing nearby water supply.	Good[2]
Ayoade 2017	Nigeria: 800 girls aged 5-15 in peri-urban areas of Abeokuta, Ogun State.	Qualitative	2013-2014	Respondents reported that they experienced fatigue due to water carriage, which negatively affected their ability to participate in school.	Poor[2]

[1]methodological quality rating of cohort study or cross sectional survey; [2]methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study; [3]index of total energy expenditure adjusted for Basal Metabolic Rate (BMR); [4]quantitative data reported Domenech et al., was water quality testing

Table 2.8 Water carriage and stress, mental wellbeing or life satisfaction (6 studies)

First author & date	Population	Study type	Dates	Key findings	Quality
BeLue 2008	South Africa: Mothers, 9 months postpartum aged 17-30 Khayelitsha, Western Cape.	Cross sectional survey	1999-2000	Piped water in the dwelling associated with significantly lower perceived stress (PSS); PSS 14.2, (sd 4.8) for piped into dwelling, 19 (sd 7.4) piped water to yard, 17 (sd 6.6) for public standpipe).	Poor[1]
Devoto 2012	Morocco: 845 households in Tangiers, not connected to a city water network, comparing subgroup of households reporting above median baseline time fetching water.	Cohort study	2007-2008	With subgroup analysis of households reporting above average median baseline water fetching time, no significant effect of allocation to water supply 'encouragement' project, or actual connection to piped water supply on a) summary index averaging 3 scores of mental wellbeing (over past 7 days respondent felt more often than not, sad/ worried/satisfied), and b) respondent's rating of life satisfaction level being ≥5 (on 0-10 scale).	Good[1]
Stevenson 2013	Ethiopia: women from cluster sample of 104 households for free listing, convenience sample of 39 women from 3 kebeles for ranking exercise, 3 focus group discussions totaling 30 women from 3 kebeles, cluster sample of 324 women.	Mixed methods	2009-2010	The 24 item water insecurity scale was correlated with time required to fetch water ($r=0.52$; $p < 0.0001$), and was positively but weakly correlated with psychosocial distress ($r=0.22$, $p < 0.001$), indicating that women who experienced more water insecurity also reported more symptoms of common mental disorders. Qualitative data indicates that social and environmental factors contribute to stress during water carriage.	Poor[1] Good[2]

Henley 2014	Kenya: Randomly selected subsample (200 of 1000 participants in health survey) from settlements in Naivasha and Mogotio.	Cross sectional survey	2011	Participants who reported feeling unsafe when they collected water or went to the toilet had increased mean hair cortisol content by 127 ng/g (Yes (safe) 607 ± 282ng/g; No (not safe) 734 ± 335ng/g; p = 0.0370).	Fair[1]
Zolnikov 2016	Kenya: 52 semi-structured interviews to examine relationship experiences among primary water gatherers and their families after receiving nearby access to water, in Kitui.	Qualitative	NR	Primary water gatherers: before water interventions easily annoyed; after intervention additional time for discussions with spouse and of school-related achievements and issues with children. Household heads: before interventions angry at lack of water availability, challenged by lack of time for household discussions, unsatisfied with work; after water interventions time for discussions and planning with spouse, made additional money. Children: after intervention school fees available, time with mother and family more frequent, more time for friendships and schoolwork, no time outside of school spent gathering water.	Good[2]
Thomas 2018	Ethiopia: survey and focus groups with 200 households in Welenchiti, Oromia region, and interviews with senior water utility staff.	Mixed methods	NR	Most households (64%) felt 'bothered' by collecting water in the previous 7 days, mostly because of having to collect water at night; emotional distress was not significantly associated with accessibility (total water collection time in minutes) of the main water source (β -0.03, p=0.677) indicating that a longer time spent collecting water did not increase the intensity of emotional distress.	Poor[1,2]

[1]methodological quality rating of cohort study or cross sectional survey; [2]methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study

Table 2.9 Water carriage and perinatal health (6 studies)

First author & date	Population	Study type	Dates	Key finding	Quality
McCray 2004	South Africa: 327 hh surveys: Mothers of child aged 12-23 months in randomly selected household Kwazulu Natal.	Cross sectional survey	1998	Report that fetching water was a daily activity affected by making a trip to the health clinic was associated with level of prenatal care utilization (χ^2 6.64, p=0.036); women two times more likely to utilize prenatal care services at a low level than at an average level (1/OR = 2.43).	Fair[1]
Gibson 2006	Ethiopia: 1,548 women (15–49) in demographic survey of 1,976 HHs; 682 children, 264 women in anthropometric study (4 villages).	Cohort study	2003	Odds of woman with access to water points giving birth in any given month three times greater than a woman without an improved water supply (OR 3.78, p=0.009). Installation of taps did not improve or predict maternal health indicated by anthropometric measures of BMI and MUAC.	Fair[1]
Ono 2014	Kenya: 306 mothers aged 18 to 49, who brought their babies to Sosiot Health Center for immunization within their first year of life, in September to November 2011. Data from 303 respondents (99%) were analyzed.	Cross sectional survey	2011	Unmarried women whose sisters helped them fetch water more likely to deliver at health facilities (HF) (P = 0.042) and married women whose neighbors helped them fetch water less likely to deliver at HF (P = 0.021) than those without support. Married women, borderline significant (p= 0.054) association between birth at home and support from husband water fetching; of women who received help from their husband to fetch water, 1 of 20 (5%) gave birth at home, 19 of 20 (95%) gave birth in a HF; women who did not have help from their husband to fetch water, 50 of 211 (23.7%) gave birth at home, 161 of 211 (76.3%) gave birth in HF. Married women more likely to deliver at HF if they did not have the support of sisters-in-law fetching water (OR = 2.2, CI 1.0-4.7, n245; husband helping not in logistic regression model).	Fair[1]

Mukhulani 2014	Zimbabwe: respondents of 3 Bulawayo suburbs.	Qualitative	NR	Physical strain and health complications from carrying 20 litre container on head while pregnant highlighted in illustrative quote from qualitative data.	Poor[2]
Bisung 2015	Kenya: convenience sample of 8 women living in Usoma, 15km from Kisumu.	Qualitative (photo-voice)	2013	Photograph of pregnant woman carrying 20 litres of water on head and holding 10 litres used to exemplify association of water carriage with maternal health.	Good[2]
Ghosh 2016	India: 79 mothers from 8 groups of 8-10 mothers of at least 1 child under 6, in 4 villages in the Sundarbans of West Bengal.	Qualitative	NR	Mothers did not get sufficient rest during pregnancy and perceived that this led to giving birth to malnourished children. "The women have to fetch water from a distant source even in their last few months of pregnancy. They force themselves to do so to avoid the quarrels with the mother-in-law".	Good[2]

[1]methodological quality rating of cohort study/cross sectional survey; [2]methodological quality of qualitative study or qualitative findings of mixed methods study

2.3.4.5 Social vulnerability.

The studies in this review provide rich qualitative evidence that water carriage is associated with social vulnerability, in seven good (Yallew et al., 2012, Isoke and Van Dijk, 2014, Schatz and Gilbert, 2014, Ghosh et al., 2016, Mbereko et al., 2016, Subbaraman et al., 2015, Zolnikov and Blodgett Salafia, 2016), three fair (Domenech et al., 2012, Asaba et al., 2013, Mukuhlani and Nyamupingidza, 2014) and three poor quality studies (Robson et al., 2013, House et al., 2014, Ayoade et al., 2017) from 31 countries (Table 2.5 and 2.10). Moderate evidence is available from one good (Devoto et al., 2012), one fair (Mugambe et al., 2014) and seven poor quality (Yallew et al., 2012, Asaba et al., 2013, Robson et al., 2013, Cook et al., 2016, Hennegan et al., 2016, Krumdieck et al., 2016, Dapaah and Harris, 2017) quantitative studies from six countries (Table 2.4 and 2.10).

Social vulnerability in relation to water access, was reported to occur through several mechanisms. Depending on available levels of social support, personal characteristics may make individuals vulnerable to water insecurity, or increase their risk of experiencing discrimination or physical, sexual and psychological abuse while collecting water. For example, older adults or people with physical disability may struggle to operate manual pumps that require strength and coordination to draw water from a well. Social support from family or friendship networks is a common mechanism used within communities to support people who would otherwise struggle to complete such essential but physically demanding tasks. Conversely a lack of social support could be the mechanism causing or exacerbating their vulnerability to water insecurity. Personal characteristics, such as sex, age, disability or known HIV status may also make an individual vulnerable to abuse or discrimination from other people, and collecting water from shared sources may create the setting in which abuse occurs. Many incidents of gender based violence are documented in the studies of this review, however authors acknowledge that incidents are likely to be under reported. Disputes and community or household tensions over water access have also been reported to manifest as interpersonal or domestic violence. Therefore, in relation to water carriage, social vulnerability emerged as a theme encompassing enhanced vulnerability to water insecurity because of personal characteristics combined with a lack of social support, and increased vulnerability to threats or violence from other people.

2.3.4.6 General health.

There is inconclusive evidence of a relationship between water carriage and self-rating of general health, because of inconsistent findings in the five studies (Table 2.4 and 2.5).

There is an indication of a dose response relationship between water carriage and self-rating of health in three (Buor, 2004, Foggin et al., 2006, Hemson, 2007) of the five studies reporting general health of water carriers, with greater amounts of time spent water fetching linked with poorer health for both children and adults (Table 2.11). These findings were inconsistent with those of Geere et al (2018a), who found that adults who currently or previously carried water, had a better (lower = healthier) mean general health rating score than adults who never carried water, whilst children who currently carried water reported better, and children who previously carried water reported worse health, compared to children who had never carried water. In qualitative data from an earlier pilot study, Geere et al., (2010b), found that some children linked water carriage to better health and stronger resilience to diseases such as ‘flu’, others to meeting basic needs and some to experiencing unfair workloads.

The inconsistencies may be due to different methods used for participants to rate their general health, and differences in confounding factors incorporated into the analyses. In three of the four studies which attempted to scale or categorise health status (Buor, 2004, Foggin et al., 2006, Hemson, 2007), recall of occasions of illness or comparison of current to previous health status was required of respondents. This may introduce bias or error to the classification of health status, weakening internal validity of the studies and rendering the findings inaccurate (NIH, 2014). Self-rated health ‘today’ on a simple five point scale has been found to have high test-retest reliability and to be an excellent predictor of future health in some studies, however, reliability of self-rated health status has also been shown to be affected by age, income and occupation in some populations (Crossley and Kennedy, 2002). Hemson’s (2007) findings may therefore have been influenced by recall and confounding factors, because the statistics presented are descriptive and lack analysis of the effect of variables such as age, sex and socio-economic status. These variables were considered in the regression analyses reported by Buor (2004), Foggin et al., (2006) and Geere et al., (2018a), with Foggin et al. reporting a very strong association between increased time spent water fetching and poorer general health. However, other potential confounding factors which were not included in analyses, such as hygiene practices, access to health care or sanitation coverage, could have influenced the results in all studies. No studies utilised a longitudinal cohort design to determine a temporal relationship between water fetching and general health status, and all could have been affected by confounding factors which were not included in analyses.

Table 2.10 Water carriage and social vulnerability (19 studies)

First author & date	Population	Study type	Dates	Key finding	Quality
Devoto 2012	Morocco: 845 households in Tangiers, not connected to a city water network, comparing subgroup of households reporting above median baseline time fetching water.	Cohort study	2007-2008	Significant reduction in risk of being in conflict with people from his/her family on water matters with a) allocation to water supply 'encouragement' project (-0.06, p=0.05), which remained significant and decreased further for households with above median baseline time fetching water (-0.09, p=0.10) or b) actual connection to piped water supply (-0.12, p=0.05), which was similar but not significant for households with above average baseline water fetching time.	Good[1]
Domenech 2012	Nepal: 120 households distributed among ten selected communities, with at least 2 year experience of rainwater harvesting.	Mixed methods[3]	2008-2009	Perceived benefits from rainwater harvesting reported as being particularly helpful to vulnerable groups, described as older people, disabled people and children.	Fair[2]
Yallew 2012	Ethiopia: 296 home based care clients living with HIV/AIDS, drawn from two NGOs in Gondar city.	Mixed methods	2009	Bivariate analysis indicated that being forced to go far distance was associated with unimproved water status (crude OR 3.91, 95%CI 1.13, 13.47, $p < 0.05$); needing help with walking was associated with improved water status (crude OR 0.11, 95%CI 0.01, 0.89, $p < 0.05$), but neither remained significant in multiple logistic regression; adjusted OR for forced to go far 3.84 (95%CI 0.41, 35.27); for needing help walking 0.13 (95%CI 0.01, 1.44).	Poor[1] Good[2]

Asaba 2013	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in 4 villages.	Mixed methods	2011-2012	Water points are sites of positive social interactions, however, fights resulting in verbal and physical attacks were also observed and reported to occur at 'improved' water points, particularly at those with queues.	Poor[1] Fair[2]
Robson 2013	Malawi: 1504 children aged 9-18 years from 12 field sites in each of 3 regions.	Mixed methods	2006-2009	Hazards of water fetching reported to be harassment, verbal abuse or attack from people, and 'meeting criminals'.	Poor[1,2]
House 2014	Various countries.[4]	Qualitative	NR	Case studies indicate that gender based violence occurs during water fetching in many countries. Violence may be sexual, psychological, physical or socio-cultural.	Poor[2]
Isoke 2014	Uganda: 127 survey respondents from Bwaise II and Kisenyi III parishes (informal settlements in Kampala). Semi structured interviews with 10 National Water and Sewerage Corporation staff. 3 focus groups, 2 with 12 leaders of the parishes and 1 of 4 NGO members.	Mixed methods[5]	NR	Reasons cited for choice of tap included securing young children from being sexually abused and preventing children from 'picking up bad habits from bad company'.	Good[2]
Mugambe 2014	Uganda: 450 respondents, with 222 from HIV/AIDS affected, 228 from HIV/AIDS non-affected households of rural districts Mpigi and Gomba.	Cross sectional survey	NR	Bivariate analysis: perceptions that fetching water takes a lot of time (OR=2.44; 95 % CI: 1.65–3.61) and requires a lot of energy (OR=1.83; 95 % CI: 1.26–2.67) strongly associated with buying water from water vendors. Multivariable analysis: perception that fetching water takes lot of time (AOR=2.15; 95 % CI: 1.21–3.82), district location (AOR=1.92; 95 % CI: 1.25–2.95), presence of person living with HIV/AIDS in household (AOR= 0.58; 95 % CI: 0.38–0.88) significant predictors of buying water from vendors.	Fair[1]

Mukhulani 2014	Zimbabwe: respondents from 3 suburbs in Bulawayo affected by water scarcity.	Qualitative	NR	Sexual assault and harassment reported at water points, during early morning queueing for water, or at night when travelling to boreholes 500m-2km away.	Fair[2]
Schatz 2014	South Africa: 30 women aged 60–75 and impacted by HIV in some way, from Phase I of the 'Gogo Project', in rural sub-district.	Qualitative	N/R	Fetching water is an activity associated with the respondents' (older women) own health and level of family support.	Good[2]
Subbaraman 2015	India: 40 adults of Mumbai slum; 3 focus groups (FGs) 6-9 women; 3 FGs 6-9 men.	Qualitative	2011	Reports of social conflict and extortion when bringing water containers home.	Good[2]
Ghosh 2016	India: 79 mothers from 8 groups of 8-10 mothers who had at least one child below 6 years of age across 4 villages in 3 blocks in the Sundarbans region of West Bengal.	Qualitative	NR	Mothers did not get sufficient rest in pregnancy, perceived that this led to birth of malnourished children. "The women have to fetch water from a distant source even in their last few months of pregnancy. They force themselves to do so to avoid the quarrels with the mother-in-law". Some beaten by in-laws.	Good[2]
Cook 2016	Kenya: 387 households near Kianjai, north-central Kenya.	Cross sectional survey	2013	Water sources are a cause of social conflict. Proportion of respondents who thought using water source would be ''somewhat'' or ''very'' likely to lead to conflict: public well 0.69, public borehole 0.51, public piped connection 0.56, surface, other public 0.62. Among well-owners, 85% reported allowing neighbors to use well, of these 28% said that sharing led to conflict with neighbors.	Poor[1]

Hennegan 2016	Uganda: 205 menstruating schoolgirls from eight schools in Kamuli District, Uganda, rural areas characterized by poor performance on health and education indicators and literacy rate below the national average.	Cross-sectional, secondary analysis of data from the final survey of a controlled trial	2012-2014	Of girls who avoid activities while menstruating, 9/48 (18.8%) using reusable pads avoid water fetching and 28/68 (41.2%) using existing menstrual management methods avoid fetching water: OR existing methods: reusable pads 3.03 (1.27-7.25).	Poor[1]
Krumdieck 2016	Kenya: 323 women at 33 weeks gestation, of mixed HIV status, recruited from 7 clinics in Nyanza province	Quantitative	2014 - 2015	Water acquisition posed psychological stress and physical risk, 77.3% stating that they felt 'somewhat or strongly concerned' for their physical safety during trips for water.	Poor[1]
Mbereko 2016	Zimbabwe: 9 of 40 villages in Nyamakate resettlement area on the southern edge of the Zambezi valley, in Hurungwe, Mashonaland West, in the north-eastern part of Zimbabwe.	Qualitative	NR	11 of 13 HIV and AIDS-affected households indicated that HIV and AIDS compromised their rights to access water resources. The 11 caregivers who experienced problems accessing water were all women. The statements demonstrate that although water is open access, people were on guard for contagious diseases and "silently resisted" water-point access to carriers.	Good[2]
Zolnikov 2016	Kenya: 52 semi-structured interviews among primary water gatherers and their families after receiving nearby water access.	Qualitative	NR	Primary water gatherers report feeling 'scared and fearful when gathering water, unhappy with water-gathering situation.'	Good[2]

Ayoade 2017	Nigeria: 800 girls aged 5-15 in peri-urban areas of Abeokuta, Ogun State.	Qualitative	2013-2014	456 (55%) reported sexual assault and/or harassment; 99 (11%) reported physical punishment by parents/ guardians when containers were lost or exchanged at water points; 184 (23%) reported punishment by parents/guardians who believed they were wasting water; 122 (14%) fearful of returning home with empty containers.	Poor[2]
Dapaah 2017	Ghana: 120 survey respondents in Ga-Mashie, Accra, and 80 in Madina, Accra.	Mixed methods[6]	NR	Incidence of fights at water collection points 102 (85.0%) in Ga-Mashie; 34 (42.5%) in Madina; 136 (68.0%) in total.	Poor[1]

[1]methodological quality rating of cohort study or cross sectional survey; [2]methodological rating of qualitative study or qualitative findings of a mixed methods study; [3]quantitative data reported Domenech et al., was water quality testing; [4]Sudan, DRC, Solomon Islands, Liberia, Guinea, Sierra Leone, Kenya, India, Cameroon, South Africa, Tanzania, Uganda, Zambia, Haiti, Afghanistan, Cambodia, Somalia, Philippines, Nigeria, Ghana, Mozambique, Pacific Islands, Pakistan, Angola, Malawi, Sudan, Iran, Nepal, Timor-Leste, Bangladesh, Sri Lanka.; [5]quantitative data in Isoke and can Dijk was not analysed for association with health outcomes; [6]qualitative data was not about health outcomes

Table 2.11 Water carriage and general health (5 studies)

First author & date	Population	Study type	Date	Key findings	Quality
Buor 2004	Ghana: 210 females aged 12+ in Kumasi; 90 from urban 'core', 120 from urban periphery.	Cross sectional survey	2001	During water scarcity: ill once every 2 weeks (fetching water ≥4hrs 39.2%; 2-3hrs 19.3%; <2hrs 21.3%); ill once a month (fetching water≥4hrs 31.4%; 2-3hrs 26.6%; <2hrs 27.7%); ill once in 3 months (fetching water ≥4hrs 19.6%; 2-3hrs 41.3%; <2hrs 31.9); ill rarely (fetching water ≥4hrs 9.8%; 2-3hrs 12.8%; <2hrs 19.1%); Multiple regression: beta coefficients total sample (-0.255; p0.011), core (-0.261; p<0.001), and periphery (-0.293; p0.003). Type of regression model not stated. If multiple linear regression, for each extra hour of water fetching, health status score reduced by 26-29%. However, health status measured on 4 point categorical scale (1 = sick once every 2 weeks, 4 = rarely sick), for which proportional odds regression is more appropriate. This would mean that for each hour spent water fetching, the likelihood of going from a lower level of the outcome variable (higher frequency of illness) to the next (lower frequency off illness) reduces by 25-29%.	Poor[1]
Foggin 2006	Tibet: herders in Sanjiangyuan region, Tibetan Plateau, southwest Qinghai Province; 50 families in Suojia Township, 49 in Zhahe Township.	Cross sectional survey and qualitative	2002	Tibetan pastoralists who spend >15 minutes collecting water are almost 10 times more likely to report being ill in the past month than those spending ≤15 minutes (OR = 9.853; p≤0.001).	Poor[1] Good[2]
Hemson 2007	South Africa: 1052 children 5-17yrs from 366 households, in 3 villages with no piped	Cross sectional survey and qualitative	NR	Compared to children collecting water 0-13hrs per week, smaller proportions of children collecting water for ≥14hrs per week rated their health as 'improved' (0-13hrs 42%; ≥14hrs 37%) or the same (0-13hrs 53%; ≥14hrs 45%) and a greater proportion as worse (0-13hrs 5%; ≥14hrs 19%). Of children	Poor[1] Fair[2]

	water supply; 2 dry flat villages in Limpopo, 1 hilly village with natural springs in Kwazulu Natal.			reporting worsened health, 77% spent ≥14hrs per week collecting water and 87% stated that their health was worsened by collecting water. Of children who said their health had got worse 82% reported collecting water more than once a day versus 18% collecting water once a day. Of children reporting their health as improved or the same, 56% collected water more than once a day, 44% collected water once a day.	
Geere 2010b	South Africa: 39 adults and children observed fetching water, 6 rural villages, Limpopo Province.	Qualitative	2008	Children linked water carriage and health in various ways, including feeling 'better and healthy' or having greater resilience to diseases like flu, as a result of the exercise required for water carriage. Children also related health to being able to participate in activities such as water fetching, as well as to having basic needs met and experiencing fair workloads.	Good[2]
Geere 2018	South Africa, Ghana, Vietnam: 1 adult and 1 child from 673 households with either at-house or off-plot water supply.	Cross sectional survey	2012 - 2013	Adults who previously carried water had a better (lower = healthier) mean general health score than adults who never carried water (β -0.58, 95%CI -0.80 to -0.35, p<0.001) and adults who currently carried water had a better mean general health rating score than adults who had never carried water (β -0.91, 95%CI -1.12 to -0.70, p<0.001). Children who currently carry water had a better mean score rating for general health than children who had never carried water (β -0. 20, 95%CI -0.37 to -0.31, p=0.003). Children who previously carried water had a worse mean score rating for general health (β0.39, 95% CI 0.02 to 0.75, n=10).	Fair[1]

[1]methodological quality rating of cohort study or cross sectional survey; [2]methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study

2.4 Discussion

To the author's knowledge, this is the first systematic review of the relationship between the work of water carriage and the health of water carriers. Forty studies were included in the review. Detrimental health outcomes directly associated with the physical work of carrying water were mainly reported, such as increased pain, fatigue and stress. Indirect detrimental health outcomes associated with the environment in which water carriage takes place, or the consequences of water carriage affecting other activities were also reported and were related to perinatal health and social vulnerability. These included serious health issues such as physical abuse and rape. The ability of the studies reporting quantitative data to demonstrate a cause and effect relationship is limited because of study design and fair or poor methodological quality. The only cohort study in the review rated as good (Devoto et al., 2012) was of limited value, because in the primary analyses of the effects of actual connection to a piped at-house water supply, the comparison group included households carrying water by container from public standpipes together with those connected by hose to a public tap or neighbour, which would eliminate or reduce the need for water carriage in some households of the comparison group. Whilst some relevant sub-group analyses of households with above median time spent fetching water at baseline were reported, the reliability and validity of the health related outcome measures used were not clear, and confounding factors which were adjusted for in the analyses did not include other forms of manual labour or potential sources of stress. A greater number of studies reporting qualitative data were rated as having good methodological quality, and whilst these provide insight into the lived experience of fetching water, they cannot provide strong evidence of a causal relationship, as the actual experience of pain or other health effects may be mediated by confounding factors and bias. Overall, the evidence in this review indicates that the work of water carriage is more often associated with harm rather than benefit to the water carriers' health. The findings indicate that the health outcomes associated with water carriage create potential barriers to achieving the targets of many of the SDGs.

Qualitative studies clearly indicate that water carriers experience pain and feel exposed to risk of injury during water carriage, which is commonly performed by carrying containers on the head. The findings of this review are supported by Lloyd et al., (2010b) who reported that discomfort in the neck was, in all cases, the cause of early termination of head-loading trials during a laboratory experiment. Geere et al., (2018a) proposed that the pain pattern they observed to be associated with water carriage might indicate referred pain as a consequence of musculoskeletal tissue deformation under compressive loading, or long term structural changes such as cervical spondylosis. Evidence of advanced cervical spondylosis has been reported among porters and people who apply loads to the head (head loading) (Joosab et al., 1994, Jumah and Nyame, 1994, Jäger et al., 1997), suggesting that this common method of water carriage may be sufficient to cause structural changes in bone and the soft tissues of the spine. Such changes have been proposed in experimental studies to occur as a consequence of biomechanical stress and strain (Kumaresan et al., 2001). Particularly in the cervical spine, spondylosis may lead to neurological impairment, such as radiculopathy or myelopathy, and related disability (Houten and Noce, 2008, Machino et al., 2012). However, none of the studies reporting pain or injury affecting water carriers were longitudinal cohort studies. Hence it remains unknown whether the loading patterns typical of domestic water carriage, by head loading or other methods, are sufficient to have important long term effects on the musculoskeletal system and to increase risk of neurological compromise. This question is particularly important for populations in sub-Saharan Africa, where other risk factors for myelopathy, including nutritional or infectious diseases such as HIV, tuberculosis or schistosomiasis, are also common (Bhigjee et al., 2001, Candy et al., 2014, Roman, 2014) and may increase susceptibility to adverse impacts of head loading. It is also important to recognise that many people will carry diverse loads in addition to water (Porter et al., 2012), and future studies should include detail of other head loading and manual labour as potential factors confounding the effects of water carriage.

No studies attempted to conduct any detailed clinical assessment of their study participants (Dudler and Balague, 2002), or reported excluding participants with long term health conditions which might cause pain and modify an association between symptoms and water carriage. This may be due to the practical and ethical challenges of conducting clinical assessments in areas of limited health services coverage, the likely situation in many areas where water carriage studies would typically be conducted (UN, 2015a). However, future studies would be strengthened by incorporating some aspects of clinical assessment to supplement self-reported health outcomes. For example, a medical history could be combined with evaluation of whether movement, compression stress or palpation of pain sensitive structures provokes symptoms comparable to those experienced during water carriage (Magee, 2002). This would help to identify a likely cause of symptoms and could confirm whether mechanical loading during water carriage is a plausible mechanism of pain production in study participants.

This review has found moderate quantitative and strong qualitative evidence that tiredness or fatigue is associated with water carriage. Head loading by African women has been described as an energy efficient way of carrying loads (Maloiy et al., 1986, Heglund et al., 1995). However, one study tested the ‘free ride’ hypothesis for head loads compared to back loads, and found that it was not generalizable, with significant individual differences in energetic cost (Lloyd et al., 2010a). In larger households, or those caring for young children, aged parents, or people living with disability or long term conditions, the need for water may be high and water carriage may become a demanding daily chore, particularly if it falls on one woman or her children. Differences in the capacity of individuals to meet their household’s need for water will influence water security and could exacerbate inter-household and inter-community inequalities of water access, a direct challenge to SDG6 target 6.1 ‘universal and equitable access to safe and affordable drinking water for all’ (UN, 2015b).

Inconclusive quantitative and strong qualitative evidence was found that stress is associated with water carriage. Qualitative evidence highlighted that the experience of stress associated with water carriage could be due to reduced family time and poorer interpersonal relationships, conflicts which arise in the community or at home over water use and domestic tasks, the physical challenges of collecting water and lack of safety. Water fetching is also indirectly linked to stress, by increasing water insecurity, and feelings of worry or shame from inability to keep oneself or one’s children clean, or complete expected household chores such as laundry, cleaning and cooking. The one good quality cohort study in this review did not find a significant effect of connection to a piped water supply on respondents’ mental health or life satisfaction, however, their mental health index was derived from the average of three separate measures of wellbeing, and its reliability and validity for use in the study population is not clear. Whilst socio-economic confounding factors were included in the analyses, other factors which may have also affected mental health and wellbeing in the population studied, were not included in the analysis. Overall, the findings are similar to a review of water insecurity and psychosocial stress (Bisung and Elliott, 2017), and highlight that reducing the work of water carriage has potential to benefit women’s and children’s mental health in settings where water carriage is physically challenging, unsafe, or exacerbates water insecurity. This aligns with SDG target 3.4 to ‘promote mental health and wellbeing’ (UN, 2015a) and further good quality cohort or intervention studies, using valid and reliable outcome measures of stress, mental health and wellbeing are warranted.

The moderate quantitative and strong qualitative evidence that water carriage can affect perinatal health and reduce up-take of health services is particularly relevant to SDG3 targets 1 and 2, to reduce maternal and new born deaths, and 7, ensure access to reproductive health-care services. Fetching water also sets the scene in which health risks due to social vulnerability are realised. Vulnerable people included in studies in this review were women, children, displaced people, people with disability and people living with HIV AIDS. It is likely that cases of abuse are under reported, due to shame and fear of further discrimination or reprisals against the victim or their family, and ineffective or inappropriate policing and support services (House et al., 2014). Older adults and people with disability are also vulnerable, as they may not be capable of collecting enough water from off-plot sources because of age related or other health problems, and may lack support from younger family members or social networks for fetching water (Schatz and Gilbert, 2014, Wrisdale et al., 2017). Future studies should investigate how to reduce social vulnerability and ensure *safe access* to safe water, and are needed to strengthen the existing evidence base and identify ways to meet the 'universal' aspect of Sustainable Development Goal 6, target 6.1.

Study findings differ on the association between general health and water carriage. Apart from differences in study design, the perceived and reported general health impact of water carriage may also be mediated by whether the work is perceived as 'normal', whether it allows basic needs to be met, and by how well the workload matches the water carrier's physical capacity for work and the comparative workload of other people (Geere et al., 2010b). In the study which reported a rating of health 'today' (Geere et al., 2018a), the association of better health with current or past water carriage might indicate a selection process, whereby healthier people are allocated the task of fetching water. It may also indicate a beneficial health effect of regular physical activity undertaken since adolescence (Hallal et al., 2006). Overall, the findings on general health from studies in this review are inconsistent and therefore provide inconclusive evidence. However, in light of this review's findings in relation to other domains of health, further research with longitudinal cohort studies is warranted.

2.5 Limitations

A sensitive search strategy was used in this review to identify published reports in academic and grey literature. Whilst one good quality cohort study evaluating the impact of connection to piped water supply was found, its findings were of limited value for the review. A limitation of this review is that study authors were not contacted for additional information or data. All other studies were either qualitative, or used cross sectional surveys, and therefore causal inferences cannot be made. However, the qualitative studies included in this review provide insight into people's experiences of water fetching and the mechanisms by which it might affect their health, and together with the substantial number of cross sectional studies reporting that water carriage is negatively associated with health outcomes, indicate that further good quality research is warranted.

2.6 Recommendations for future research

The design of future studies should ideally evaluate the temporal relationship between water carriage (exposure) and health (outcome) to evaluate cause and effect, or utilise randomisation and control groups or villages to reduce risk of confounding and bias. They should also include multivariable analyses of important potential confounding factors, such as socio-economic level, health status and comorbidities, manual labour and carriage of loads other than water (Beaglehole et al., 1993). Studies should incorporate standardised, valid and reliable methods of exposure and outcome measurement, including measured time spent carrying water, weight of water carried, frequency of water carriage, years of exposure, and methods of water carriage. Health outcome measures should be piloted for reliability and validity of use in the study populations, and include severity, duration, location and functional impact of pain, as well as indicators of fatigue, stress, mental health and general health, social vulnerability and perinatal health care access. Clinical assessment by trained health workers could supplement self-reported outcome measures, to support better evaluation of the health status of study participants against selection criteria, at baseline assessment and at follow-up. Whilst the challenges of limiting the effects of confounding and bias in WaSH research are well recognised (WSUP and SHARE, 2011), a stronger body of evidence derived from good quality studies with comparable health outcome measures, will allow future reviews to better evaluate risk of bias, more precisely estimate measures of treatment or intervention effect and conduct sensitivity analyses to reduce risk of overall bias.

2.7 Summary

Through its association with pain, fatigue, stress and reduced access to perinatal health care services, the existing evidence suggests that water carriage is a potentially important barrier to achievement of many health targets set for SDG3. Because in most households of low and middle income countries it is women and girls who fetch water for household use, it will also compromise SDGs related to gender equality, quality education for all and reducing inequalities. Because water is essential for life, but fetching it is often not safe, water carriage is also a barrier to ensuring safe and inclusive societies, and decent work for all, a further challenge to reducing poverty in all its forms. Combined, all of these factors reduce the likelihood of achieving SDG6 target 1 by 2030; ‘universal and equitable access to safe and affordable drinking water for all’.

Chapter 3. The association between water carriage and health: Secondary analysis of Multiple Indicator Cluster Survey data.

3.1 Introduction

Target 6.1 of the UN Sustainable Development Goal on clean water and sanitation is to ‘achieve universal and equitable access to safe and affordable drinking water for all’, and target 6.2 is to ‘achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations’, by 2030 (UN, 2015b). Equitable or fair access implies that different levels of water supply and sanitation services, or usage of different types of water source and toilet facilities, should not or will not disadvantage specific individuals or households.

In 2015, 844 million people still lacked even a basic drinking water service, defined as access from an improved source requiring less than a 30 minute round trip to fetch water. Although out of the people lacking a basic service, 263 million could access an ‘improved’ drinking water source, they spent over 30 minutes per round trip to collect water (defined as a limited drinking water service). The remainder of the 844 million without a basic service relied on unimproved or surface water sources, and people obtaining water in this way are most likely to spend more than 30 minutes to collect water and return home (WHO and UNICEF, 2017a). In the same year, 2.3 billion people lacked a basic sanitation service (WHO and UNICEF, 2017b). Off-plot access to water commonly requires a household member to spend time walking to the source, queuing and physically carrying home enough water filled containers to meet their needs, as well as the needs of other household members (Evans et al., 2013, Geere, 2015). It therefore creates an immediate challenge to obtaining equitable access in comparison to households with water piped into their home, or which is accessible in the yard. It may also disadvantage individuals tasked with fetching water, usually the poorest women and children in low income regions (UN, 2016, WHO and UNICEF, 2017b). Many of these women and children also contend with a complete lack of, or unimproved sanitation facilities, which may further challenge their ability to maintain their own and their families’ hygiene, health, safety and dignity and compromise any benefits derived from accessing an improved or at-home water source (WHO and UNICEF, 2017a).

Inequitable access to safe water may impact upon individuals and households through a variety of mechanisms. Attempts to improve access to safe drinking water may alter the location of water sources and therefore the work of water carriage, and are often combined with interventions to improve sanitation usage and hygiene practices. However epidemiological evidence of the health benefits of access to safe water and sanitation is still equivocal, at least in low and middle income countries. Recent large scale multi-country randomised controlled trial studies have not reported clear associations between improvements in water or sanitation provision and either childhood diarrhoea or indicators of malnutrition (Clasen et al., 2014, Luby et al., 2018, Null et al., 2018). Even when randomised controlled trials of water and sanitation interventions have reported improved health, concerns were raised that such impact may be explainable largely by reporting bias as a result of lack of blinding of participants and investigators (Hunter, 2009, Schmidt and Cairncross, 2009).

An aspect of water supply provision that has not been adequately studied is the impact that having to carry water home from off the site, or 'off-plot' water sources, may have on public health. Studies suggest that the work of water fetching may affect the health and wellbeing of the water carrier (Wutich and Ragsdale, 2008, Geere et al., 2010a, Geere et al., 2010b, Geere et al., 2018a). Poor health, disability or older age may create additional challenges to accessing sufficient water when it must be physically carried home, further limiting capacity to obtain enough water to maintain health and personal hygiene (Schatz and Gilbert, 2014, Wrisdale et al., 2017). Through time costs, water fetching might also limit capacity for engagement with occupations which would otherwise enhance personal and family wellbeing, such as paid employment or caring for young children (Wrisdale et al., 2017). Because women and girls in the poorest families are most often tasked with fetching water (Hopewell and Graham, 2014, Graham et al., 2016, WHO and UNICEF, 2017b), it is likely that a differential burden from inequitable water access and the impact of water fetching will become apparent as poorer maternal and child health outcomes (Wang and Hunter, 2010, Pickering and Davis, 2012, Porter et al., 2012, Geere and Cortobius, 2017, Geere et al., 2018b). Inadequate sanitation facilities and levels of usage may also impact on individuals and households through a variety of mechanisms leading to faecal contamination of the environment and within the home, with subsequent transmission of infectious disease (Clasen et al., 2014). Usage of sanitation facilities is therefore an important health risk factor to consider in any assessment of maternal and early childhood health impacts of water carriage.

Large scale demographic and health surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) are regularly conducted in many countries. MICS provide data on household water access, the sex and age of the person responsible for collecting water within a household, sanitation usage and a substantial number of indicators of the health of women and children in the household, as well as potential confounding factors such as wealth, age, sex and education of the household head (UNICEF, 2017). They have been used to provide descriptive statistics for comparison of demographic and health variables between countries, such as time to fetch water and return and the sex and age of person responsible for fetching water (Sorenson et al., 2011, Hopewell and Graham, 2014, Graham et al., 2016). However, they have not been used to test hypotheses about associations between water fetching, water supply and sanitation usage, and the health and wellbeing of household members, including whether the age and sex of the person responsible for fetching water has any significant association with maternal or child health and wellbeing. Combining data from a number of MICS creates a large data set suitable for secondary analysis of relationships between variables, adjusting for potential social, economic and cultural confounding factors related to country, wealth, and education level. The aim of this study was to provide an estimate of the association of water fetching, categorised by age and sex of the person collecting water, adjusted for water supply and sanitation usage, with women's and children's health outcomes. Analysis of data from 49 MICS is reported, to test the hypothesis that the age and sex of the water carrier, independent of water supply and sanitation usage, is associated with a range of adverse health impacts on child and maternal health.

3.2 Methods

3.2.1 Data collection

Data sets from 41 countries derived from 49 MICS conducted between 2009-14 and with results reported and publicly available in April 2015, were downloaded after obtaining permission from UNICEF, using the Statistical Package for the Social Sciences (SPSSv22) software. Separate files recording household level variables related to water access, women's health and child health for each survey were merged by creating unique identity numbers for each case in the spreadsheet, derived from survey, cluster, household and individual line numbers. All surveys were then merged to include a total of 2,740,855 people from 539,915 households in the final data set (Table 3.1). All independent and dependent variables relevant to this study were checked to ensure that value labels were consistent, and transformed if necessary prior to merging surveys and in preparation for analysis.

Health indicators or outcomes included in each survey differed and not all households had members who were relevant cases for each indicator, for example only women of child bearing age were asked about birth history, and only those reporting a live birth can provide data on child deaths. Cases with implausible values or missing data for the dependent or any of the independent variables were omitted from the analyses. Therefore, the number of MICS and individuals or cases included in the analysis related to each outcome tested against the hypotheses varies and is less than the number of individuals in the whole data set (Table 3.1, and Appendix 11 supplementary files, Table S3.1 - S3.7). The number of individuals included in the analysis for each outcome, and the percentage of original MICs data cases included once those with missing data were removed, is indicated below each table as well as the number of households, clusters and countries included in each analysis. Number and percentage of included cases by country is indicated in supplementary files (Appendix 11 Tables S3.1 – 3.7).

3.2.2 Primary hypotheses and dependent variables

The primary hypothesis is that household water carriage is associated with increased risk of adverse maternal and child health consequences, represented by seven outcome measures. The aim of testing this hypothesis is to establish whether an association exists, not to establish that water carriage causes the health outcomes investigated. Judgement of whether an independent or predictor variable causes an outcome is established by evaluating multiple sources of evidence and considering a range of factors, for example through use of the Bradford Hill criteria (Bradford Hill, 1965; Bonita et al., 2006). The issue of causality is discussed under section 5.5.

The key predictor variable for the specific hypothesis linked to each outcome is age and sex of the person in the household identified as usually responsible for collecting water. Other key independent variables were included in the analyses because of a known or plausible relationship with the health outcomes, as described in 3.3.3. As well as socio-demographic variables, whether or not people had access to an improved water supply, category of toilet or latrine usually used in the house and the proportion of homes in a cluster using improved sanitation were included as additional independent variables to test the following four specific hypotheses;

Age and sex of the water carrier is associated with

1. an increase in the risk of child deaths
2. higher two week prevalence of diarrhoea in children under five years of age
3. decreased WHO weight for age z scores (WAZ)
4. decreased WHO height for age z scores (HAZ)

In addition, the following health indicators were tested only against age and sex of the water carrier and sociodemographic variables;

5. reduced likelihood of giving birth in a health care facility (HCF)
6. reduced uptake of antenatal care
7. increased likelihood of a child under five being left alone for more than one hour, for one or more days per week

The dependent variable ‘times received antenatal care’ included a very small number of respondents with very high rates of antenatal care up-take, which may have been due to data entry errors, creating a highly skewed distribution of count data. A square root transformation of the data was therefore used to achieve a constant variance relative to the mean and reduce the effect of bias due to a small number of extreme values in the data.

3.3.3 Independent or predictor variables and covariates

Several new variables were created by combining or transforming responses to some of the original MICS survey questions (Appendix 11, Table S3.7) to prevent the skip pattern within the surveys omitting cases unnecessarily. For example, responses to the original MICs survey question WS1, which indicated the main water source type accessed for household drinking water, were combined with responses to survey question WS3, which was only asked of survey respondents reporting at WS1 that their main drinking water was obtained from a public tap or standpipe, or other non-piped sources. WS3 specified whether the location of a non-piped water source was in the dwelling, yard or elsewhere and so the two variables were combined to create a new variable capturing the location (in own dwelling, in own yard/plot or elsewhere) of the drinking water source for all households. To achieve this, responses indicating the water source type, but not the location of the water source, were transformed into the following response categories;

- ‘piped into dwelling’, ‘piped into compound or yard’ and ‘rainwater collection’ were assumed to be located in the home or yard;
- ‘piped to neighbour’, ‘public standpipe or tap’, ‘filter plant’, ‘water yard/hand pump’, ‘tanker truck’, ‘cart with small tank/drum’, ‘surface water’, ‘bottled water’ and ‘sachet water’ were assumed to be located elsewhere;
- ‘tube well/borehole’, ‘hand pump’, ‘motorised pump’, ‘protected/unprotected well’, ‘protected/unprotected spring’, ‘reverse osmosis’, ‘other’ and ‘missing’ were

designated as missing if WS3 had not been answered because these sources could possibly be located in the respondents own yard or elsewhere.

Finally, respondents with their main drinking water located in their own dwelling or yard were assumed to be a household in which no one had to fetch water, whilst those obtaining water from elsewhere were assumed to be a water fetching household. However, households remained which were categorised as collecting water from ‘elsewhere’, but did not provide information on the age and sex of the person who usually collects water, and these, together with those already classified as ‘missing’ were omitted from the analyses.

Large differences in risk of faecal contamination of drinking water have been found between different water source types, and between water source types categorised as improved and unimproved (UNICEF and WHO, 2015). Household use of improved versus unimproved water sources was therefore considered an important independent variable for childhood diarrhoea, due to risk of exposure to pathogens associated with faecal contamination of drinking water. Increased exposure to pathogens provides a plausible diarrhoeal disease transmission pathway, and subsequently reduced WHO WAZ and HAZ scores and increased risk of childhood death, as a consequence of severe or recurrent episodes of diarrhoeal disease (Lamberti et al., 2012, Pruss-Ustun et al., 2014, Luby et al., 2018). Improved sanitation by definition minimises human contact with excreta, and therefore may also reduce risk of diarrhoeal disease and its sequelae (Pruss-Ustun et al., 2014, UNICEF and WHO, 2015).

Improved water supply and sanitation were defined according to the UNICEF/WHO Joint Monitoring Programme definitions introduced in 2000 and used in 2015 (UNICEF and WHO, 2015). Improved water supply included household connection, public standpipe, borehole, protected dug well, protected spring or rainwater collection, whilst unimproved supplies included unprotected well or spring, vendor provided water, bottled water or sachet water, tanker truck provision of water or surface water. Improved sanitation included connection to a public sewer, connection to a septic system, pour flush latrine, simple pit latrine or ventilated improved pit latrine, whilst unimproved sanitation included service or bucket latrines where excreta are manually removed, public latrines, open latrine and open defecation (UNICEF and WHO, 2015).

In addition to household water supply and sanitation characteristics, a range of possible confounding variables which are incorporated into MIC surveys and which were relevant to each outcome were included as covariates in the analyses. They were chosen based on existing research evidence of an association with one or more independent variables or the outcome, and a plausible theoretical basis supporting their association with the predictor variable or outcome of interest, as described below.

Socioeconomic status has been reported to be associated with six of the health outcomes investigated in this study; child deaths (Gibson and Mace, 2006, Black et al., 2008, Eckert and Kohler, 2014); diarrhoea (Luby et al., 2018); WAZ and HAZ scores (Black et al., 2008, Eckert and Kohler, 2014, Keino et al., 2014, Birhanu, 2015, Akombi et al., 2017, Luby et al., 2018), place of birth (Ono et al., 2013, Pulok et al., 2016); and antenatal care uptake (McCray, 2004, Pulok et al., 2016). Its association with leaving a child under five alone is not reported in the literature, but wealth or social status could allow for monetary or in-kind payment for child care, to secure water or sanitation services on premises, or to employ someone to fetch water from off-plot sources, and therefore reduce any need to leave a child alone at home. In the analyses socio-economic status was represented by family wealth quintile, as it is associated with access to improved water supply, water supply in the home, use of improved sanitation services and open defecation (UNICEF and WHO, 2015). Socio-economic status was also represented by the highest level of education achieved by the household head and sex of the household head, as either paternal or maternal level of education may variably influence health outcomes and access to a range of resources and services (Alderman and Headey, 2017, Adjiwanoua et al., 2018).

The age of the child is associated with risk of diarrhoea, which is greatest in younger children (Lamberti et al., 2012, Pruss-Ustun et al., 2014), with WAZ and HAZ scores (Akombi et al., 2017) and is also likely to be associated with the ability of a mother or carer to carry her child while accessing water and willingness to leave a child alone (Wrisdale et al., 2017). Sex of the child also has an effect on WAZ and HAZ scores (Keino et al., 2014, Akombi et al., 2017), whilst age of the mother has been shown to be associated with childhood deaths (Fretts et al., 1995, Kozuki et al., 2013, Selemani et al., 2014), place of birth (Ono et al., 2013) and antenatal care uptake (McCray, 2004).

Comparison of rural and urban areas reveal inequalities in access to water and sanitation (WHO and UNICEF, 2017a, WHO and UNICEF, 2017b) and health services (WHO, 2015, Seward et al., 2017). Child deaths and growth (Eckert and Kohler, 2014, Keino et al., 2014) diarrhoea, place of birth (Pulok et al., 2016, Seward et al., 2017), and uptake of antenatal care (Pulok et al., 2016, Seward et al., 2017) also vary in rural and urban areas within countries. In most regions of the world, a greater percentage of urban households as compared to rural households access improved water sources and sanitation facilities and have piped water on premises (UNICEF and WHO, 2015). The sex and age of the person who usually collects water has been shown to vary by rural and urban location in many countries (Porter et al., 2012, Robson et al., 2013, Geere and Cortobius, 2017, UNICEF, 2017, WHO and UNICEF, 2017b).

3.3.4 Analysis

SPSS data files were uploaded to MLwiN (v3.01) (Charlton et al., 2017) software to conduct multilevel, multivariable regression analyses of the associations between the key independent variables and maternal and child health outcomes. Multilevel models, also known as 'mixed effects' models, can incorporate analysis of clustered observations affected by two or more levels of a hierarchy, such that observations are affected by random variation within in each level of the hierarchy, and are also correlated within each level (Katz, 2011). In this study clustering occurred at the level of the survey, geographic cluster within the survey and household. Individuals within each cluster are more likely to be similar because of shared characteristics, than individuals from different clusters. Whilst analyses with SPSS and STATA software were initially attempted, analysis at three or more levels are in reality computationally difficult (Hox et al., 2018) and MLwiN was the only software which could function with the size of the data set and the four levels of analysis required for the data set. Therefore, the final multilevel analyses were performed with MLwinN (v3.01) to account for clustering at the survey (country and/or surveyed region within a country), cluster (a number of households randomly selected from within an enumeration area, or segment of an enumeration area of the survey) and household level.

The type of outcome or dependent variable determines the multivariable analysis chosen and multilevel models can incorporate a range of outcomes or dependent variables such as those included in the hypotheses tested in this study (Katz, 2011). Where the dependent variable was binary logistic regression was used, where count data negative binomial regression was used and where linear, ordinary linear regression was used. An advantaged of mixed effects models is that they do not require a minimum sample size per group and can handle an unequal number of observations per cluster (Katz, 2011), both of which were features of the data set.

Multilevel models are 'conditional'. This means that they estimate the individual level impact of the exposure, taking into account the random effects of the clusters in which the individual is situated and adjusting for the covariates in the model. The co-efficient generated by the model is an estimate of the within person change in the outcome, comparing the effect of exposure to no exposure, as if it had occurred to the same individual (Katz, 2011). For example, in a logistic regression model for a dichotomous outcome, the odds ratio would represent the odds of an individual not exposed to the independent variable having the outcome, compared with the odds of the same person having the outcome if they were exposed to the independent variable (Sribney, 2018). Therefore, multilevel models were deemed an appropriate analysis method to provide an estimate of the independent association of the key predictor variables and covariates, with each health outcome of interest.

3.3 Results

Table 3.1 lists the 49 studies included in this analysis. The results of the seven regression analyses are shown in tables 3.2 and 3.3. Table 3.2 shows the results of the regression analyses for child mortality, diarrhoea, and WHO WAZ and HAZ scores. Table 3.3 shows the results of regression analyses for likelihood of giving birth in a health care facility, uptake of antenatal care, and likelihood of leaving a child under five years of age alone for one or more hours, one or more days per week.

Tables 3.2 and 3.3 present the p-values for all response categories of individual independent variables included in the model, including those which are not statistically significant. Whilst this means that the analysis incorporates multiple comparisons, the comparisons were of key interest in addressing the research hypotheses, and they provide more detailed information than simply providing an overall p-value for a model, or for each independent variable in the model. For example, the research aim was to understand whether a woman, man, girl or boy being designated as the usual household water carrier was associated with health outcomes, rather than whether sex and age of the water carrier was a significant variable overall. Multiple comparisons increase the risk of identifying a statistically significant association by chance, and it is possible to lower the level of significance of the p-value which is considered significant, for example with a Bonferroni adjustment (Katz, 2011). However, there are disadvantages to doing so, including the flawed assumption that chance is the most common explanation for an association, and that fact that individual comparisons cannot 'know' how many other comparisons have been made (Rothman, 1990, cited in Katz, 2011). Therefore, the actual p-values for each response category of the independent variables are reported, unless the software package produced a default value of 0.000, indicating a value less than 0.001 (<0.001 in tables 3.2 and 3.3). The importance of the results are discussed considering the strength and direction of association, the findings of other authors and biological plausibility, rather than focussing on the significance of p-values.

The results for the outcomes of childhood death, diarrhoea and growth scores are described against the predictor variable household water carriage, followed by a summary of their association with improved water supply and sanitation facility usage and coverage, for ease of comparison. However, the discussion section focuses mainly on the observed associations between age and sex of the water carrier and these health outcomes, given that the other independent variables are not the focus of this thesis and multivariable analysis has adjusted for their effects.

Table 3.1 MIC surveys merged for analysis

Survey Country (region)	Year	Number (hh[1])	Number (cases)	% sample[2]
Afghanistan	2011	13116	101671	3.7
Argentina	2012	23791	89799	3.3
Barbados	2012	2872	8148	.3
Belarus	2012	8284	23650	.9
Belize	2011	4424	17538	.6
Bhutan	2010	14676	68351	2.5
Bosnia and Herzegovina (Roma Settlements)	2012	1544	5864	.2
Bosnia and Herzegovina	2012	5778	20248	.7
Central African Republic	2010	11756	54281	2.0
Chad	2010	16386	88564	3.2
Congo DR	2010	11393	61543	2.2
Costa Rica	2011	5561	21322	.8
Cuba	2011	9183	35454	1.3
Ghana (Accra)	2010-11	1409	4878	.2
Ghana	2011	11925	54228	2.0
Indonesia (Selected Districts of Papua)	2011	2866	12112	.4
Indonesia (Selected Districts of West Papua)	2011	2816	11533	.4
Iraq	2011	35701	238327	8.7
Jamaica	2011	5960	19277	.7
Kazakhstan	2010-11	15800	54316	2.0
Kenya (Mombasa Informal Settlements)	2009	1016	3216	.1
Kenya (Nyanza Province)	2011	6828	30763	1.1
Lao PDR	2012	18843	98440	3.6
Lebanon (Palestinians)	2011	4747	20983	.8
Madagascar (South)	2012	2968	15556	.6
Mauritania	2011	10116	59993	2.2
Moldova	2012	11354	28852	1.1
Mongolia (Khuvsgul Aimag)	2012	1982	6975	.3
Mongolia	2010	10092	35747	1.3
Montenegro	2013	4052	14691	.5
Nepal (Mid and Far Western Regions)	2010	5899	31753	1.2
Nigeria	2011	29077	150810	5.5
Pakistan (Baluchistan)	2010	11612	88427	3.2
Pakistan (Punjab)	2011	95238	599617	21.9
Saint Lucia	2012	1718	4922	.2
Serbia (Roma Settlements)	2014	1743	9014	.3
Serbia	2014	6191	22194	.8
Sierra Leone	2010	11394	66571	2.4
Somalia (North East Zone)	2011	4777	28604	1.0
Somalia (Somaliland)	2011	4808	30777	1.1
South Sudan	2010	9369	55973	2.0
Sudan	2010	14778	83510	3.0
Suriname	2010	7407	28783	1.1
Swaziland	2010	4834	19843	.7

Togo	2010	6039	30948	1.1
Tunisia	2012	9171	38861	1.4
Ukraine	2012	11321	33761	1.2
Vietnam	2011	11614	44831	1.6
Zimbabwe	2014	15686	65336	2.4
Total		539915	2740855	100.0

[1]hh = households; [2]% sample indicates the percentage of the total number of cases in the merged data set represented by cases from each country

Relative risk of child death was significantly greater in households that fetched water compared to households in which no one collected water. In households where women carried the water the relative risk of child death was 1.05 (95% confidence intervals (CI) 1.02 – 1.08). Where men carried the water, the risk was lower but still significant (1.04, 95% CI 1.00 – 1.07). Where children primarily collected water, there was no increased risk of death. Having access only to an unimproved drinking water source was not independently associated with increased risk of child death. Living in a household where members did not usually use a flush toilet was associated with 9-12% greater relative risk of child death than living in a household where members usually used flush toilets. However, there was little obvious difference in mortality rates between those households using non-flush improved sanitation, unimproved sanitation or practicing open defecation. As the percentage of households in a cluster using improved sanitation increased in communities, the association with child deaths declined. Those children born into communities with over 90% improved sanitation usage were 12% less likely to die than those born into communities with 20% or lower levels of usage (Figure 3.1).

An increase in the odds of a child under five years of age being reported to have had diarrhoea in the previous two weeks (10-13%) was associated with children collecting water, but not with adults collecting water, when compared to households in which no one collects water (Table 3.2). Having access to unimproved drinking water supply compared to improved drinking water supply was associated with an increase in the odds of diarrhoea by 5%. Use of an improved or unimproved toilet and open defecation in comparison to a flush toilet was also associated with an increase in the odds of diarrhoea, with improved toilets associated with a greater comparative increase (16%) than unimproved toilets (11%) or open defecation (5%). Improved sanitation usage was associated with the odds of childhood diarrhoea reducing by 8%, 13% and 21% in the 61% to 80%, 81% to 90% and over 90% categories of coverage respectively (Figure 3.2).

A decrease in children's WHO WAZ scores, which indicate acute undernutrition, was significantly associated with water carriage performed by women, men or boys when compared to non-water fetching households (Table 3.2). No significant association was observed between WAZ scores and use of an improved compared to unimproved water supply. The use of non-flush toilets (improved or unimproved) or open defecation compared to flush toilets, was associated with a decrease in WHO WAZ scores. A gradual increase in WAZ score was associated with each higher level of improved sanitation coverage beyond 60% (Figure 3.3). No significant association between children's WHO HAZ scores, which indicate childhood stunting, and household water fetching or improved water supply was observed (Table 3.2). Use of non-flush toilets (improved or unimproved) or open defecation compared to flush toilets was associated with a significant decrease in HAZ scores, and when more than 80% of people within a cluster used improved sanitation an association with increased HAZ scores was observed (Figure 3.4).

Water fetching was associated with reduced odds of a woman giving birth in a health care facility (10-12% reduction), compared to non-water fetching households, with little difference according to the age and sex of the person responsible for collecting water (Table 3.3). A significant reduction in uptake of antenatal care was observed in households where a girl or woman usually collected water, however, when men or boys usually collected water, the odds ratio for antenatal care uptake was not significantly different from that of women living in non-water fetching households (Table 3.3). The odds of a child under five years of age being left alone for an hour or more, on one or more days of the week, was significantly increased in households where a woman or female child was responsible for collecting water, but not in those where a man or boy collects water, when compared to households where no one collects water (Table 3.3).

Table 3.2 Risk of childhood death, odds of diarrhoea affecting a child under five years of age in the previous two weeks, and regression parameters for WHO weight for age and height for age z-scores by socio-economic characteristics, demographic variables, water supply, sanitation type, sanitation usage and water carriage.

Independent Variable	Child death RR (95% CI)	p-value	Diarrhoea OR (95% CI)	p-value	WAZ β (95% CI)	p-value	HAZ β (95% CI)	p-value
Wealth								
Poorest	1.00		1.00		0		0	
Second	0.96 (0.94, 0.99)	0.004	0.91 (0.87, 0.95)	<0.001	0.08 (0.06, 0.10)	<0.001	0.08 (0.06, 0.10)	<0.001
Middle	0.89 (0.87, 0.91)	<0.001	0.82 (0.78, 0.85)	<0.001	0.16 (0.14, 0.18)	<0.001	0.16 (0.14, 0.18)	<0.001
Fourth	0.81 (0.78, 0.84)	<0.001	0.77 (0.73, 0.81)	<0.001	0.25 (0.23, 0.27)	<0.001	0.27 (0.25, 0.30)	<0.001
Richest	0.66 (0.63, 0.68)	<0.001	0.62 (0.58, 0.66)	<0.001	0.44 (0.42, 0.47)	<0.001	0.49 (0.46, 0.51)	<0.001
Education of household head								
Primary/none	1.00		1.00		0		0	
Secondary+	0.85 (0.83, 0.86)	<0.001	0.89 (0.86, 0.92)	<0.001	0.11 (0.10, 0.12)	<0.001	0.13 (0.12, 0.15)	<0.001
Area								
Urban	1.00		1.00		0		0	
Rural	0.99 (0.97, 1.02)	0.663	0.92 (0.88, 0.97)	0.001	0.02 (0.00, 0.04)	0.036	0.01 (-0.01, 0.03)	0.476
Sex of household head								
Male	1.00		1.00		0		0	
Female	0.99 (0.97, 1.01)	0.424	0.99 (0.94, 1.03)	0.495	0.06 (0.04, 0.07)	<0.001	0.05 (0.04, 0.07)	<0.001
Sex of child								
Male	n/a		1.00		0		0	
Female	n/a		0.92 (0.90, 0.94)	<0.001	0.06 (0.05, 0.07)	<0.001	0.08 (0.07, 0.09)	<0.001
Age in years [a, b]	1.02 (1.02, 1.02)	<0.001	0.75 (0.74, 0.76)	<0.001	-0.08 (-0.08, -0.08)	<0.001	-0.17 (-0.18, -0.17)	<0.001
Water supply								
Improved	1.00		1.00		0		0	
Unimproved	1.00 (0.98, 1.03)	0.926	1.05 (1.01, 1.10)	0.014	0.02 (0.00, 0.03)	0.055	0.00 (-0.02, 0.02)	0.729
Toilet facility								
Flush toilet	1.00		1.00		0		0	

Other improved	1.10 (1.07, 1.13)	<0.001	1.16 (1.10, 1.22)	<0.001	-0.03 (-0.05, -0.01)	0.003	-0.10 (-0.12, -0.07)	<0.001
Unimproved	1.12 (1.08, 1.16)	<0.001	1.11 (1.04, 1.18)	0.002	-0.03 (-0.06, -0.01)	0.021	-0.09 (-0.12, -0.06)	<0.001
Open defecation	1.09 (1.06, 1.13)	<0.001	1.05 (0.99, 1.11)	0.147	-0.06 (-0.08, -0.04)	<0.001	-0.08 (-0.11, -0.05)	<0.001
Improved sanitation usage [c]								
≤20	1.00		1.00		0		0	
>20 to 40	1.02 (0.98, 1.06)	0.323	0.96 (0.90, 1.03)	0.281	-0.02 (-0.05, 0.01)	0.186	-0.04 (-0.07, -0.00)	0.032
>40 to 60	1.01 (0.97, 1.05)	0.776	0.93 (0.86, 1.00)	0.056	-0.01 (-0.04, 0.02)	0.441	-0.02 (-0.05, 0.02)	0.368
>60 to 80	0.98 (0.93, 1.02)	0.251	0.92 (0.86, 1.00)	0.046	0.04 (0.01, 0.07)	0.007	0.03 (-0.00, 0.07)	0.079
>80 to 90	0.92 (0.87, 0.97)	0.001	0.87 (0.79, 0.95)	0.002	0.07 (0.03, 0.10)	<0.001	0.07 (0.03, 0.11)	0.001
>90	0.88 (0.85, 0.93)	<0.001	0.79 (0.73, 0.86)	<0.001	0.08 (0.05, 0.12)	<0.001	0.07 (0.03, 0.10)	<0.001
Person collecting water								
No one	1.00		1.00		0		0	
Male child (age <15 years)	0.99 (0.94, 1.05)	0.828	1.13 (1.02, 1.25)	0.022	-0.05 (-0.09, -0.01)	0.021	-0.03 (-0.09, 0.02)	0.185
Man (age 15+ years)	1.04 (1.00, 1.07)	0.051	0.98 (0.92, 1.05)	0.602	-0.03 (-0.05, -0.01)	0.012	-0.02 (-0.05, 0.01)	0.139
Female child (age <15 years)	1.00 (0.95, 1.04)	0.871	1.10 (1.02, 1.20)	0.016	-0.00 (-0.04, 0.03)	0.857	-0.01 (-0.05, 0.03)	0.582
Woman (age 15+ years)	1.05 (1.02, 1.08)	0.001	1.05 (1.00, 1.10)	0.069	-0.02 (-0.04, -0.00)	0.028	-0.01 (-0.03, 0.01)	0.345

Note: Number of women reporting child deaths once individuals with missing data excluded = 299 084 (86.6% of original MICs data), households = 274 145, clusters = 26 519, MIC surveys = 40;

Number of women reporting diarrhoea affecting child under 5 years of age in the previous 2 weeks, once individuals with missing data excluded = 290 176 (78.8% of original MICs data), households = 190 641, clusters = 27 030, MIC surveys = 43;

Number of WHO WAZ scores once individuals with missing data excluded = 230 406 (84.8% of original MICs data), households = 154 742, clusters = 24 367, MIC surveys = 36;

Number of WHO HAZ scores once individuals with missing data excluded = 217 210 (80.2% of original MICs data), households = 148 670, clusters = 24, 262, MIC surveys = 36;

RR, relative risk; OR, odds ratio; β, regression parameter; WHO WAZ, World Health Organization weight for age z-score; WHO HAZ, World Health Organization height for age z-score.

[a] for children dead 'age' = age of mother.

[b] for diarrhoea, HAZ and WAZ 'age' = age of child.

[c]% with improved sanitation within cluster.

Table 3.3 Odds of a woman giving birth in a health care facility, uptake of antenatal care and odds of leaving a child under five alone for one hour or more on one or more days per week by socio-economic characteristics, demographic variables and water carriage.

Independent variable	Response category	Birth in a health care facility OR	P value	Times received antenatal care β (95% CI)	P value	Child left alone OR	P value
Wealth	Poorest	1.00		0		1.00	
	Second	1.33 (1.27, 1.40)	<0.001	0.06 (0.05, 0.08)	<0.001	1.02 (0.97, 1.06)	0.459
	Middle	1.76 (1.67, 1.85)	<0.001	0.12 (0.10, 0.13)	<0.001	1.02 (0.97, 1.07)	0.496
	Fourth	2.34 (2.21, 2.48)	<0.001	0.15 (0.14, 0.17)	<0.001	0.99 (0.93, 1.04)	0.58
	Richest	3.74 (3.47, 4.03)	<0.001	0.25 (0.23, 0.27)	<0.001	0.90 (0.85, 0.97)	0.003
Education	Primary/none	1.00		0		1.00	
	Secondary+	1.22 (1.18, 1.27)	<0.001	0.05 (0.04, 0.06)	<0.001	0.99 (0.95, 1.02)	0.427
Area	Urban	1.00		0		1.00	
	Rural	0.84 (0.80, 0.87)	<0.001	-0.05 (-0.07, -0.04)	<0.001	1.08 (1.02, 1.14)	0.01
Sex of HH	Male	1.00		0		1.00	
head	Female	1.15 (1.10, 1.21)	<0.001	0.02 (0.00, 0.03)	0.012	1.02 (0.98, 1.07)	0.298
Age	Years [a]	0.99 (0.99, 1.00)	<0.001	0.001 (0.00, 0.002)	0.004	1.44 (1.42, 1.45)	<0.001
Water	No one collects water	1.00		0		1.00	
carriage	Male child (age<15)	0.88 (0.79, 0.99)	0.032	-0.02 (-0.07, 0.02)	0.285	0.99 (0.91, 1.08)	0.878
	Adult man (age 15+)	0.90 (0.84, 0.96)	0.001	-0.01 (-0.04, 0.01)	0.29	0.98 (0.93, 1.05)	0.605
	Female child (age<15)	0.89 (0.82, 0.98)	0.015	-0.06 (-0.09, -0.03)	<0.001	1.16 (1.08, 1.25)	<0.001
	Adult woman (age 15+)	0.89 (0.84, 0.93)	<0.001	-0.04 (-0.05, -0.02)	<0.001	1.07 (1.02, 1.13)	0.003

Note: Number of women reporting place of birth 100, 505 (85.4% of original MICs data), households = 95 890, clusters = 22 784, MIC surveys = 44; Number of women reporting times received antenatal care 52, 696 (80.0%), households = 50 689, clusters = 14 904, MIC surveys = 40; Number of women reporting whether a child under 5 years of age is left alone for an hour or more, on 1 or more days per week = 228, 307 (84.9%), households = 154 705, clusters = 21 617, MIC surveys = 43; OR = odds ratio; β = regression parameter; [a] for birth in health care facility and uptake of antenatal care, 'age' = age of woman, for child left alone, 'age' = age of child.

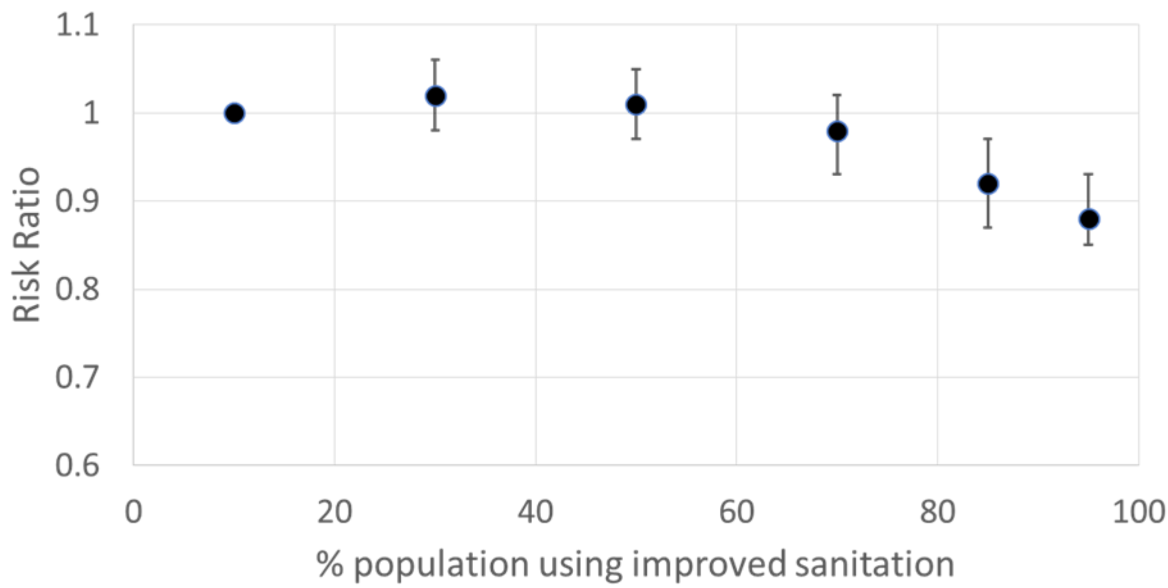

Figure 3.1 Relative risk of child mortality by percentage of population using improved sanitation (reference category <20% using improved sanitation). Model: negative binomial regression; Covariates: wealth index, education of household head, urban/rural area, sex of household head, age of mother, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

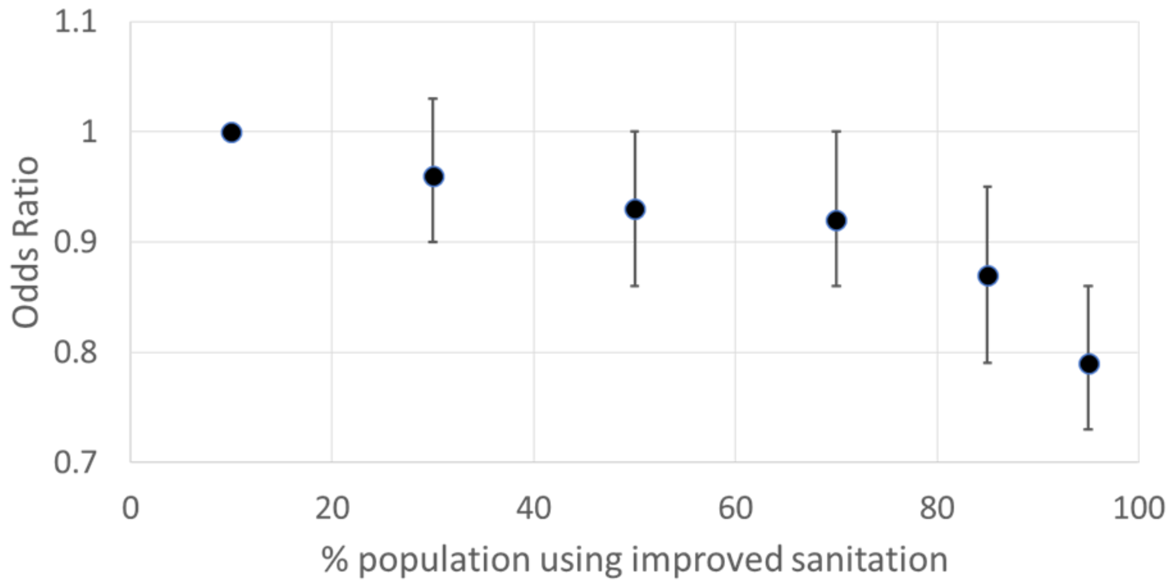

Figure 3.2 Odds ratio for childhood diarrhoea by percentage of population using improved sanitation (reference category <20% using improved sanitation). Model: logistic regression; Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

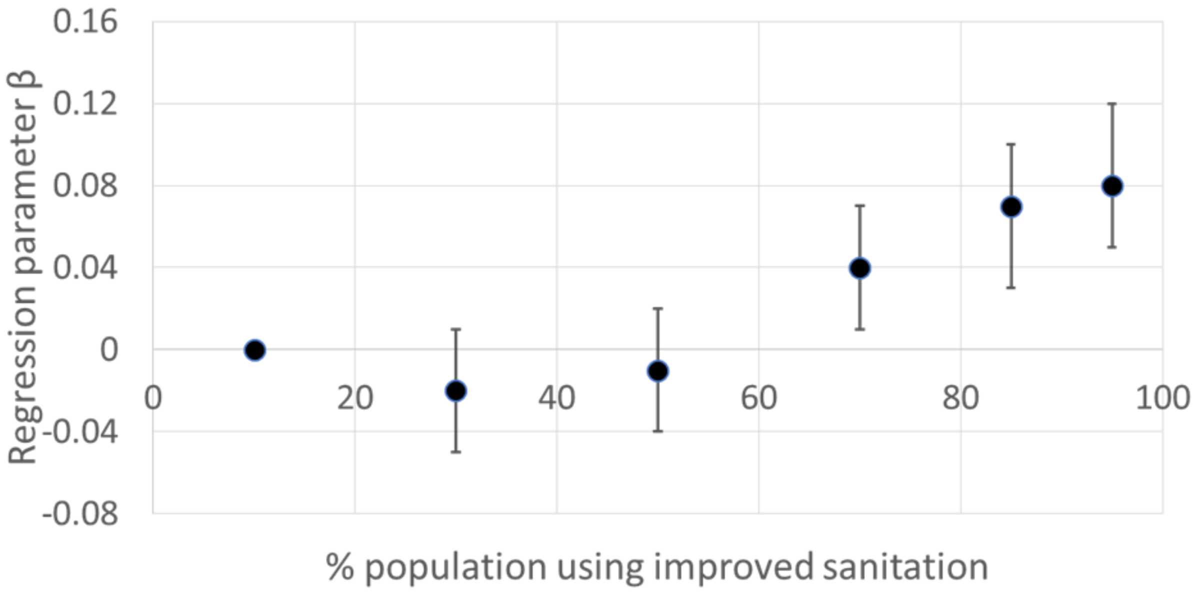

Figure 3.3 WHO weight for age z-score by percentage of population using improved sanitation (reference category <20% using improved sanitation). Model: linear regression; Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

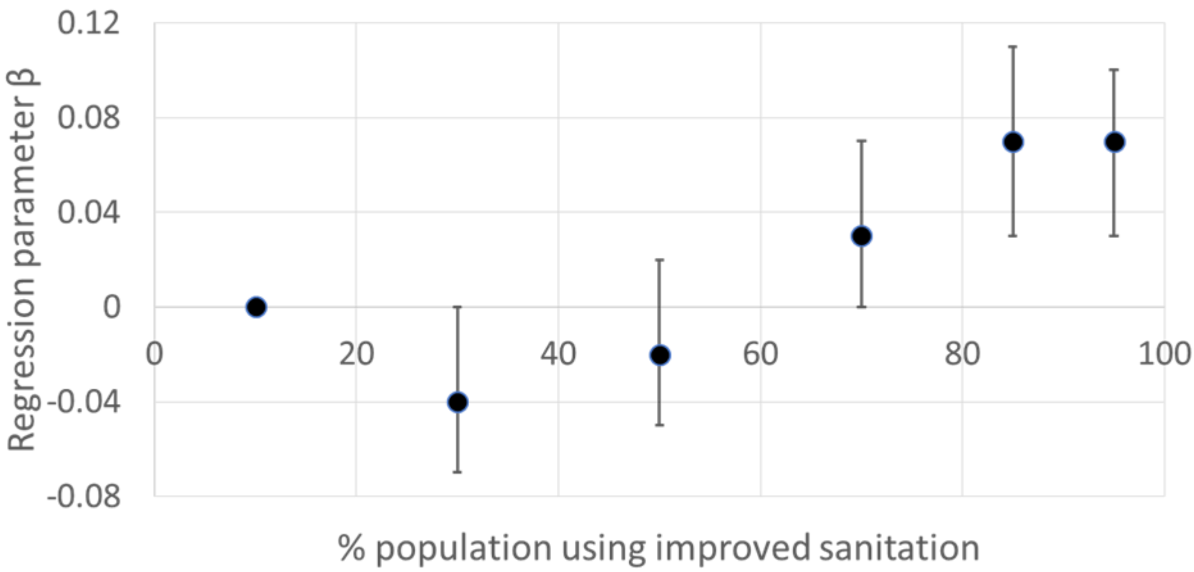

Figure 3.4 WHO height for age z-score by percentage of population using improved sanitation (reference category <20% using improved sanitation). Model: linear regression; Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

3.4 Discussion

To the author's knowledge this is the first study to utilize data from a large number of MICS, and analyse the relationships between health outcomes and the work of water carriage, sex and age of water carrier, access to improved drinking water and usage of improved sanitation. It was possible to control for a range of potential confounding factors and allow for random effects at the household, cluster and survey level. The results indicate that having to carry water home is independently associated with a range of adverse child and maternal health outcomes. In comparison to households where no one has to collect and carry water, adults carrying water is associated with increased risk of child death, children carrying water with increased odds of childhood diarrhoea, and adults or boys carrying water with reduced WHO WAZ scores. Women of water fetching households are less likely to give birth in a health care facility, and women or girls collecting water, is associated with reduced antenatal care up-take and children under five being much more likely to be left alone at home. This evidence supports the view that interventions for improved water access should aim toward provision of safe water on premises.

Whilst very young children are unlikely to be water carriers, the death of a young child is likely to have a severe and detrimental effect on the psychological health of parents and siblings, and particularly mothers, who are most likely to be the water carriers in households lacking at-home supply. Similarly, improved ability to fulfil a social role as the main caregiver of young children due to improved water access and reduced need to carry water from off-plot sources, may reduce stress and improve psychological well-being of water carriers who also care for young children. Of note in this study, is that whilst access to improved or unimproved water supply was not associated with risk of childhood death, the need for an adult to collect water from an off plot source was associated with an increased risk of child death. When adults must fetch water, it is likely that in many households children are left unsupervised for the time it takes to walk to a water source, wait in a queue for water and return. Unsupervised children may be at more risk of death from accidental injury, or simply from reduced parental care when it is needed, for example during illness or when they are very young. In Ethiopia, Gibson and Mace (2006) found that when women's work of water fetching was substantially reduced because of access to tap stands much closer to home, the monthly risk of child death was 50% lower among children of the women with access to the new taps. They suggested that the increase in child survival was most likely due to increased quantity and improved quality of water available for household use, but also greater opportunities for mothers to care for their young children.

For many mothers, the alternative to leaving young children alone at home is to take them with them to fetch water. Water collection routes are often unsafe because of poorly maintained pathways, and proximity to busy road ways and dense or fast traffic (Geere, et al 2010). Water carriers and any children accompanying them may also be exposed to a range of other environmental and social hazards, including unsafe water sources (risk of drowning), damaged urban infrastructure in conflict zones, extremes of temperature, or interpersonal violence (Geere et al, 2018). Particularly once women are carrying containers, they may be less able to react quickly to protect their children from such hazards, or even to turn and see hazards if they are carrying water filled containers on their head. Once older children closer to the age of 15 are able to collect water, adults, particularly mothers, may be relieved of the task and therefore able to keep very young children more safely with them at home.

Whilst children under five do not usually carry substantial amounts of water, infectious diarrhoea affecting them may increase risk of diarrhoea being transmitted to other household members, including older siblings within the household who are engaged in water carriage. The significantly increased odds (10-13%) of children under five having diarrhoea in households where children fetch water compared to households that do not, could simply reflect differing water quality from different source types as reported by Esrey (1996), and that children fetching water away from their home are more likely to be using an unimproved source, and therefore at more risk of diarrheal disease through consumption of contaminated drinking water. However, the analysis adjusted for the 5% increase in diarrhoeal risk from using an unimproved water supply. Furthermore, if use of an unimproved water source were the only reason for the observed association, one would not expect to see significant increases in diarrhoeal disease when children but not when adults collect water, after adjusting for differences in household toilet facilities and sanitation usage. It is known that water quality can deteriorate after collection from a shared source and during storage (Jagals et al., 2003, Diouf et al., 2014) and it’s possible that children may be less likely or able to maintain hygienic practices, such as handwashing or cleaning containers adequately prior to refilling them. They may also be more likely to play in or drink untreated water at the source point than adults, and therefore more vulnerable to water borne disease, which could then also be transmitted to younger children in the household. The results showed borderline significance of an association between a woman fetching water and increased risk of diarrhoea (RR 1.05, $p = 0.067$), whilst men showed no significant association with any increased risk of diarrhoea (0.98, $p = 0.602$) compared to non-water fetching households. It is possible that by fetching water, adults, and particularly men, may bring larger quantities of water to the house, either because they are simply stronger

(Marras et al., 2002, Marras et al., 2003, Stemper et al., 2008) and therefore able to carry more water, or because they are more likely to use equipment to collect more water (Geere, 2015). Men are also more likely to collect water when it is located closer to home, and women when it is located further away, such that men may collect larger quantities of water due to proximity of the supply point (WHO and UNICEF, 2017b). A larger quantity of water may enable all household members to improve cleanliness and hygiene practices such as handwashing to reduce the incidence of diarrhoea (Esrey et al., 1989, Hunter et al., 2010). By fetching water, an adult man or woman may also enable other family members, particularly other women but also children, to have more time and energy to engage in household management and chores, including hygiene practices related to washing, cooking and cleaning (Rao et al., 2007, Domenech et al., 2012, Zolnikov and Blodgett Salafia, 2016).

Energy expenditure due to the work of water fetching may be important for nursing mothers, and if it affects breast feeding behaviour, might influence childhood nutrition and therefore children's weight for age (WAZ) or height for age (HAZ) scores (Keino et al., 2014, Goudet et al., 2015). WAZ and HAZ scores indicate acute undernutrition and chronic undernutrition or 'stunting' respectively (Dangour et al., 2013). Despite this potential effect, a significant but only small reduction in mean WAZ score in water fetching households was associated with adults or boys collecting water, and no association of water fetching with HAZ scores was found. In contrast, Gibson and Mace (2006) found that in an area of rural Ethiopia, children under five of women with access to water points which reduced the distance and time to fetch water, had significantly increased risk of being malnourished and stunted compared to children of women fetching water in the same area prior to the installation of labour saving taps. They proposed that reduced energy expenditure on water collection supported the observed increase in birth rate (OR 3.78, p=0.009), which as a consequence, meant that smaller, low birth-weight babies were coming to full term and surviving early childhood. Others have reported the energy costs of fetching water as moderate to high (Rao et al., 2007) and highlighted that the energy expenditure required for water fetching may become important in 'food-scarce' environments (Domenech et al., 2012). Several other studies also reported fatigue and tiredness affecting water carriers (Hemson, 2007, Geere et al., 2010a, Geere et al., 2010b, Porter et al., 2012, Zolnikov and Blodgett Salafia, 2016), and one study (Evans et al., 2013) reported that people who carried water had significantly less (40 minutes) 'inactivity' time (defined as sleep, resting or watching television) than those who did not carry water. Therefore, whilst findings from a range of studies indicate that the energy expenditure of water fetching may impact detrimentally on pregnant women and mothers, and that reducing the work of water carriage is likely to benefit them, other factors related to maternal or child nutritional intake (Luby et al., 2018, Stewart et al., 2018) and availability of family planning services (Dangour et al., 2013) may determine whether any impact on perinatal or maternal health leads to further impacts on under five weight for age and stunting. It was not possible to include any indicators of food intake, nutritional status, feeding programs, birth rates or illness affecting mothers in the analyses, and therefore it is not possible to exclude other possible confounding factors which may have influenced the results.

Dangour et.al., (2013) conducted a meta-analysis including 4,627 children and found no evidence of an effect of water, sanitation and hygiene (WaSH) interventions on WAZ score (mean difference 0.05; 95% CI -0.01 to 0.12) and a borderline statistically significant but small effect of WaSH interventions on HAZ score (mean difference 0.08; 95% CI 0.00 to 0.16). However, in studies conducted in Kenya (Null et al., 2018), Bangladesh (Luby et al., 2018) and India (Patil et al., 2014), WaSH interventions alone did not improve child growth, and did not add to the improvements observed with nutrition interventions. In the analysis of observational surveys, the effects of water fetching, water supply and sanitation usage were small in comparison to the effects of wealth, which may enable families to secure enough food to optimize maternal and child nutrition. Overall this suggests that sufficient nutrition is of key importance (Black et al., 2008), which may explain why WaSH interventions or living in a non-water fetching household are insufficient to achieve meaningful improvements in childhood growth.

It was found that being from a water fetching household was associated with a significant reduction in the likelihood of a woman giving birth in a health care facility, but with little difference according to who was responsible for collecting water in the household. Ono et al.'s (2013) findings in Western Kenya indicate that decisions about giving birth at home or in a health care facility are complex and may differ according to which family member provides support with water fetching. Women who lack sufficient social support for household water collection may not feel able to spend time away from home to give birth and recover in a health care facility, particularly if they have other very young children to care for at home. Improved water supply and sanitation within the home might enable a woman to ask for and receive social support in the perinatal period (Subbaraman et al. 2015), which could then facilitate her access to perinatal care, including opportunity to travel to and give birth in a health care facility. Alternatively, communities where people have to fetch their own water may not have health care facilities, health facilities and services that do exist may also lack adequate water supply and sanitation services, or they may require payment at the point of use, both of which could dissuade women from using them (Bouzid et al., 2018). The findings that wealth, higher education level of the household head, rural location and sex of the household head had the largest odds ratios associated with place of birth indicate that mechanisms such as these, and other residual socioeconomic confounding might explain the association between water carriage and place of birth. Ono et al (2013), also found that place of giving birth was significantly influenced by other factors in addition to social support. However, because the analysis was adjusted for wealth index and educational level of the household head, it is reasonable to suggest that this study provides some evidence that as a modifiable risk factor, providing water on premises may independently increase the odds of women giving birth in health care facilities. This may be particularly important for women from lower socio-economic groups living in rural areas, and is an issue which could be investigated with further research.

It was also found that uptake of antenatal care is likely to be lower for women from water fetching households, when a woman or girl is responsible for collecting water. The time and energy taken for water carriage might reduce women's opportunities to also spend time and energy attending antenatal clinics. This is supported by the findings of McCray (2004) who conducted a cross sectional survey of mothers of a child aged 12-23 months, from 327 randomly selected households in Kwazulu Natal, South Africa. They found that if a woman reported fetching water to be a daily activity affected by making a trip to the clinic, she was twice as likely to utilize prenatal care services at a low level, than an average level. Their conclusion was that making water more easily accessible would facilitate access to health care facilities for antenatal care (McCray, 2004). Furthermore, antenatal clinic attendance has been shown to be associated with a woman giving birth in a health care facility (Séraphin et al. 2015), which may be an additional reason for the reduced likelihood of women from water fetching households giving birth in a health care facility. The added perspective from this research, is that where the location of a water source is not likely to change during a woman's pregnancy, help from her husband or sons to fetch water might enable her to receive antenatal care more times, because there was no decrease in uptake of antenatal care when men or boys collect water, compared to up-take of antenatal care in non-water fetching households. This suggests that by fetching water for household use, men and boys can make an important contribution to their family's health, as increased utilisation of antenatal care has been shown to be associated with better maternal and child health outcomes (Lincetto et al., 2006).

The association of women or girls collecting water with an increase in the odds that a child under five is left alone for more than one hour for one or more days per week, highlights the challenges of providing child care and supervision when water is not accessed on premises.

Qualitative research has highlighted the ‘Hobson’s choice’ that carers face when they must obtain water from off-plot sources, and then choose to either leave their child alone, or take (often carrying) the child with them along what may be an unsafe route (Geere et al., 2010a, Schatz and Gilbert, 2014, Wrisdale et al., 2017).

> “Interviewee: *“Except for looking after her, I have to go to the chief’s place to fetch water using a wheel barrow, when I go to fetch water at the chief’s place I have a very serious problem of leaving her alone in the house.”*
> Interviewer: *“What problem do you have when you have left her alone?”*
> Interviewee: *“My problem is that, these days it is no longer safe, I may have locked her inside the house and somebody may come and break in or burn the house, what people would say I have done, they would say I ran away from her.”*
> Interviewer: *“What you are saying is a problem is when you think of what may people do when you have left her alone, right?”*
> Interviewee: **“***Yes, when I have left her alone, because when you walk around you will hear people say that there is a child who alone in this house. You will hear older people thinking of doing bad things to a child who is unable to walk it is really bad.” (Wrisdale et al., 2017)*

Compared to water fetching households, the lack of change in the odds that a child is left alone when a man or boy collects water may indicate that the woman in the household is relieved of a task which would require her to leave children alone, and that she utilises the additional time to engage in household tasks that allow her to be with her children. When a woman collects water, it is possible that in some households, there may not be another adult at home and available to supervise children. It is also possible that even when living at home, men will prioritise time for income generating or other daily activities which take place away from home over child minding, and assume that a woman will manage to combine child minding with water fetching.

3.5 Limitations

MIC surveys are cross-sectional studies, which therefore cannot provide strong evidence of causal relationships between variables, because exposure data is not collected prior to outcomes occurring. The use of completed MICS questionnaires also limits the extent to which it is possible to control for bias or confounding in the analyses. For example the variable ‘person collecting water’ is indicated by mutually exclusive response categories for the question ‘who usually goes to this source to collect the water for your household?’ A response option is not available to indicate that multiple people collect water. Therefore data from households where water carriage is performed by multiple people, for example as work shared by women and children, might introduce bias and have a mediating or confounding effect on the association between the person nominated as usually carrying water and the outcomes observed in this study. Similarly there is no option to classify households that have improved or unimproved toilet facilities and practice open defecation, because the survey question asks 'what kind of toilet facility do members of your household usually use?' with only mutually exclusive response categories available. Usual toilet facility use does not exclude the possibility of some household members practicing open defecation, which may introduce bias and confound or mediate the findings associated with toilet usage and sanitation coverage in this study. However, this type of bias or confounding would most likely reduce the strength of associations observed.

A further limitation of the study was the use of water source type categorised as 'improved' or 'unimproved' as an indicator of water quality in the analyses. A piped water supply does not ensure provision of good quality water free from contamination in all situations. Contamination or reduced water quality may occur due to poor maintenance of infrastructure, inadequate chlorine residuals or from contaminant ingress through corroded or broken pipes. 'Unimproved' water sources, such as natural springs, may in fact have better water quality than a poorly maintained piped supply. However, data on water quality testing was not included in the MICS data sets, and therefore the use of 'improved' versus 'unimproved' water source, as used by the JMP in 2015 (UNICEF and WHO, 2015) was deemed the best possible indicator of likely water quality in the data. Thus inaccurate indication of water quality may have been a confounding factor affecting the results from analyses of childhood deaths, diarhhoea and growth scores.

It is also possible that respondents may have simply reported their access to piped water infrastructure and a toilet facility, which might not have correlated directly to their household usage of the reported water or sanitation facilities. Usage may be affected by the quality of facilities and services, for example people may have intermittent or unreliable access to a piped water supply, and therefore still need to carry water at times. A family may have access to toilet facilities, however these may be broken, unclean or unhygienic and therefore not used by any or some household members. However, the wording of the toilet facility question does specify 'use' rather than 'access', to reduce the likelihood of this type of bias with regard to sanitation. Again, it is most likely that such confounding would have reduced the strength of associations observed and therefore the effects reported here may be underestimated. Several of the outcome variables rely on self-reported information which may introduce reporting bias, however, outcomes such as number of children who have died are likely to be well remembered by respondents, with little gain to be had from intentional misreporting.

In multivariable analyses, it is inevitable that data will be lost due to cases having missing information in one or more of the predictor or covariate variables. This is a further potential source of bias and confounding which may affect the results, however, the percentage of missing cases compared to the number of respondents surveyed in the original MICS data was low, with response rates ranging from 78.8% to 86.6%, with a low percentage of missing data for most countries. Multilevel or mixed effects modelling can handle randomly missing data, and it was assumed that the data is randomly missing. However, it has been reported that multilevel modelling can also handle non-randomly missing data if the outcome is interval (Katz, 2011). In the final analysis Swaziland had a large amount of data missing (96.9%) for cases of children with diarrhoea and those left alone for one or more hours per day, one or more days per week. However, data from Swaziland contributes 0.7% of the overall data set and the proportions of yes to no responses for each outcome were similar to those in the original MIC surveys for Swaziland. Therefore whilst this may introduce bias, it was have assumed that it will not have a substantial effect on the overall results.

The data set included a large number of studies from different countries, which were not conducted at the same time. However, the studies were all conducted within a five year timespan (2009-2014), and utilizing data from all 49 MICS of 41 countries which were available in April 2015 maximizes the generalizability of the results, and therefore the relevance of the findings to global health. The surveys were not designed to specifically test the hypotheses which were tested, however MICS and DHS data sets from multiple countries conducted at different times have been used to generate descriptive statistics (Sorenson et al., 2011, Hopewell and Graham, 2014, Graham et al., 2016) and to analyse associations between improved water supplies and sanitation usage and incidence of childhood diarrhoea, height and weight (Esrey, 1996). Utilizing a large set of surveys from different countries may increase the risk of variation in study design across surveys, however MICS are conducted after training enumerators to use standardized data collection tools and methods, and with population sampling which is either nationally representative, or representative of a target group or region within a country (UNICEF, 2017). The variables used for analysis in this study were checked and transformed if necessary to ensure that they had identical response options and value labels before data sets were merged for analyses.

Considering these limitations, the associations observed remain plausible, unlikely to have occurred by chance, are strong in some analyses and consistent with the results of other studies (Bonita et al., 2006). Therefore, whilst the study design has limitations due to exposure data being collected at the same time as outcome data, and the possibility of bias and confounding cannot be eliminated, it does contribute to the body of evidence supporting causal relationships between the predictor and the outcome variables which were analysed (Bonita et al., 2006). Further longitudinal cohort studies are required to allow firmer judgements on causation to be made.

3.6 Recommendations for future research

Further research should investigate the factors which influence who is tasked within a household to fetch water when it is accessed away from the home. Particularly in rural sub-Saharan Africa, societal construction of gendered roles for water fetching may be an important influence, however there may be other factors which influence practical decisions about who should fetch water, such as commuting distances for employed family members, or migration within or between countries for employment. Where opportunities for men to fetch water exist, the effectiveness of behaviour change strategies which challenge social norms and reduce the burden of water fetching on women should be evaluated, to test whether improved maternal and child health outcomes can be achieved with such an intervention.

3.7 Summary

Data from 49 surveys in 41 countries indicate that the work of fetching water when the water source is not located in the home or yard is significantly associated with poorer maternal and child health outcomes. This study is the first to report associations between maternal and child health and the age and sex of the person responsible for collecting water. Water fetching by any household member is associated with reduced odds of a woman giving birth in a health care facility. Adults collecting water, is associated with increased risk of childhood death, children collecting water with increased risk of diarrheal disease and women or girls collecting water, with reduced uptake of antenatal care and increased odds of leaving a child under five alone for an hour or more, one or more days per week. The results demonstrate that water access on premises is associated with significant improvements in maternal and child health and safety.

Chapter 4. Cross sectional survey: The association between water carriage and physical health of water carriers in communities of South Africa, Ghana and Vietnam

4.1 Introduction

The percentage of the population using safely managed drinking water services *at home* has been proposed as the indicator for monitoring achievement of SDG 6, target 6.1 (WHO and UNICEF, 2017a, WHO and UNICEF, 2017b). This represents a major shift toward recognising important differences in access to safe drinking water, to distinguish water accessible within the home or yard, ('at-house' access), from water accessible at a supply point or source away from home ('off-plot' access). A key difference with the different levels of water supply service or access, is the work of water carriage required to bring water home from off-plot sources. Whilst past research has indicated that water collection time greater than 30 minutes for a round trip reduced the quantity of water collected, which may increase risk of water washed disease affecting household members (Cairncross, 1987), little research has been done to investigate whether water collection affects the health of the water carrier.

Perhaps the most influential study on the social and other impacts of water carriage was "Drawers of Water" (White et al., 1972), followed up some 30 years later by "Drawers of Water II" (Thompson et al., 2002). Conducted in East Africa, these studies raised awareness of the burden of fetching water for many African women. The work of carrying water each day continues to mainly fall on women and girls, as reflected in a 2017 report of the WHO/UNICEF Joint Monitoring Programme, which found that women and girls were responsible for water collection in 'eight out of ten households with water off premises'. Women were responsible for water collection in 73.5% and girls in 6.9% of households of 61 DHS and MICs surveys (WHO and UNICEF, 2017b). Water carriage has potential to be a major constraint on the achievement of other SDGs, including:

- SDG 1 "End poverty in all its forms" – when women have to spend much of their day fetching water they may not have the time to devote to other activities that could increase their income, for example having to carry sufficient water home has been reported to be a constraint to productive activities such as home gardening for food production and sale (Geere et al., 2010a).
- SDG 4 "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" – when children, most often girls, spend time carrying

water this prevents them from accessing or fully engaging with education (Porter et al., 2012).

- SDG 5 “Achieve gender equality and empower all women and girls” – it is difficult to see how girls and women could be fully empowered to reach their potential when they must spend much of their time fetching water (Puri, 2012).
- SDG 8 “Promote inclusive and sustainable economic growth, full and productive employment and decent work for all” – sustainable economic growth is less likely in those societies where half the work force spends much of its time fetching water (Puri, 2012).

Neither of the Drawers of Water studies, or studies since, have been definitive about the impact of fetching water on health, because of the limitations of study design, or risk of bias affecting studies’ results. If carrying water adversely affects health, then it would also be a constraint on achieving SDG 3 “Ensure healthy lives and promote well-being for all at all ages”. Although there has been speculation, there has been little good quality evidence that adverse health impacts are associated with water carrying (Geere et al., 2010a). Research on water access has focussed mostly on water source type, and location or distance to water source rather than the work of water carriage, and on health outcomes such as acute diarrhoeal disease affecting children under five years of age rather than direct indicators of the health of household members who fetch water (Overbo et al., 2016). For example, in a systematic review Wang and Hunter (2010) found an association between distance to water source and diarrhoeal disease. In another study Pickering and Davis found that both diarrhoeal disease and mortality in children under five years of age were associated with time taken to fetch water from the nearest source (Pickering and Davis, 2012). However, in both these studies the adverse health impact was on children in the home and did not directly address the health of the person carrying the water.

Studies have reported detrimental effects of load carriage on the head (Levy, 1968, Joosab et al., 1994, Jäger et al., 1997, Porter et al., 2012, Porter et al., 2013) and limited evidence suggests that musculoskeletal disorders may be associated with water carrying (Hemson, 2007, Geere et al., 2010a, Geere et al., 2010b, Robson et al., 2013, Geere, 2015). Carrying water containers, particularly on the head (head loading), may impart physical stress to the bones and soft tissues of the neck and upper back through vertical compression or ‘axial loading’, and/or shear forces generated by translation in the horizontal plane (Panjabi et al., 1986, Jäger et al., 1997, Panjabi et al., 1998, Geere et al., 2010a). The stress may tend to be greatest at specific regions or vertebral levels of the spine due to differences in structural anatomy of the vertebrae at different spinal levels, with additional variation due to age related vertebral column changes or sex differences (Pal and Routal, 1986), or an individual's habits of posture and movement (Jull et al., 2008). Peak or cumulative tissue stress loading during water carriage may be sufficient to produce pain and/or injury at the time of the activity or soon after, and if focussed at different regions of the spine may produce symptoms perceived in different locations of the body through well reported mechanisms of 'referred' pain (Schellhas et al., 1996, Schellhas et al., 2000, Slipman et al., 2005, Jull et al., 2008). Therefore, given the substantial disease burden of musculoskeletal disorders in low and middle income countries (Hoy et al., 2014, Vos et al., 2015), the substantial amount of women's and children's time spent carrying water (Pickering and Davis, 2012, Puri, 2012, Graham et al., 2016) and the small amount of evidence suggesting an association between water carriage and musculoskeletal disorders (Hemson, 2007, Geere et al., 2010a, Geere et al., 2010b, Geere, 2015), it is important to further investigate and better understand how water carriage is associated with the physical health of water carriers.

Because a key feature of musculoskeletal disorders is pain, it was hypothesized that water carriage would be significantly associated with self-reported pain, as well as disability and general health. This chapter reports the first large scale study undertaken across three countries, which has attempted to identify the physical health outcomes associated with water carriage, and which affect the individuals who collect and carry their family's water home. The objective of the study reported here was to evaluate the relationship between water carriage from an off-plot water source and physical health status as indicated by self-reported general health, pain, physical functioning and disability.

4.2 Methods

4.2.1 Study design and setting

A cross-sectional survey was conducted, with recruitment and data collection occurring during June to December 2012 in Ghana, South Africa and Vietnam. The study reported in this thesis was part of a broader study funded by the U.K. Department for International Development (DfID) on the health and social benefits of at-house water supplies (Evans et al., 2013). The principle investigator (PI) for the broader study was located at the University of Leeds (UL), and the collaborative institutions included the University of East Anglia (UEA), the University of North Carolina at Chapel Hill (UNC), the London School of Hygiene and Tropical Medicine (LSHTM), Kwama Nkrumah University of Science and Technology

(KNUST) in Ghana, Tshwane University of Technology (TUT) in South Africa, and the Hanoi School of Public Health (HSPH) in Vietnam.

The decision to conduct the research in South Africa, Ghana and Vietnam was based on the potential for water access research to make a difference to people's lives in these countries, strong existing research links between the academic institutions, and an intention to generate study findings which could be applied to similar settings in other countries affected by similar issues. The diversity of study sites was intended to optimize the generalizability of the findings and the lessons learned from the research.

Districts which were typical of low-income regions with sub-optimal water supply, and known to have communities with a mix of households with at-house and off-plot water supplies, were selected as the sampling frame in each country. A computer generated random number sequence was used to randomly select communities or villages from each district to be included in the survey. In Ghana the research was conducted in four communities near Kumasi in the Ashanti region. All four communities were located around a main road and could broadly be defined as urban or peri-urban. Water was supplied through a combination of private taps, public taps, private boreholes and purchase of 'sachet' water, which is drinking water sold in small plastic bags. In Vietnam the research was conducted in the remote, rural and mountainous Lao Cai province. The communities in Lao Cai were generally small scattered rural hamlets and most households accessed water from several sources, including piped water supply to the home, private boreholes and wells and public springs. In South Africa fieldwork was carried out in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province. Two communities were located in the dry, flat area west of Makhado town. The water sources here were communal taps located in the village streets, or private drilled wells with either a yard tap or in-house connection. The third community was located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while some households had yard-taps or in-house taps.

4.2.2 Sampling strategy

Assuming a sample size of 1000 participants and using the approach outlined by Hsieh et al (1998), based upon simple logistic and linear regression, it was calculated that a Power of 90% would be obtained even with a relatively small proportion of subjects with the outcome of interest. Random sampling from within strata based on source of drinking water was used to recruit an even number of households with at-house and off-plot water supplies.

In South Africa 210 households were enrolled, in Ghana 255 and in Vietnam 208 generating a total of 997 participants who were asked about the variables of interest (Table 4.1). All household members usually resident in selected households were eligible study participants.

4.2.3 Data collection and management

The author's role was to lead on the development and refinement of survey questions pertaining to physical health outcomes reported in this chapter, specifically bodily pain (distinguished from psychological or mental pain), physical disability, physical functioning and general health. In June 2012, prior to commencement of any fieldwork activities, the data collection tools and protocol were revised, refined and standardised at a project workshop attended by the principle investigator, co-investigators and field work team leads for each country. Care was taken by the study team during the development, revision, translation and back translation of the survey to avoid use of leading questions. To provide a logical order of questions the survey was structured into two key thematic sections, focusing on demographic variables, water supply and water use in part I, and questions about health outcomes in part IIa and IIb (Appendix 12). Time taken to complete the whole survey was estimated to take at least one to two hours for each part because of the number of questions included, but expected to vary because of differences in the number of people per household. Therefore, part I and part II were conducted on separate days, to reduce the time burden for the respondent during each interview occasion, and to reduce risk of bias (see 4.2.5.). The survey questions were then separately piloted in all three project locations and a final survey instrument was confirmed for use in all three countries.

The survey was administered to participants orally in face to face interviews conducted by field workers, in a location (usually the respondent's home or yard) and at a time convenient to the respondent. Field workers were trained to ask the survey questions in a polite, non-coercive and standardised manner as a one to one interview in the participant's preferred language, and to fill in a paper version of the form to indicate the participant's responses (Appendix 13) The field workers were recruited from villages in the study regions of each country by the host country universities to ensure that they were able to communicate in the local language with study participants, and to ensure that they were familiar with local customs and sensitivities toward behaviour and communication during interactions with study participants. Fieldworkers were also required to have sufficient level of written and spoken English to be able to communicate with the field work team leads in each location and record survey responses. Seventeen field workers were employed in Ghana, four in South Africa and four in Vietnam.

Fieldworkers were trained to administer the survey orally by the team leads and researchers resident within each country (Appendix 13). Training included sessions on ethics, gaining informed voluntary consent, researcher conduct and safety, data collection and data management. In Vietnam, the study was executed in Vietnamese, therefore the Hanoi School of Public Health was responsible for translation of the structured household questionnaires from English to Vietnamese, and the University of Leeds used an independent translator to back translate the questionnaire to confirm retention of content during translation. The Hanoi School of Public Health was also responsible for translation of data from Vietnamese to English, and data entry in English. Similarly in Ghana, the study was executed in Twi, therefore KNUST was responsible for translation of the structured household questionnaires from English to Twi and UNC used an independent translator to back translate the questionnaire to confirm retention of content during translation. KNUST was also responsible for translation of data from Twi to English, and for weekly data entry in English. In South Africa, whilst the paper version of the survey was written in English, then translated into and independently back translated from the local language Tshi Venda, the field workers preferred to use the paper survey version written in English during survey interviews, because their reading and writing skills were stronger in English. They asked the survey questions verbally in the participant's preferred language, Tshi Venda or English, or in a mixture of English and Tshi Venda as required and inputted responses into the English version of the survey form.

The household survey collected demographic information about all household members, and included questions about water carriage exposure variables and the health outcomes reported in this chapter. The water carriage and related health questions were administered to one adult respondent (93% women) and one child (57% girls) from each household. In houses with off-plot water supply, the questions were addressed to an adult and child identified by participants as a person in the household who would normally collect water. In households with at-house supply they were addressed to an adult and a child who would be responsible for collecting water if it were necessary. If a child was not present, the adult was asked to respond on their behalf.

Field work team leads remained in country during the period of data collection (South Africa), or for the first two weeks and at a midpoint of data collection (Ghana and Vietnam). They were responsible for training and supporting the field workers, data quality management and electronic data entry. Quality management was done by checking a sample of completed surveys for logical and plausible responses as they were returned by field workers, by checking responses during electronic data entry, and in Ghana and Vietnam by the provision of weekly progress reports written in English and shared with members of the research team located in North Carolina and Leeds respectively. In South Africa the fieldwork team lead remained for the duration of data collection and completed all electronic data entry. Data collected on paper survey forms was entered into laptop computers using epi-data software (v2.2.2. build 177). Paper surveys were stored securely by the field workers and field work team leaders and electronic data were stored on password protected computers which were only accessible to the members of the research team.

4.2.4 Variables

The independent variables included self-report of whether the main household water supply was currently obtained from an at-house or off-plot supply point, whether the respondent currently or had ever carried water and their usual method of water carriage. Anyone who obtained and physically carried water home at the time of the survey was identified and considered a current water carrier. These respondents were asked about their usual method of water carriage, frequency of water fetching trips per day, frequency of water fetching days per week and to estimate usual round trip collection time. Those who were not carrying water at the time of the survey, but who had done so at any time in the past were identified and categorised as having a 'previous history' of water carriage, and these respondents were asked how old they were when they started and when they stopped carrying water. It was not considered appropriate to ask respondents with a previous history of water carriage about their method and frequency of water carriage in detail, as this could have varied over time and their answers could be substantially affected by recall bias. The calculation of the average number of years spent fetching water by people in each country with a previous history of water carriage indicated that previous water carriage work was usually substantial, and by using generalised estimating equations (GEE) to generate population averaged models, the risk of individuals with a history of trivial amounts of previous water carriage biasing the results was reduced. Respondents who did not report either current, or past experience of water carriage were identified and classified as having 'no history of water carriage.

Dependent variables were self-reported health outcomes describing pain, general health, disability and functioning, which were addressed to the subset of participants described above. Respondents were asked whether they had experienced any physical pain in the previous week, with a yes/no response option. Those who responded yes were asked to indicate their pain severity in the previous week as ‘mild’, ‘moderate’ or ‘severe’ (Singer et al., 2001, Anderson, 2005, Broderick et al., 2006). They were then asked whether their pain had lasted less than one month, one month or more but less than three months, or for three months or more, to indicate pain duration. To indicate pain frequency, respondents were asked if pain was ‘always present’, or whether ‘it comes and goes’. Respondents were also asked ‘Where do you mainly feel that pain’ and could indicate more than one area of pain by responding yes or no to each area of the body, which was read aloud from a list by the interviewer. The body areas listed were head, neck, shoulders/arms, hands, lower back, upper back, chest/ribs, abdomen/stomach, hips/pelvis or legs, and feet.

To indicate general health, respondents were asked ‘In general, how would you rate your health today?’ and could select their response from a five point rating scale (1= Very good; 2 = Good; 3 = Moderate; 4 = Bad; 5 = Very Bad). The short set of questions on disability developed and recommended for use in national surveys by the Washington Group on Disability Statistics (Madans et al., 2011) were used. Respondents were asked to rate whether they had difficulty in doing the activities of seeing, breathing, hearing, walking or climbing steps, remembering or concentrating, self-care and communicating. The response options were ‘no difficulty’, ‘some difficulty’, ‘a lot of difficulty’ or ‘cannot do it at all’. Questions on functioning used by Atijosan et al, shown to have excellent reliability and validity in developing country settings (Atijosan et al., 2007) were used to indicate impairment of functioning. Respondents were asked whether they had difficulty using their arms, legs, any other part of their body such as the back or neck and whether they have ‘fits’ or ‘epilepsy’. Response options were ‘no’, ‘yes, lasted less than 1 month’ or ‘yes, lasted more than one month or is permanent’. Information was also gathered on the potential confounding factors of age and sex.

4.2.5 Minimising risk of bias.

Potential sources of bias (Hammer et al., 2009) were minimised during data collection by using random sampling of households to reduce selection bias, limiting descriptive information about pain to pain experienced in the previous seven days to reduce recall bias, training field-workers in a standardised interview protocol and monitoring the quality of data collection during fieldwork to reduce interviewer bias, and surveying households about exposure variables and outcome variables on separate days to minimise response and classification bias. However, some minor discrepancies occurred which reduced the consistency with which the survey was administered. For example, although questions about pain, disability and general health were only meant to be asked of one adult and one child per household, some field workers gathered this information from a larger number of people per household. Although questions about pain severity, duration, consistency and location were only to be asked of people who reported pain in the previous seven days to reduce recall bias, some fieldworkers gathered information on pain severity, duration and consistency from people who had not had pain in the previous seven days, but had experienced pain over a longer time period. This resulted in six additional respondents.

4.2.6 Data analysis

Data entered into epi-data software were transformed into SPSS v 22 for analysis. Summary descriptive statistics were generated for self-reported pain, general health, physical functioning of body regions and functional disability of people for the whole data set, as well as for comparison of people from different countries and with at-house supply compared to those using off-plot water supplies (Appendix 14, Tables S4.1 - S4.18, figures S4.1- S4.4). However, categorisation into at-house or off-plot water supply did not distinguish between people who did or did not engage in water carriage (Figure 4.1) and resulted in very small numbers of, or no responses in the response categories of some outcomes of interest. Therefore, personal history of carrying water by any method, categorised as a person who is currently carrying water, a person who previously carried water but is no longer doing so, or a person who had never carried water, was used as the predictor variable. It was assumed that this represented different levels of exposure to water carriage, with no history of water carriage as the lowest level of exposure, currently carrying water as the highest, and assuming that someone who had previously carried water but no longer did so, would have had time for positive or negative health impacts related to the activity of water carriage to have reduced.

Primary analyses of the association between history of water carriage and the health outcomes of pain reported in the previous seven days, bodily pain location, and self-rating of bodily functioning, disability and general health ‘today’ were done using Generalised Estimating Equations (GEE) adjusted for age and sex. Subject variables were entered into the analysis representing the respondent’s household, village and country to account for the effect of clustering at these levels. Secondary analyses of the association between history of water carriage and pain severity, pain duration and pain consistency were also done for a smaller subset of adult respondents who reported that they had experienced pain in the previous seven days. These were not done for children because of the small number of children reporting pain in the previous seven days, and therefore the very small numbers of children in each response category of pain descriptors.

GEE were chosen as the analysis method because they can adjust for correlated observations, which occurred in this study due to the recruitment of a number of participants from groups, or ‘clusters’ of related individuals (Katz, 2011), including two people from each household, a number of households from the study villages in each country, and participants from three different countries. The participants within each grouping, or level of clustering are likely to have similar characteristics based on their group membership. This violates the assumption of independent observations required for ordinary least squares regression, and if ignored can lead to incorrect estimates of the standard errors, resulting in incorrect statistical significance and incorrect conclusions (Robson and Pevalin, 2016). Correlated observations were used because they realistically reflect the way that human social and geographical relationships or organisational structures occur and influence access to water and health status (Bronfenbrenner, 1977). It was also deemed most appropriate to recruit participants by household, village and region within country, because the exposure variable of water carriage and covariates would have related effects on the behaviour of the people within these groups, rather than just an independent effect at the level of the individual (Katz, 2011). Clustering at household level is particularly important in this study because the respondents were likely to often be a mother and child, and therefore likely to have the most similar characteristics of potential relevance to the outcomes of interest. For example, children, particularly girls, have been shown to mimic parental health and pain behaviour (Boerner et al., 2017), and twin studies have reported that genetic influences account for about 50% of the variance in chronic pain (Fillingim et al., 2008).

GEE analyses can model the relationships between a variety of risk factors or predictor variables and different types of outcomes of interest, and the appropriate regression model is selected to suit the type of outcome variable being evaluated (Katz, 2011). Where the outcome variable was binary negative binomial regression with a log link was used, for ordered categorical data ordinal logistic regression was used, and where the outcome variable was scalar linear regression models were used. GEE can handle different numbers of observations from different clusters, which occurred in the data at village and country level, can accommodate randomly missing or small amounts of missing data, and can also handle unequal numbers of observations in each cluster. An independent working correlation matrix was used, which is appropriate when the number of observations per cluster is small relative to the number of clusters (Katz, 2011). Participants with missing data were excluded from the analyses.

GEE are ‘population averaged’ models, also known as ‘marginal models’, which means that the mean of the dependent variable is modelled as a function of the independent variables. Therefore GEE estimates the average response over the population (‘population-averaged’ effects) rather than the regression parameters that would allow prediction of the effect of changing one or more predictor variables on a given individual. The coefficient is the between person difference in the outcome comparing the effect of exposure to no exposure, as if the exposure had affected two separate individuals (Katz, 2011). For example, in a logistic regression model for a dichotomous outcome, the odds ratio would represent the odds of an average person in the exposure group having the outcome, compared with the odds of the average person in the non-exposed group having the outcome (Sribney, 2018). The effect of GEE is to decrease the precision of the parameter estimates, because it increases the standard errors and therefore widens the confidence intervals around the parameter estimate (Katz, 2011).

The collection of data on the location of a person’s pain resulted in ten dichotomous responses which indicated for each individual whether each part of their body was painful or not. If a number of variables are correlated, it is possible to conduct an exploratory factor analysis and resolve a number of variables into a smaller number of factors. Portney and Watkins (2000, p 607) define a factor as consisting of ‘a cluster of variables that are highly correlated among themselves, but poorly correlated with items on other factors.’ Because a correlation matrix indicated that reporting of pain at different parts of the body was correlated, a factor analysis of the different pain location variables was undertaken. Principle component analysis was used to extract two factors from the overall data correlation matrix which accounted for the largest proportion of the total variance in the pain location data. As part of the factor analysis, a factor score was generated for each individual study participant to indicate the extent of correlation between each individual’s pain pattern and the extracted factors. Published literature was used to develop a theoretical construct offering a plausible explanation of the observed correlations between the pain locations within each factor and to name each factor (Portney and Watkins, 2000). GEE with linear regression was then repeated for each factor, with factor score as the dependent variable and history of water carriage as the independent variable, adjusting for age and sex. The analysis was repeated to evaluate the strength of association between factor score and pain duration, and water carriage by head loading compared to other methods.

4.2.7 Ethical review

This study was approved by MEEC (Faculties of Maths, Engineering and Physical Sciences) Research Ethics Committee at Leeds University, which as the lead university for the overall DfID project, submitted an application for ethical approval on behalf of the University of East Anglia and Leeds University to cover work in South Africa and Vietnam (Appendix 15 and 16). Staff at UNC were required to seek additional and separate ethical approval from an Internal Review Board in the United States, and to cover work in Ghana (Appendix 17). In South Africa ethical clearance was also granted by the Tshwane University of Technology central ethical clearance committee, and the research team were invited by local chiefs within the study area to present their proposed research. Local chiefs approved of the study and welcomed the research teams to work in their communities. In Ghana ethical approval was obtained from both the District Director of Health Services for Atwima Nwabiagya and the Atwima Nwabiagya District Assembly. In Vietnam, ethical clearance was obtained by the ethical research board of the Hanoi School of Public Health. Participants were included only after they had given informed, written, voluntary consent if they were more than eighteen years old, or if they and their guardian had given informed voluntary consent if they were less than eighteen years old.

Ethical issues taken in to account by the research teams included the conduct and safety of the researchers, the safety and expectations of study participants, management and protection of data across and between multiple study sites and institutions, and dissemination of the study findings. Insufficient access to water is an emotionally and politically sensitive topic, which can generate frustration and conflict among people because of real or perceived inequalities within and between communities. A research training workshop of in-country research team leads and fieldworkers was held prior to commencing data collection, to anticipate and reduce risk of harm from conflict or adverse events which might arise during or after the project. The workshop included discussion of transparency and honesty in communication, data collection, data management and study reporting; sensitivity to local expectations and norms of behaviour; and risk assessment and mitigation to ensure safety of researchers and participants. Research teams were sensitive to the risk of raising expectations for improvements to water supply as a consequence of study participation, and took care to avoid either directly or indirectly implying that change to the local situation would occur as a result of the study. Fieldworkers were recruited from the study regions, to ensure that cultural norms and expectations for behaviour were understood across the research teams and respected. Institutional protocols for risk assessment and maintaining researcher safety during travel and field work were also adhered to in each study site.

The study participants included children and people potentially vulnerable because of their age, sex, poverty or social standing within households and communities. Vulnerable people were included as participants, because in all of the study sites, collecting water for household use is a chore often delegated to children, and negotiating and gaining sufficient access to water can be particularly challenging for vulnerable people. Whilst informed written consent was obtained from parents or guardians for children to participate in the study, children were also asked to provide consent and sign a consent form when they were able to (Appendix 18 and 19). Researchers and fieldworkers were trained in how to obtain informed, voluntary consent, as well as how to recognise behaviours and communication which might indicate or be perceived as coercion or 'bullying' of vulnerable people, and in dealing appropriately with issues related to child protection (Appendix 13).

Research teams adhered to their University's policy and guidelines on data security, to ensure that personal data was kept securely and that personal information was not disclosed to any unauthorised third party. Participants were assigned a number referent upon recruitment to the study to preserve their anonymity, authorised research team members anonymised all personal data during electronic data entry, and all communications between the study sites used only the number referents. Personal data was accessible only to members of the research teams and kept either in a lockable room with controlled access, a locked filing cabinet or drawer, or protected by password and encrypted files if held on a computer. Collection and use of personal data at the study sites created risk of loss, theft or damage of data or the equipment it was stored in during fieldwork. Therefore, the research teams took appropriate security precautions to manage data during fieldwork and before it had been anonymised. This included care to ensure that paper based data and equipment was not visible or left unattended during fieldwork, data on the screens of computers or electronic devices were not visible to unauthorised people or left unattended during data entry, and that computer passwords and encryption codes were kept confidential.

The dissemination plan for the study included communication with key stakeholders, including DFiD, the wider scientific and public health community and interested members of the general public and study communities. The dissemination strategy to reach these stakeholders focussed on publication of a final report for the whole study which is freely available on-line (Evans et al., 2013), and publication in peer reviewed journals and books

(Geere, 2015, Overbo et al., 2016, Geere et al., 2018a). Findings from field studies were made available to participating communities through a nationally-appropriate mechanism. For example, in South Africa a summary presentation of the study findings was provided to community members and key community representatives in workshops located in the study region (Appendix 20).

4.3 Results

Three thousand three hundred and sixty five people were recruited to the overall study, from 673 households. For the aspect of the study reported in this thesis, 997 respondents (Table 4.1). Respondents were an adult identified as main survey respondent for households with at-house supply or usual water carrier for households with off-plot supply and a child identified for response to health, disability and pain questions.

4.3.1 Patterns of water carriage

Respondents with at-house or off-plot water supplies were recruited in each country and household members were identified as being current water carriers, previous water carriers, or those who had never carried water (Table 4.1, Appendix 14, Table S4.1 and S4.2). In South Africa and Ghana, substantial numbers of adults (South Africa 36.9%; Ghana 61.9%) and children (South Africa 19.2%; Ghana 43.4%) with at-house supply who were asked questions about general health, pain and disability, categorised themselves as currently carrying water (Table 4.2). Whilst proportionately more women and children with off-plot supply in Ghana carried water by head loading, a considerable proportion of women and children with at-house supply also did so. A larger proportion of people with at-house supply in South Africa carried water by head loading compared to those with off-plot supply, as 42.4% of respondents with off-plot supply used a wheelbarrow to transport water (Figure 4.1). In both countries, participants reported episodes of interruption to at-house water supplies requiring water carriage from off-plot sources, which has also been reported in previous literature (Majuru et al., 2012, Arnold et al., 2013). In all countries, substantial numbers of women with at-house supply had previously carried water (South Africa 56.3%; Ghana 21.6%; Vietnam 26.8%). The mean number of years in which they had engaged with water carrying were 25.4 (sd19.4) for South Africa, 19.7 (sd14.5) for Ghana and 7.1 (sd10.2) for Vietnam (Appendix 14, Table S4.3).

Table 4.1 Demographics

	Ghana	South Africa	Vietnam	Total Number
Population of study communities	5160	-	-	N/A
Number of households (HH) in study communities	-	2113	264	N/A
HH enrolled in survey N (%)	255 (37.9%)	210 (31.2%)	208 (30.9%)	673 (100%)
Number of participants enrolled in survey N (%)	1326 (39.4%)	1230 (36.5%)	809 (24.1%)	3365 (100%)
Adults and children responding to pain, disability, general health and history of water carriage questions (1 adult and 1 child from each household) N (%)	397 (39.8%)	333 (33.4%)	267 (26.8%)	997[3] (100%)
Female sex whole survey: N (%)	753 (57.6%)	639 (52.0%)	401 (49.7%)	1793 (53.6%)
Female sex participants responding to pain, disability, general health and history of water carriage questions: N (%)	334 (84.8%)	234 (70.3%)	221 (82.8%)	789 (79.4%)
Mean age (standard deviation): whole survey	22.2 (23.5)	27.7 (21.3)	29.8 (20.9)	25.9 (22.4)
Mean age (standard deviation): participants responding to pain, disability, general health and history of water carriage questions	25.5 (16.3)	31.6 (22.2)	33.5 (20.5)	29.7 (19.8)
Adult[1] respondents to pain, disability, general health and history of water carriage questions with at home water supply N (%)	97 (43.1%)	103 (51.0%)	142 (77.2%)	342 (56.0%)
Adult[1] respondents to pain, disability, general health and history of water carriage questions with off plot water supply N (%)	128 (47.6%)	99 (49.0%)	42 (22.8%)	269 (44.0%)
Child[2] respondents to pain, disability, general health and history of water carriage questions with at home water supply N (%)	76 (45.5%)	73 (55.7%)	25 (30.5%)	174 (45.8%)
Child[2] respondents to pain, disability, general health and history of water carriage questions with off plot water supply N (%)	91 (54.5%)	58 (44.3%)	57 (69.5%)	206 (54.2%)

[1]adult identified at Q14 as main survey respondent for households with at-house supply or usual water carrier for households with off-plot supply; [2]child identified at Q15 for response to health, disability and pain questions; [3]includes 6 additional respondents to those identified at Q14 and Q15

Table 4.2 Personal history of water carriage by at-house supply and country

Adults			History of water carriage: Currently	Previously	No history	Total
Ghana	At-house supply	No	102	20	6	128
			79.7%	15.6%	4.7%	100.0%
		Yes	60	21	16	97
			61.9%	21.6%	16.5%	100.0%
	Total		162	41	22	225
			72.0%	18.2%	9.8%	100.0%
South Africa	At-house supply	No	84	9	6	99
			84.8%	9.1%	6.1%	100.0%
		Yes	38	58	7	103
			36.9%	56.3%	6.8%	100.0%
	Total		122	67	13	202
			60.4%	33.2%	6.4%	100.0%
Vietnam	At-house supply	No	36	2	4	42
			85.7%	4.8%	9.5%	100.0%
		Yes	12	38	92	142
			8.5%	26.8%	64.8%	100.0%
	Total		48	40	96	184
			26.1%	21.7%	52.2%	100.0%

Children			History of water carriage: Currently	Previously	No history	Total
Ghana	At-house supply	No	45	1	45	91
			49.5%	1.1%	49.5%	100.0%
		Yes	33	0	43	76
			43.4%	0.0%	56.6%	100.0%
	Total		78	1	88	167
			46.7%	0.6%	52.7%	100.0%
South Africa	At-house supply	No	28	2	28	58
			48.3%	3.4%	48.3%	100.0%
		Yes	14	7	52	73
			19.2%	9.6%	71.2%	100.0%
	Total		42	9	80	131
			32.1%	6.9%	61.1%	100.0%
Vietnam	At-house supply	No	19	0	6	25
			76.0%	0.0%	24.0%	100.0%
		Yes	1	1	55	57
			1.8%	1.8%	96.5%	100.0%
	Total		20	1	61	82
			24.4%	1.2%	74.4%	100.0%

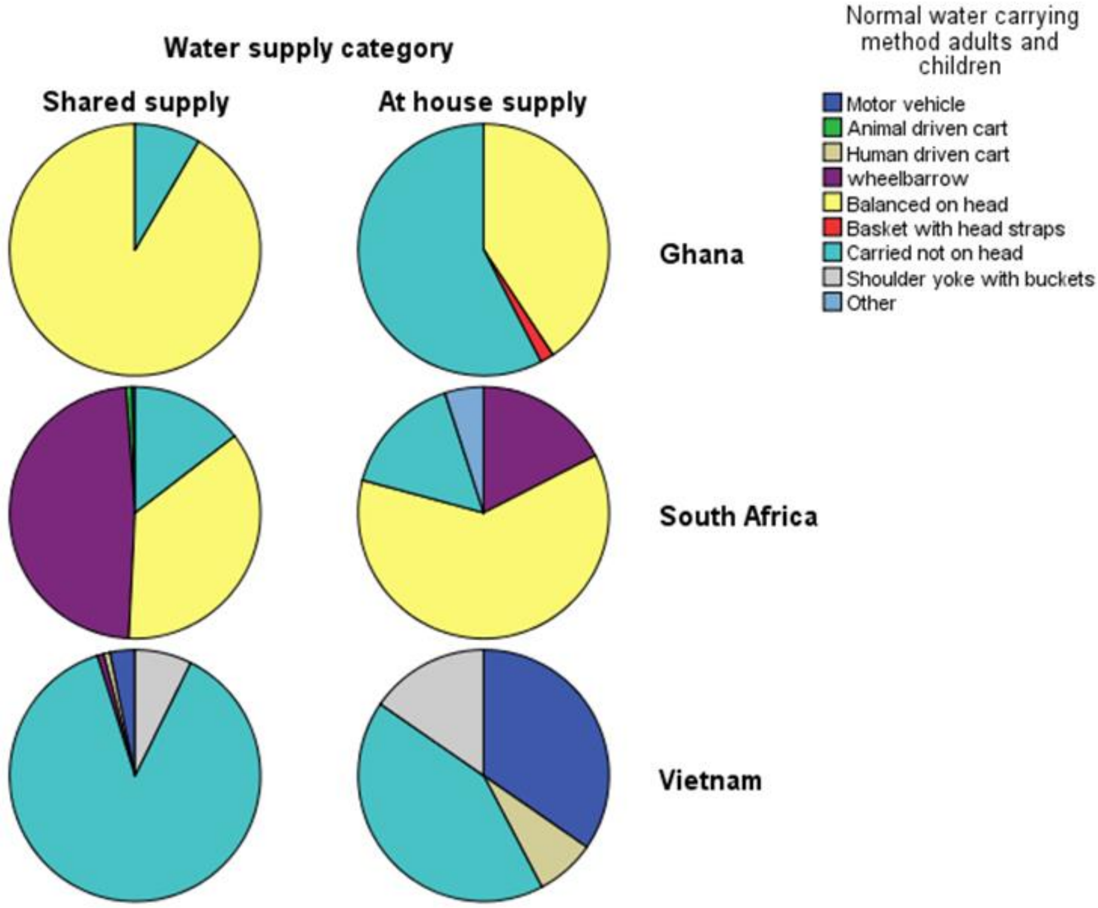

Figure 4.1 Water carriage method by supply type and country

4.3.2 Pain

Irrespective of at-house or off-plot supply categorisation, in South Africa proportionately fewer adults and children reported feeling pain in the previous seven days (SA adults 36.1%; children 4.6%) than in Ghana (adults 57.3%; children 18%) or Vietnam (adults 54.3%; children 21.7%) (Table 4.3). Overall, comparing people with at-house versus off-plot supply within countries, there was no substantial difference in reporting of pain experienced in the previous seven days (Table 4.3, Appendix 14, Table S4.6).

Table 4.3 Pain in last seven days by country (n = 992)

Adult		Pain in last 7 days		Total
		No	Yes	
Ghana	Count	96	129	225
	%	42.7%	57.3%	100.0%
South Africa	Count	129	73	202
	%	63.9%	36.1%	100.0%
Vietnam	Count	84	100	184
	%	45.7%	54.3%	100.0%
Total	Count	309	302	611
	%	50.6%	49.4%	100.0%
Children		Pain in last 7 days		Total
		No	Yes	
Ghana	Count	137	30	167
	%	82.0%	18.0%	100.0%
South Africa	Count	125	6	131
	%	95.4%	4.6%	100.0%
Vietnam	Count	65	18	83
	%	78.3%	21.7%	100.0%
Total	Count	327	54	381
	%	85.8%	14.2%	100.0%

History of water carriage did not significantly affect likelihood of reporting pain experienced in the previous seven days (Table 4.4). However, pain reported in particular locations of the body (Appendix 14, Table S4.6) was associated with personal history of water carriage. Table 4.5 presents overall p values for the risk of reporting pain in each area of the body against history of water carriage, with no history of water carriage as the comparator category. Figures 4.2 and 4.3 indicate risk of pain in each location of the body comparing people who have never carried water, to those who previously and currently carried water respectively. Compared to people who had never carried water, people who previously carried water had increased relative risk of reporting pain in the hands and upper back (Table 4.5, Figure 4.2), as did people who currently carry water (Table 4.5, Figure 4.3).

Those who currently carried water also had increased risk of pain in the abdominal region, chest or ribs and head, compared to people who had never carried water (Figure 4.3). They had reduced risk of reporting shoulder or arm pain compared to those who had never carried water (Figure 4.3).

Table 4.4 Self-report of pain in previous seven days against history of water carriage (n = 982)

Pain previous seven days	Predictor variable	Number	Relative Risk	Lower 95%CI	Upper 95%CI	P value
Adults	No history of water carriage	130	1			0.962
	Previous history of water carriage	145	0.97	0.77	1.23	
	Currently carries water	329	1.00	0.82	1.23	
Children	No history of water carriage	228	1			0.640
	Previous history of water carriage	11	NA			
	Currently carries water	139	0.89	0.55	1.44	

Table 4.5 Relative risk of pain location from personal history of water carriage (n = 997)

Pain location	Predictor variable	N[1]	RR[2]	Lower CI (95%)	Upper CI (95%)	P value
Abdominal pain	No history of water carriage	364	1			0.082
	Previous history of water carriage	159	1.43	0.76	2.69	
	Currently carries water	474	1.70	1.07	2.69	
Chest/rib pain	No history of water carriage	364	1			0.054
	Previous history of water carriage	159	1.60	0.71	3.60	
	Currently carries water	474	2.13	1.14	4.00	
Feet	No history of water carriage	364	1			0.394
	Previous history of water carriage	159	1.70	0.74	3.91	
	Currently carries water	474	1.55	0.77	3.13	
Hands	No history of water carriage	364	1			0.020
	Previous history of water carriage	159	3.62	1.34	9.75	
	Currently carries water	474	3.11	1.34	7.23	
Head	No history of water carriage	364	1			0.071
	Previous history of water carriage	159	1.16	0.67	2.02	
	Currently carries water	474	1.53	1.03	2.27	
Hips/ Pelvis /legs	No history of water carriage	364	1			0.373
	Previous history of water carriage	159	1.13	0.74	1.72	
	Currently carries water	474	0.85	0.61	1.20	
Lower back	No history of water carriage	364	1			0.828
	Previous history of water carriage	159	0.86	0.53	1.40	
	Currently carries water	474	0.96	0.68	1.38	
Neck	No history of water carriage	364	1			0.512
	Previous history of water carriage	159	1.26	0.74	2.16	
	Currently carries water	474	0.95	0.62	1.45	
Shoulders /arms	No history of water carriage	364	1			0.053
	Previous history of water carriage	159	0.91	0.52	1.60	
	Currently carries water	474	0.59	0.38	0.92	
Upper back	No history of water carriage	364	1			0.017
	Previous history of water carriage	159	2.27	1.17	4.40	
	Currently carries water	474	2.16	1.25	3.73	

[1]N = number; [2]RR = relative risk

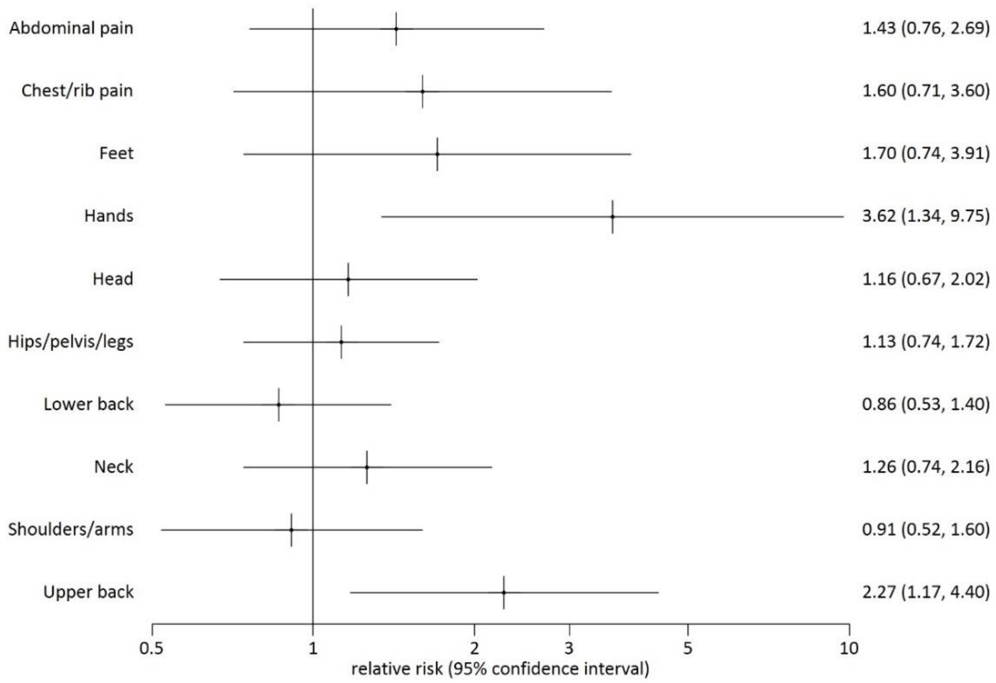

Figure 4.2 Sites of reported pain by past vs never water carrying

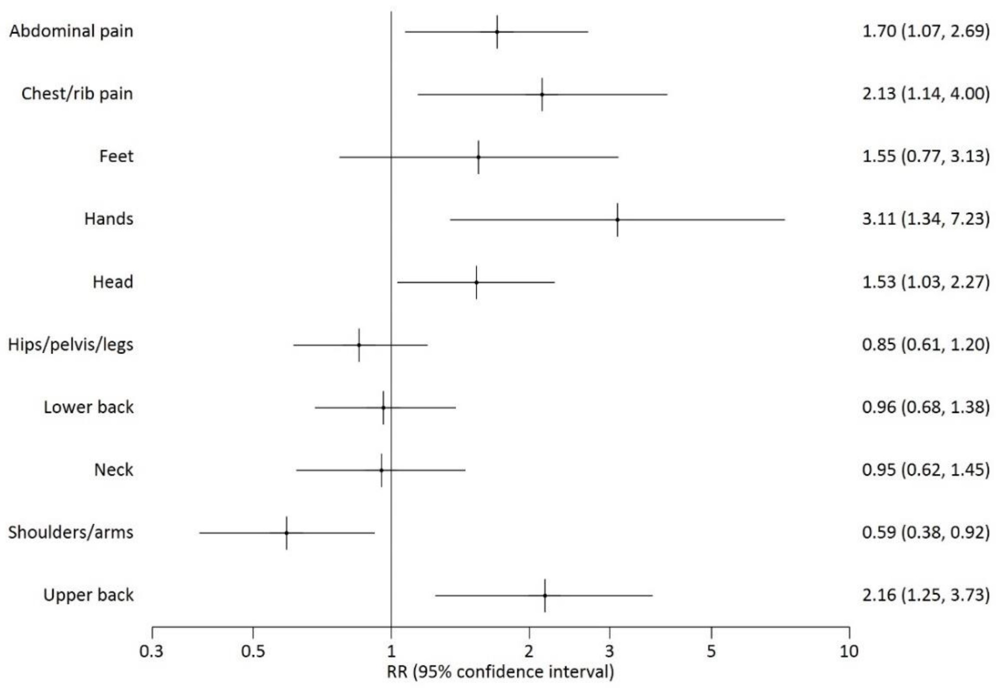

Figure 4.3 Sites of reported pain by current vs never water carrying

The factor analysis (Portney and Watkins, 2000) results (Table 4.6) indicated that two factors explained 54.8% of the variance in self-reported pain locations. Factor 1, labelled 'axial compression', is correlated with pain in the head and upper back, chest/ribs, hands, feet and abdomen/stomach. A person's 'Factor 1 score', indicating the extent to which their pain pattern is correlated with Factor 1, is associated with currently (β 0.30, 95% CI 0.17 to 0.43) or previously (β 0.21, 95% CI 0.01 to 0.42) carrying water (Table 4.7). Further analysis of people currently carrying water showed that Factor 1 score is significantly increased in people reporting head loading compared to those carrying by other means (Table 4.7). In an ordinal logistic regression analysis, adults with higher Factor 1 scores also tended to report shorter pain duration (Table 4.8).

Factor 1 was interpreted as representing pain related to the short term effects, or long term but intermittent effects of spinal or 'axial compression' loading, based on the association of Factor 1 score with water carriage, particularly by head loading, the pattern of correlated pain areas and existing evidence from spinal loading research. In the neck compression stress is created by the weight of the head, contraction of cervical spine muscles, and any additional load placed on the head (Panjabi et al., 1998, Jull et al., 2008). Axial loading creates compression stresses on the whole spine, but between the first and second cervical vertebra stress is transferred from anteriorly situated structures to more posterior structures and in the cervico-thoracic junction and thoracic region from posteriorly situated to more anteriorly situated structures (Pal and Routal, 1986). These regions may therefore be exposed to acute strain deformation when under high compressive loading, which could cause pain, or if prolonged over time, structural remodelling and adaptation as is seen in cervical spondylosis. Structures of the upper cervical spine commonly cause pain to be perceived at the back of the head and in the sub-occipital region; the lower cervical and upper thoracic spine structures commonly cause pain to be perceived in the upper back, chest and inter-scapula region, as well as in the hands; whilst the thoracic spine may refer pain to the ribs and abdominal region (Maitland, 1986, Fukui et al., 1996, Slipman et al., 2005), thus closely matching the areas of pain correlated with each other and Factor 1. Because either acute strain due to axial compressive loading during water carriage, or longer term changes in response to regular axial loading, such as cervical spondylosis, might plausibly increase risk of experiencing and therefore reporting pain in these areas, Factor 1 was labelled 'axial compression'.

Factor 2 is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs and a person's Factor 2 or 'soft tissue strain' factor score is marginally negatively associated with currently carrying water (-0.18, 95%CI -0.32 to -0.04) (Table 4.7). Factor 2 was interpreted as representing symptoms produced through a different biomechanical loading mechanism, such as translation or shear stress leading to ‘soft tissue strain’. The shoulder joint is very mobile and relies to a large extent on contraction of shoulder muscles to maintain joint stability and minimise translation stress during functional movements. Pain due to dysfunction of the shoulder joint is commonly experienced in the shoulder region or arm. The relatively mobile mid cervical region and lowest lumbar regions are also more likely to be subject to high shear stresses when stooping, lifting and carrying objects (Adams et al., 2002), with the mid cervical spine commonly causing perception of ‘neck’ pain and referring pain to the shoulders and arms, and the lower back commonly causing perception of ‘low back pain’ and referring pain to the pelvis, hips and legs (Fukui et al., 1996, Adams et al., 2002, Slipman et al., 2005). Spinal muscle contraction can increase compression loading, but at the same time stabilise the spine to reduce soft tissue strain due to shear forces (Adams et al., 2002). Therefore, in some people susceptible to pain due to shear stress affecting the shoulder, or mid cervical or lower lumbar spine, risk of pain in these areas may be slightly reduced by the protective effect of muscle contraction and enhanced muscle functioning maintained by water carriage, particularly if the effect of spinal compression does not aggravate pain sensitive structures. Therefore Factor 2 was labelled as ‘soft tissue strain’.

Table 4.6 Factor analysis of self-reported pain locations

Pain location	Factor 1: axial compression (correlation)	Factor 2: soft tissue strain (correlation)
Abdomen/stomach	.632	.131
Chest/ribs	.706	.151
Feet	.695	.221
Hands	.706	.266
Head	.616	.272
Hips/pelvis or legs	.179	.757
Lower back	.223	.750
Neck	.340	.697
Shoulders/arms	.238	.790
Upper back	.608	.347

Notes: Extraction Method: Principal components;
Rotation: Varimax with Kaiser Normalisation. Variance explained: *54.8* %

Table 4.7 Linear regression analysis of personal history of water carriage on Factor 1 (axial compression) and Factor 2 (soft tissue strain) (n = 997)

Factor correlated pain areas	Predictor variable	N[1]	β[2]	LCI[3] (95%)	UCI[4] (95%)	P value
Factor 1 'Axial compression'	No history of water carriage	364	0			0.000045
	Previous history of water carriage	159	0.21	0.01	0.42	
	Currently carries water	474	0.30	0.17	0.43	
	Currently carries water, no head loading	214	0			0.034
	Currently carries water, head loading	260	0.36	0.03	0.70	
Factor 2 'Soft tissue strain'	No history of water carriage	364	0			0.023
	Previous history of water carriage	159	-0.03	-0.25	0.19	
	Currently carries water	474	-0.18	-0.32	-0.04	
	Currently carries water, no head loading	214	0			0.64
	Currently carries water, head loading[5]	260	-0.07	-0.35	0.22	

[1]N = number; [2]β = regression parameter; [3]LCI = lower confidence interval; [4]UCI = upper confidence interval; [5]subgroup 'currently carries water – head loading' only contains participants from South Africa and Ghana, as no-one in Vietnam carried water by head loading.

Table 4.8 GEE Ordinal logistic regression of pain duration against Factor 1 (axial compression) and Factor 2 (soft tissue strain) with pain defined in three categories as <1 month, ≥1 month <3 months and ≥3 months (n=333)

Predictor	Odds Ratio[1]	LCI[2] (95%)	UCI[3] (95%)	P value
Factor 1 'Axial compression'	0.61	0.44	0.84	0.003
Factor 2 'Soft tissue strain'	1.30	0.59	2.86	0.521

[1]Odds of being in a longer pain duration category with each unit increase in factor score; [2]LCI = lower confidence interval; [2]UCI = upper confidence interval

Generalised estimating equations were also used to analyse the association of history of water carriage with pain severity, duration and consistency among adults who had experienced pain in the previous seven days. The number of children reporting pain experienced in the previous seven days was too small to have sufficient variation in the exposure variable (history of water carriage) and conduct similar analyses (Appendix 14, Tables S4.8 to S4.12). Adults who currently carried water were just over three times as likely to rate their pain as being in a more severe category, and those who previously carried water were 62% more likely to report their pain as being in a higher severity category, compared to people with no history of water carriage (Table 4.9). People who currently or previously carried water were likely to report pain of shorter duration, compared to people with no history of water carriage (Table 4.10) and there was no significant association between history of water carriage and pain consistency (Table 4.11).

Table 4.9 GEE Ordinal logistic regression of personal history of water carriage against adults' rating of pain severity (n = 298)

Pain severity[1]	Water carriage	N[2]	OR[3] (95% CI[4])	P value
Rating of pain severity (adults)	No history	64	1	0.001
	Previous history	71	1.62 (0.87, 3.02)	
	Currently carries	163	3.15 (1.70, 5.83)	

[1]pain severity categorised as 0 = mild, 1 = moderate, 2 = severe; [2]N = number; [3]OR = odds of respondent being in higher (worse or more severe pain) response category compared to average respondent with 'no history' of water carriage, adjusted for age and sex, accounting for clustering at household, village and country level; [4]95% confidence interval

Table 4.10 GEE Ordinal logistic regression of personal history of water carriage against adults' rating of pain duration (n = 329)

Pain duration[1]	Water carriage	N[2]	OR[3] (95% CI[4])	P value
Rating of pain duration (adults)	No history	85	1	<0.0001
	Previous history	78	0.35 (0.18, 0.68)	
	Currently carries	166	0.15 (0.08, 0.27)	

[1]pain duration categorised as 0 = less than one month, 1 = one month or more but less than 3 months, 2 = three months or more; [2]N = number; [3]OR = odds of being in longer pain duration category (higher) compared to respondent with 'no history' of water carriage, adjusted for age and sex, accounting for clustering at household, village and country; [4]95% confidence interval.

Table 4.11 Negative binomial regression of personal history of water carriage against adults' rating of pain consistency (n = 335)

Pain consistency	Water carriage	N[1]	RR[2] (95% CI[4])	P value
Rating of pain consistency (adults)	No history	86	1	0.186
	Previous history	80	1.15 (0.87, 1.53)	
	Currently carries	169	1.26 (0.98, 1.61)	

[1]pain consistency 0 = always present, 1 = comes and goes; [2]N = number; [3]RR = relative risk of being in higher category (pain comes and goes) adjusted for age and sex, and accounting for clustering at household, village and country level; [4]95% confidence interval.

4.3.3 Physical functioning and disability

The numbers of people, particularly children, reporting problems with functioning or disability were very small (Appendix 14, Table S4.13 to S4.17). In Vietnam, proportionately more adults with at-house supply reported problems using their legs (χ^2=8.8; p=0.01) or body (χ^2=8.8; p=0.01) which had lasted for more than a month or was permanent (Appendix 14, Table S4.14) compared to those with off-plot supply. There were no significant differences in disability related to walking or self-care comparing people with at-house to those with off-plot supply within or across countries (Appendix 14, Tables S4.15 and S4.16). Results of the generalised estimating equations using history of water carriage as the predictor variable, indicate that past or current water carriers, are more likely to be in a better body or limb functioning category than people with no history of water carriage (Tables 4.12 to 4.14). History of water carriage was not significantly associated with ability to walk (Table 4.15).

Table 4.12 Ordinal logistic regression of personal history of water carriage against difficulty using body, categorised as 0 = no difficulty, 1 = difficulty for less than 1 month, 2 = difficulty for more than one month or which is permanent (n = 597)

Functioning	Water carriage	N[1]	OR[2] (95% CI[3])	P value
Difficulty using body (adults)	No history	128	1	<0.0001
	Previous history	140	3.50 (2.07, 5.94)	
	Currently carries	329	2.62 (1.71, 4.01)	

[1]N = number; [2]OR = odds of respondent being in lower (better) response category compared to average respondent with no history of water carriage, adjusted for age and sex, accounting for clustering at household, village and country; [3]95% confidence interval.

Table 4.13 Ordinal logistic regression of personal history of water carriage against difficulty using legs, categorised as 0 = no difficulty, 1 = difficulty for less than 1 month, 2 = difficulty for more than one month or which is permanent (n = 600)

Functioning	Water carriage	N[1]	OR[2] (95% CI[3])	P value
Difficulty using legs (adults)	No history	129	1	<0.0001
	Previous history	141	2.92 (1.73, 4.93)	
	Currently carries	330	2.56 (1.68, 3.90)	

[1]N = number; [2]OR = odds of respondent being in lower (better) response category compared to average respondent with no history of water carriage, adjusted for age and sex, accounting for clustering at household, village and country; [3]95% confidence interval.

Table 4.14 Ordinal logistic regression of personal history of water carriage against difficulty using arms, categorised as 0 = no difficulty, 1 = difficulty for less than 1 month, 2 = difficulty for more than one month or which is permanent (n = 600)

Functioning	Water carriage	N[1]	OR[2] (95% CI[3])	P value
Difficulty using arms (adults)	No history	129	1	0.014
	Previous history	142	1.94 (1.12, 3.35)	
	Currently carries	329	1.89 (1.19, 2.98)	

[1]N = number; [2]OR = odds of respondent being in lower (better) response category compared to average respondent with no history of water carriage, adjusted for age and sex, accounting for clustering at household, village and country; [3]95% confidence interval.

Table 4.15 Ordinal logistic regression of personal history of water carriage against difficulty walking, categorised as 0 = no difficulty, 1 = some difficulty, 2 = a lot of difficulty, 3 = cannot do it at all (n = 605)

Disability	Water carriage	N[1]	OR[2] (95% CI[3])	P value
Difficulty walking (adults)	No history	129	1	0.137
	Previous history	144	1.44 (0.90, 2.31)	
	Currently carries	332	1.48 (0.99, 2.22)	

[1]N = number; [2]OR = odds of being in lower (better) category, adjusted for age and sex, accounting for clustering at household, village and country; [3]95% confidence interval.

4.4.4 General health

Most people in South Africa and Ghana rated their health as very good, good or moderate with no significant difference according to whether they had at-house or off-plot water supply (Appendix 14, Tables S4.19). In Vietnam, most adults rated their general health as moderate or bad (76.1%), none rated it as very good. A larger proportion of adults in Vietnam with off-plot supply rated their health as bad, and a smaller proportion as moderate, compared to those with at-house supply (χ^2=9.8; p=0.01) (Appendix 14, Table S4.19).

Interestingly, adults who previously carried water had a mean general health rating score 0.58 less (i.e. healthier) than adults who never carried water (β -0.58, 95%CI -0.80 to -0.35, p<0.001) and adults who currently carried water had a mean general health rating score 0.91 less (i.e. healthier) than adults who had never carried water (β -0.91, 95%CI -1.12 to -0.70, p<0.001) (Table 4.16). Children who currently carry water had a better mean score rating for general health than children who had never carried water (β -0.20, 95%CI -0.37 to -0.31, p=0.003). Children who previously carried water had a worse mean score rating for general health (β 0.39, 95% CI 0.02 to 0.75), however the number of children in this category was very small (n=10).

Table 4.16 Impact of personal history of water carriage on rating of general health

General Health	Predictor variable	N[1]	β[2]	LCI[3] (95%)	UCI[4] (95%)	P value
Rating of general health today (adults) n = 591	No history of water carriage	123	0			<0.000001
	Previous history of water carriage	143	-0.58	-0.80	-0.35	
	Currently carries water	325	-0.91	-1.12	-0.70	
Rating of general health today (children) n = 342	No history of water carriage	204	0			0.003
	Previous history of water carriage	10	0.39	0.02	0.75	
	Currently carries water	128	-0.20	-0.37	-0.31	

[1]N = number; [2]β = regression parameter; [3]LCI = lower confidence interval; [4]UCI = upper confidence interval

4.4 Discussion

Current and past history of water carriage was associated with location of self-reported pain and ratings of general health. Reported pain locations were correlated and factor analysis revealed that an increase in Factor 1 score, which has been interpreted as the effects of ‘axial compression’, was associated with current or past water carriage, whilst Factor 2 score, interpreted as ‘soft tissue strain’ was slightly negatively associated with current water carriage. The factor ‘axial compression’ was most strongly associated with water carriage by head loading. The findings highlight that the experience of pain needs to be qualified in some detail to discriminate between people with different exposures to water carriage and with potentially different underlying causal mechanisms for their pain. The risk of reporting pain anywhere in the body indicated by a yes/no response to the question ‘in the past week (seven days) have you had any physical pain?’ was not significantly associated with different water supply or history of water carriage, likely reflecting the fact that physical pain is a common phenomenon in the general population. However, risk of reporting pain in specific parts of the body was significantly associated with history of water carriage. This is consistent with approaches to the clinical assessment of pain, in which location of pain is used to inform a differential diagnosis (Magee, 2002), and clinical pain research, in which the importance of pain location and multiple sites of pain is recognised (Carnes et al., 2007). Researchers should ask people where they feel pain, in addition to whether or not they have had any pain.

There is biological plausibility in the increased relative risk of pain in specific locations of the body in people with a current or past history of water carriage, as well as the correlation of pain areas within each factor and the association of axial compression factor score with pain duration, water carriage history and head loading in particular. Sustained axial compressive loading through the cervical spine and upper back, as occurs with carrying water filled containers on the head, is a plausible mechanism by which intervertebral discs or vertebrae of the upper cervical spine and cervico-thoracic junction may be stressed. Pal and Routal (1986) described axial weight transmission through the cervical and thoracic spine and found that the second cervical vertebra and the cervico-thoracic junction anatomy indicate that load transference between the anterior and posterior columns of the spine occurs at these levels, increasing tissue stress to make them more susceptible to adverse effects such as bending or buckling deformity, which may in turn cause pain or tissue injury. Pal and Routal (1986) cite Taylor and Twomey (1984) to highlight that pubescent females have more slender spines and may be most vulnerable to adverse effects. Therefore, adverse effects due to axial loading stress could occur during water carriage by head loading and cause acute tissue stress or deformation to stimulate pain sensitive structures at specific spinal segmental levels, or occur gradually in response to repeated episodes of loading, leading to degenerative changes in the intervertebral disc and/or associated zygoapophyseal joints, known as cervical spondylosis (Joosab et al., 1994, Jumah and Nyame, 1994, Jäger et al., 1997, Panjabi et al., 1998, Echarri and Forriol, 2002). Through recognised pain referral mechanisms, such loading stress at specific segmental spinal levels could cause pain to be perceived in the head (for example, from cervical (C) spinal levels C0-1, C1-2 or C2-3), the upper back and chest region (from C5-6, C6-7 or C7-T1) or in the hands if symptoms manifest most noticeably in the distal part of a dermatomal distribution (from C6, C7, C8 spinal nerves or nerve roots) (Taylor, 2018). The pain from cervical degenerative disc disease tends to be associated with headache and inter-scapular (upper back) pain and may also cause irritation of spinal neural tissues located in the spinal canal or intervertebral foramen to produce symptoms anatomically remote from the site of irritation, such as pain in a dermatomal distribution in the hand (Fukui et al., 1996, Schellhas et al., 1996, Clark, 1997, Schellhas et al., 2000, Slipman et al., 2005). Alternative explanations for the correlation of symptoms in the upper back, head and hands include 'T4 syndrome' (Evans, 1997), 'double crush' syndrome (Mackinnon and Dellon, 1988), or injury in the hands occurring with similar frequency as upper cervical and upper thoracic pain, but due to separate pathology or injury mechanisms affecting each region of the body during water carriage.

Because the cervical spinal canal protects both the spinal cord and peripheral nerve roots descending to lower regions of the spine, cervical problems can potentially cause more widespread symptoms and neurological impact than problems in the lumbar spine. Particularly in Africa, regular head loading has been linked to cervical spondylosis (Jumah and Nyame, 1994, Joosab et al., 1994, Jäger et al., 1997, Adeloye, 1999, Echarri and Forriol, 2002, Belachew et al., 2007) and very heavy head loading to incidents of severe trauma and death (Levy, 1968). People with cervical spondylosis causing spinal canal stenosis have been shown to be more at risk of serious spinal cord injury and its severely disabling consequences after even minor, indirect trauma to the cervical spine (Regenbogen et al., 1986, Fujiyoshi et al., 2010, Yoo et al., 2010, Ackland et al., 2011, Fengbin et al., 2013).

This study is the first to find an association between water carriage and a pattern of correlated pain locations, which is interpreted here as most likely due to a specific spinal musculoskeletal disorder caused by axial loading. Musculoskeletal disorders are within the top ten causes of years lived with disability due to non-communicable diseases in developing countries (Hoy et al., 2014). Combined with fractures and soft tissue injuries they accounted for 20·8% of global years lived with disability in 2013, which would be even greater if years lived with disability due to sequelae of cervical disorders such as neurological impairment and headache were added (Vos et al., 2015). Because water carriage is a modifiable activity, this study highlights functional at-house water supply as an important potential mechanism to reduce the burden of years lived with disability due to serious musculoskeletal disorders affecting children and adults, particularly women due to the gendered role of water carriage, in developing countries. The findings also indicate that where people must continue to access their water from off-plot sources, enabling them to use alternative water carriage methods rather than head loading is a good first step. This could involve provision of affordable equipment, such as wheelbarrows, or improving access pathways to facilitate their use (Geere et al., 2010b, Robson et al., 2013, Geere, 2015).

The correlation of pain locations with factor 2 (soft tissue strain) are more typical of simple non-specific pain in the shoulder or neck and back which often produces somatic referred pain in the upper and lower limbs respectively. It may be due to the effects of soft tissue strain, for example strain generated by shear or translation stress, which can be reduced through better postural muscle control and functioning (Jull et al., 2008). Water carriage and regularly walking to an off-plot water source could develop and maintain a level of muscle function and endurance which is slightly protective of joint or soft tissue strain (Carroll et al., 2009, Heneweer et al., 2011, Heneweer et al., 2012). It is plausible that whilst some individuals may experience pain associated with detrimental effects of axial compression; others may in fact benefit from the protective effect of exercise and better muscle control minimising non-contractile soft tissue shear strain.

Differential effects may be influenced by differences in individual fitness or total work load; for some water carriage may represent a major fraction of activity, and for others a minor fraction. Alternatively, water carriage patterns may be affected by unreliable water supplies (Majuru et al., 2012), which could force women to collect as much water as possible when it is available, rather than pacing their work to avoid fatigue or pain due to tissue overload. Inability to pace water carriage work may increase physical loading of the spine and exacerbate pain perception through biopsychosocial mechanisms. For example, in a developed country setting, Davis et al., found that mental stress occurred as a function of time pressures on lifting task performance and significantly increased spine loading, particularly by increasing the compression load on the spine through increased muscle activation and performance of less controlled movements (Davis et al., 2002). Thus individual, task and environmental differences may lead to real differences in the experience of pain and therefore ability or willingness to fetch and carry sufficient quantities of water, exacerbating inequalities of water access between households (Hoy et al., 2014, Geere, 2015).

In all countries, proportionately more adults with off-plot supply, as compared to adults with at-house supply complained of pain lasting for less than a month. People with a higher axial compression factor score, and adults who currently or previously carried water, were more likely to report pain of shorter duration. The most common clinical pattern of simple musculoskeletal disorders, and degenerative disc disease or cervical spondylosis, is episodic exacerbation or 'flare up' of symptoms which may last for days or weeks, followed by periods of remission or stability (Clark, 1997). Pain persisting beyond three months is a complex phenomenon, likely to be associated with a variety of causes which were not investigated in this study. Whilst longer duration of pain may reflect severity of injury or tissue damage related to physical activity such as water carriage, chronic pain lasting for three months or more is more typically a feature of disordered pain perception as can occur with neuropathic pain, or if constant and persistent, may indicate serious pathology such as fracture, infection, systemic disease or cancer (Greene, 2001, Guzman et al., 2008). Individuals with long term pain related to serious health conditions may be less likely to be allocated the task of household water collection, or more likely to delegate the task to others, such as children, when it is possible to do so.

Among the sub-group of adults who had experienced pain in the previous seven days, water carriers were likely to report more severe pain than non-water carriers, with current water carriers just over three times more likely to be in a worse response category than non-water carriers. Experience of greater pain intensity in current water carriers could be induced by increased tissue loading or physical deformation during water carriage, with or without the exacerbating effect of psychosocial distress on pain perception (Davis et al., 2002, Bisung and Elliott, 2017). In both current and previous water carriers, increased pain severity may also be due to reduced tissue tolerance of loading, induced by gradual changes to anatomical structures associated with loading exposure over time, such as cervical spondylosis (Belachew et al., 2007). Furthermore, the systematic review reported in this thesis found that there is moderate quantitative and strong qualitative evidence that tiredness is associated with water carriage, which is known to be associated with pain (Reyes-Gibby et al., 2003). However, indicators of psychosocial distress or fatigue were not included in this study and it was not possible to provide clinical assessment or radiological investigation of study participants, which might have allowed more confident explanation of the observed differences in reported pain severity.

The better ratings of general health in those who previously or currently carry water may indicate some health benefits linked to increased physical activity. It could also indicate a greater sense of wellbeing linked to positive social interactions associated with water carriage. Results from a South African census also support the finding that the majority of the population in South Africa rate themselves as being in good health (Lehohla, 2012). However, this finding, together with the finding that water carriers are more likely to be in a better body or limb functioning category, may indicate that healthier and more physically able people tend to become the household water carriers. Not everyone in a household will be tasked with carrying water and generally, people with more severe disabilities or illness are less likely to carry water (Groce et al., 2011). Alternatively, in South Africa, the concept of 'good health' has been linked to the ability to perform water carriage (Geere et al., 2010b), an example of how cultural groups may define 'health' in terms of capacity to perform activities or to participate in society (Schatz and Gilbert, 2014). Such cultural differences in how health is conceptualised may to some extent influence self-rating of general health and functional ability amongst water carriers, and may also explain the greater proportion of adults rating their health as moderate or bad in Vietnam. Furthermore, the questions used in the survey to capture problems with functional use of the limbs or body, incorporated longer duration of problems to indicate worse dysfunction. Because pain associated with water carriage tended to be of a shorter duration, this response categorisation may have allowed pain duration to confound the association between 'better' function and water carriage. Questions about problems with functioning and disability specifically related to pain, but separate from any indication of problem duration, may have been more useful.

The findings of little difference in perceived health with on-plot or off-plot supplies in Ghana and South Africa, yet better health among water carriers past and present than non-carriers indicate that there is an association with the activity of water carriage, but not with the type of household water supply. This is likely due to the large number of people categorised as having at-house water supply, who actually had previously carried water, or still have to carry water because of interruptions to supply, as shown in Figure 4.1. The finding that water carriage is associated with pain location, and in a sub-group of water carriers with increased pain severity, yet more weakly associated with better rating of general health may seem contradictory. However, it is possible to perceive that one's general health, as a broader indicator of wellbeing or fitness, is good, but at the same time experience pain related to performance of specific activities. For example, trained athletes or people who engage with high levels of physical activity may perceive that they have good general health related to their level of physical fitness, but do commonly experience musculoskeletal pain related to the activities they participate in. Pain location or patterns of pain are frequently used to indicate the underlying pathology or type of disorder causing the pain, or the level of vertebral motion segment dysfunction and symptom production in spinal musculoskeletal disorders.

4.5 Limitations

The study did not include data about load carriage of materials other than water to reduce the size of the questionnaire and subsequent respondent burden, and to keep the focus on water access which was the primary aim of the research. However it is acknowledged that head loading of other materials, such as firewood (Echarri and Forriol, 2002, Lloyd et al., 2010b), could be a confounding factor affecting the results. In the multivariable analysis, clustering at country, village and household level was accounted for and this would have adjusted for the potential confounding effect of other activities associated with differences in geographic location, such as collecting fire wood, likely to be more similar within sites but different between the sites.

It was not possible to develop a culturally appropriate measure of wealth across the three study countries, because current assets based wealth indices were not considered valid for the study settings, and resources were not available to develop a new set of valid and reliable indices. Wealth may have therefore been a confounding factor affecting the study results, however the differences in wealth within the study communities did not appear to be substantial and would not be as extreme as those which occur within regions of each country, or between the countries. By including country in the multivariable analyses, adjustment was made at least in part for differences in wealth associated with residence in each country.

A further limitation of the study was that water quality was not included as a potential confounding factor in the analyses, as investigation of the association between water quality and source type, water storage practices or distance to water sources was not an aim of the thesis, nor part of the terms of reference for the broader DfID study in which this survey was nested (Evans et al, 2013). It was also considered unlikely that water quality would have any effect on health outcomes indicating musculoskeletal disorders, physical disability or functioning of the limbs. However, if poorer quality water was used in some households and was linked to conditions such as infectious diarhhoea, this may have affected the results for the outcomes of self-reported general health and self-reported pain, particularly in the abdominal region, and so could have been a confounding factor affecting the results. Additional funding to that provided by DfID was used in the broader study to undertake some water quality testing in a sub-sample of 20 households per country, piloting the 'Aquatest' method (Bristol, 2013, cited by Evans et al., 2013). The pilot study data indicated that water quality, as indicated by E. coli concentrations, was significantly better for those with improved water supply at home, than for those who obtained water from unimproved and/or off-plot sources (Evans et al., 2013). However, differences in water quality for stored water were not significant, and use of an at home water source, or fetching any water from out of home, were not significantly associated with relative risk of diarhhoea, skin disease or eye disease (Evans et al., 2013). In other settings, differences in water quality may cause health conditions such as diarhhoea, and as a consequence lead to differences in self-report ratings of general health and pain. Therefore, to minimize confounding, future studies of water carriage should include some assessment of household water quality using valid and reliable testing techniques.

Although a limitation of the study was the use of a main survey respondent to answer health questions for household members if they were not present, the main respondent was most often an adult female who would be likely to have more insight into the health and medical history of her family members and have personal experience of water carriage herself. The survey questionnaire was developed to collect information about household demographics, respondent's sources and uses of water, general activities and a range of health outcomes beyond those reported in this thesis. The questionnaire was necessarily long and time consuming to complete and capture all of this information, which meant that part of the survey (part IIb) was only administered to a sub-set of the study sample. The length of the survey may have also led to rushed or inaccurate interview responses and introduced response or classification bias. A more focused research question and survey instrument may provide more comprehensive and accurate information on water carriage and the health of water carriers.

Clinical assessment and/or radiological investigation of participants by a trained health professional would facilitate more informed interpretation of the likely underlying causes of self-reported pain. Cause and effect must be established from a range of evidence including that derived from studies involving clinical assessment, and longitudinal cohort studies which allow for exposure to be measured before the onset of a health condition. Such studies may reveal more complicated relationships between physical, psychological and social factors affecting health and associated with water fetching. Nevertheless, previous studies have reported correlation across populations between subjective symptom reporting and underlying radiological findings, and even in affluent countries, a diagnosis would usually be based more on reported symptoms without reliance on ancillary investigations (Clark, 1997, Binder, 2007). However, this study provides important evidence in support of the hypothesis that water carriage is significantly associated with the water carrier's experience of pain and their perception of their own general health. Further research investigating the relationship between water fetching and health, ideally to include clinical assessment of water carriers by trained health professionals in a longitudinal cohort study, is warranted.

4.6 Summary

This study has shown that people reporting a past or current history of water carriage were much more likely to report pain in locations typically associated with cervical compression syndromes. Cervical compression is associated with far more serious sequelae than back pain and can lead to serious long term disability in later life. Given that in 2015, 663 million people still used unimproved drinking water sources (WHO and UNICEF, 2017b) it is likely that the burden of musculoskeletal disease from water carriage is substantial. The findings support the ambition of the SDG target 6.1: 'universal and equitable access to safe and affordable drinking water for all' and indicate that to achieve the target, individual differences in the health outcomes associated with water carriage must be recognised and addressed. Where access to water is likely to remain off-plot, alternative methods to load carriage on the head should be supported. The findings also support the proposed shift to monitoring the percentage of the population using safely managed drinking water services at home as a key indicator.

Chapter 5. Conclusion

5.1 Research aim and specific hypotheses

The aim of this PhD thesis was to answer the research question ‘Is water carriage associated with the water carrier’s health?’ The findings support the overall hypothesis that the human work of water carriage is significantly associated with the health of water carriers. The results of the four specific hypotheses tested in relation to this question and which focussed on key domains of health are summarised below.

5.1.1 Hypothesis 1: Household water carriage is associated with increased risk of adverse maternal and child health consequences

Hypothesis 1 is supported by the results of analysis of 49 MICS conducted from 2009 to 2014 in 41 countries. Compared to households that do not collect water, water collection by any household member was associated with reduced likelihood of a woman giving birth in a health care facility; adults collecting water was associated with increased risk of child deaths; children collecting water with increased risk of childhood diarrhoea; adults or boys collecting water with slightly reduced WHO WAZ scores for children under five years of age; and women or girls collecting water was associated with reduced up-take of antenatal care and with increased risk of a child under five years of age being left alone for one hour or more, on one or more days of the week.

5.1.2 Hypothesis 2. Carrying water is associated with water carriers experiencing bodily pain

Hypothesis 2 is supported by the findings of the cross sectional survey in South Africa, Ghana and Vietnam. Compared to people who have never carried water, previous water carriers had increased risk of reporting upper back and hand pain, and current water carriers had increased risk of reporting pain in the head, upper back, ribs or chest, abdomen or stomach, and hands. Current water carriers had reduced risk of reporting shoulder or arm pain. Reported areas of pain were correlated, and previous and current water carriage was most strongly associated with a pattern of pain interpreted as indicating a spinal musculoskeletal disorder exacerbated by axial compression. Adult water carriers experiencing pain are likely to report more severe pain and pain of shorter duration than adults who have never carried water.

5.1.3 Hypothesis 3. Carrying water is associated with increased disability affecting the water carrier

Hypothesis 3 is not supported by the analysis of responses to questions on disability derived from the cross sectional survey conducted in South Africa, Ghana and Vietnam. No association between water carriage and ability to walk was observed, and water carriers were more likely to report a better category of limb and body functioning than people who have never carried water. However, categorisation of limb and body functioning may have been confounded by the association between water carriage and shorter pain duration. If the observed pain pattern which was associated with water carriage represents an underlying musculoskeletal disorder such as cervical spondylosis, water carriage may yet be found to be a major contributor to the burden of disability which develops over time from such disorders.

5.1.4 Hypothesis 4. Carrying water is associated with general health of the water carrier

The hypothesis is supported by the findings of the cross sectional survey in South Africa, Ghana and Vietnam. Adults who previously or currently carried water, and children who currently carried water were likely to report slightly better ratings of general health compared to adults and children who had never carried water.

5.2 Summary and interpretation of findings

The findings on maternal and child health from analysis of MICS data collected in 41 countries, and on pain from a cross sectional survey conducted in South Africa, Ghana and Vietnam are generally consistent with the key findings from other studies included in a systematic review of literature on the association between water carriage and health. The cross sectional survey findings on general health differ from the findings reported in some studies of the systematic review.

The analyses of MICS data indicate that being from a household whose members must fetch water is significantly associated with poorer maternal and child health indicators and outcomes, compared to people from non-water fetching households. Health outcomes vary depending on the age and sex of the water carrier. In comparison to non-water fetching households, the odds of a woman from a water fetching household giving birth in a health care facility is reduced and women or girls collecting water is associated with reduced uptake of antenatal care. Access to health facilities in the perinatal period is a key strategy for improving the health and wellbeing of mothers and very young children. When adults collect water there is an associated increase in risk of child deaths, and when women or girls collect water, the odds of leaving a child under five alone for an hour or more, on one or more days per week is also increased compared to when no-one collects water. These findings highlight that water carriage may reduce child safety, and is also a potential source of emotional distress for the water carriers if they must trade off caring for a young child against the essential chore of collecting water. When children are responsible for collecting water, there is an associated increased risk of diarrheal disease affecting a child under five years of age compared to non-water fetching households. Whilst children under five do not usually carry any substantial amounts of water, infectious diarrhoea affecting them may increase risk of diarrhoea being transmitted to other household members, including older siblings within the household who are engaged in water carriage. The results demonstrate that water access on premises is associated with significant improvements in indicators of maternal and child health and safety, and that who collects and carries the water home is important.

The cross sectional survey indicates that the relationship between water carriage and experience of pain is complex, with some pain locations and patterns more likely to occur with a history of past or current water carriage, and some slightly less likely to occur with current water carriage. The pain pattern most strongly and positively associated with water carriage is likely to represent an underlying disorder affecting the cervical spine. The interpretation of the data is informed by existing empirical knowledge about pain referral mechanisms from different levels of the cervical spine (Fukui et al., 1996, Schellhas et al., 2000, Slipman et al., 2005), biological effects of spinal loading particularly in the direction of axial compression (Pal and Routal, 1986, Davis et al., 2002), and the common causes and prevalence of pain and disability in low and middle income countries (Belachew et al., 2007, Hoy et al., 2014). Whilst the cross sectional survey did not collect data on fatigue or mental stress, the systematic review provides strong qualitative and moderate quantitative evidence that fatigue or tiredness is associated with water carriage. The systematic review found inconclusive evidence of a relationship between measured or self-reported stress and water carriage, however, it did reveal very plausible social and environmental mechanisms through which water carriage may lead to stress. Both fatigue and stress are associated with pain intensity (Reyes-Gibby et al., 2003), which may explain the finding that current and past water carriers are more likely to report pain of a higher intensity category than people who have never carried water.

The cross sectional survey results suggest that water carriers rate their health as better than people who don’t carry water, and are likely to rate themselves as being in a better category of limb and body functioning. This may indicate a selection process, whereby water carriage is allocated to the more able bodied family members, and less likely to be a task allocated to or taken up by people living with persistent or permanent physical problems. It may also represent a benefit due to the physical activity of water carriage, which is not a contradiction to the association of pain with water carriage. For example, athletes may achieve a high level of fitness and rate their general health as good, yet frequently experience pain and injury associated with their sporting activities. As an energetic task involving regular manual handling, water carriage may be allocated to the healthiest family members, or maintain fitness and therefore be associated with better personal ratings of general health, but at the same time be associated with the experience of pain during physical loading or due to injury mechanisms.

5.3 Policy implications

In 2015, 884 million people still lacked a basic level of drinking water service, defined as drinking water obtained from an improved source, with a round trip collection time of not more than 30 minutes (WHO and UNICEF, 2017b). Given that this excludes people collecting and carrying water for 30 minutes or less, the global number of people engaged in water carriage will be even higher, and it is likely that the global burden of disease associated with water carriage is substantial.

The existing evidence suggests that water carriage is an important barrier to achievement of many health targets set for SDG 3 which relate to health and wellbeing across the lifespan and perinatal health care. Because in most households of low and middle income countries it is women and girls who fetch water for household use, it will also affect SDGs related to education and reducing inequalities, particularly gender inequality. The systematic review revealed that water fetching if often problematic for individuals who are socially vulnerable, for example due to their age, sex or disability. This indicates that water carriage is also a potential barrier to ensuring safe and inclusive societies, decent work for all and reducing poverty in all its forms. Combined, the health and social problems associated with water carriage reduce the likelihood of achieving ‘universal and equitable’ access to drinking water as targeted in SDG6.1.

The findings of projects reported in this thesis support a shift to provision of water at home to reduce the number of people collecting water from off-plot sources. It therefore also supports the ambition of SDG target 6.1 and the proposed monitoring of the percentage of the population using safely managed drinking water services at home as a key indicator of progress. However, the findings also highlight that where water carriage must continue, the risk of negative health outcomes associated with water carriage could be reduced through a range of strategies. These could include, but need not be limited to;

- Encouraging men to help with water carriage through public health campaigns, particularly when women are pregnant and/or have young children, to reduce risk of the adverse maternal and child health outcomes which are associated with women and children fetching water
- Providing access to affordable equipment, such as wheelbarrows, so that people can choose alternative water carriage methods to head loading if it causes them pain
- Keeping paths and water point access areas in good condition and free of obstacles to enable easy use of wheelbarrows or other equipment, and to reduce the risk of injury due to slips and falls
- Improving reliability of water supply services, so that people can plan when to fetch water and pace their work, rather than collecting as much water as possible within a limited time of water availability
- Providing and maintaining a high number of shared water points throughout communities to reduce return water fetching trip distance and mitigate pain and fatigue
- Ensuring that water points are functional for extended periods of time during daylight hours, to reduce the need to collect water in the very early morning or at night, for safety and to reduce fatigue
- Locating water points in visible, open, public places, avoiding areas where people gather to drink alcohol, to reduce risk of gender based violence or abuse
- Promoting behaviours which enable *safe access* to safe drinking water for *all* in public health programmes aimed at reducing gender based violence or discrimination and creating safe and inclusive communities

5.4 Limitations of the thesis

Most of the quantitative data incorporated into this thesis is derived from cross sectional observational studies. Cross sectional studies are less able to provide clear evidence of a temporal relationship between water carriage and the health conditions associated with it than longitudinal cohort studies. Responses to cross sectional survey questions may indicate that exposure preceded the health condition or outcome, however, because the exposure and health outcome data is collected at the same time and is based on the participant's subjective report, recall bias may affect the results. A similar limitation applies to qualitative evidence included in the systematic review and derived from individual or group interviews. Furthermore, the two cohort studies included in the systematic review, reported only a limited amount of data that was disaggregated by exposure to water carriage.

A further limitation of the projects reported in this thesis is the use of self-reported health outcomes and indicators, without additional clinical assessment or medical investigation to provide a clinical diagnosis. However, the experience of pain is a subjective phenomenon which cannot be directly measured and can only be captured through self-report, and variables such as the number of children who have died are likely to be well remembered. Whilst the cross sectional survey and analysis of MICS data did not incorporate psychological factors potentially associated with water carriage, evidence derived from existing reports included in the systematic review was used to inform the interpretation of the results.

5.5 Indications of a causal relationship between water carriage and health

A temporal relationship revealed by longitudinal or experimental study design is only one factor to be considered in determining whether a cause and effect relationship between two variables is likely. Bradford Hill (1965) considered temporality together with nine other characteristics of association, indicating that it should not independently determine whether causality is likely. Other criteria to consider in judging whether exposure is likely to cause a health outcome include the strength of association; consistency (has the association been 'repeatedly observed, by different persons, in different places, circumstances and times?' (Bradford Hill, 1965p8); specificity; biological gradient or 'dose response'; plausibility; coherence; experiment; analogy; and reversibility. The data incorporated into this thesis satisfy a number of the Bradford Hill criteria as described below, suggesting that a causal relationship between water carriage and health is likely.

5.5.1 Strength of association

The cross sectional survey conducted in South Africa, Ghana and Vietnam, found that water carriage is strongly associated with pain in specific locations, for example water carriers were more than twice as likely to complain of upper back pain, and three times as likely to complain of hand pain (Table 4.5, Figures 4.2 & 4.3). Current water carriers were over three times as likely to report more severe pain compared to non-water carriers (Table 4.9). Analysis of MICS data indicated that whilst the risk or odd ratios for poorer maternal and child health outcomes which are associated with water carriage are not large, the estimates are independent of and often similar in magnitude to other key risk factors. Whilst the increase in risk of childhood death associated with adults collecting water is not as large as that associated with being in the higher three wealth quintiles (Table 3.2), in countries where the mortality rate of children under five years of age is high, a 5% increase in risk independently associated with a modifiable risk factor is potentially important. For example the data set includes two surveys from Somalia conducted in 2011, when the mortality rate of children under five for the whole country was reported to be 153.5 deaths/1000 live births or 15.4%. Similarly, settings where the number of children affected by diarhhoea is high, a 10-13% increase risk (Table 3.2) is substantial and important, because childhood diarrhoea may have important short and long term consequences.

5.5.2 Consistency

Findings of the cross sectional survey (Chapter 4) are derived from data collected in three different countries, and the MICS data (Chapter 3) is collected from 41 countries across a five year time span. The systematic review (Chapter 2) demonstrates that the key findings from both of these projects, that water carriage is associated with pain experienced by water carriers and poorer maternal and child health indicators, are generally supported by a number of studies conducted by other researchers, in many different countries and at different times.

5.5.3 Specificity

Whilst specificity is not apparent, it is logical that the activity of water carriage may have many and variable consequences for health, and that those consequences may also be caused by other exposures or confounding factors. To mitigate this, multivariable analysis was used to account for the effects of key confounding factors and clustering within study samples. Therefore this thesis reports an estimate of the independent association between water carriage and the health outcomes which were investigated.

5.5.4 Biological gradient

It was not possible to collect reliable and comparable data related to the magnitude and frequency of physical loading performed over time by current and past water carriers in the cross sectional study conducted in Ghana, South Africa and Vietnam. Researchers using a longitudinal cohort study to gather observational and physical measurement methods for all study participants over time, would be better able to quantify the work of water carriage and investigate whether health outcomes are associated with the 'dose' of water carriage work. However, through the use of history of water carriage (none, previous or current) as a predictor variable, the cross sectional survey was able to demonstrate a biological gradient to some extent. Compared to people who never carried water, previous history of water carriage was associated with increased axial compression score (β 0.21), which was more strongly associated with current water carriage (β 0.30), and more strongly associated with water carriage by head loading than other means (β 0.36) (Table 4.7).

5.5.5 Plausibility

There are plausible biological, psychological and social mechanisms by which water carriage as an activity could lead to the observed health outcomes, as explained in more detail in the discussion sections of chapters 2, 3 and 4. For example, it is plausible that pain could be caused by water carriage, because pain is a known consequence of adverse physical loading or injury of the musculoskeletal system (Magee, 2002), and the musculoskeletal system sustains considerable weight and therefore loading forces during water carriage (Geere et al., 2010a). Water carriers report experiences of pain occurring *during* water carriage in many studies (Geere et al., 2018b), which indicates that the association between water carriage and pain reported in Chapter 4 is likely to be real, and further supports a causal mechanism.

5.5.6 Experiment

It was not possible to collect data as part of an experimental design. However, the findings of the cross sectional survey reported in Chapter 4, that headache and upper back pain, common symptoms indicative of a cervical or upper thoracic spinal disorder, are associated with water carriage, are consistent with the findings of experimental studies investigating mechanisms of referred pain (Schellhas et al., 1996; Schellhas et al, 2000; Slipman et al, 2005), and an experimental study (Lloyd et al 2010b) reporting the subjective perceptions of load carriage on the head and back in Xhosa women.

5.5.7 Analogy

Analogies can be drawn between the findings of the cross sectional survey reported in Chapter 4 and studies conducted by other researchers in occupational health (Kilbom et al., 1996), but particularly with research into the effects of carrying water and other loads as domestic or paid porterage work in sub-Saharan Africa (Porter et al., 2012; Porter et al., 2013). In their review and a mixed methods study conducted in Ghana, Malawi and South Africa, Porter et. al., (2012; 2013) found that children and adults experienced pain, fatigue and stress during carriage of water, wood, refuse, farm goods and grain by head loading or other manual methods. Other studies of porterage work have reported increased prevalence of cervical spondylosis and incidents of spinal injury among people who regularly carry heavy loads by head loading (Joosab et al., 1994, Jäger et al., 1997, Jumah and Nyame, 1994, Levy, 1968).

5.5.8 Reversibility

The studies reported in Chapter 3 and 4 of this thesis cannot demonstrate reversibility, because with the use of cross sectional survey data, it is not possible to experimentally stop symptomatic people from carrying water, and re-assess whether their symptoms disappear and health status or outcomes improve. Furthermore, it is possible that a sustained period of water carriage may lead to long term consequences which are not reversible and may cause persistent symptoms, such as cervical spondylosis. Similarly, reversibility of the maternal and child health outcomes reported in Chapter 3 would be difficult to demonstrate experimentally at the level of the individual. However, use of a longitudinal design as described in 5.5.4 could monitor whether any reversible health outcomes changed in individuals once they no longer carried water.

5.6 Recommendations for further research

The research reported in this thesis provides evidence in support of a shift to provision of water supply services at home where possible, because of the adverse health outcomes associated with water carriage from off-plot sources. Where interventions to supply water in people’s homes or on their premises are planned, research to evaluate the health of household members is warranted to more fully capture the benefits of reliable at-house water supply which eliminates the need for water carriage. This could be investigated with before and after studies, to evaluate whether people experience reduced pain as a result of the intervention (WSUP and SHARE, 2011), however, monitoring the efficacy of the intervention to relieve household members from the work of water carriage would be necessary for valid analysis. Alternatively, research could be done with a longitudinal cohort study, to establish whether changes in exposure to water carriage occur before changes in health indicators such as self-reported pain (Bonita et al., 2006).

In either type of study evaluation of household health should include maternal and child health indicators, including access to perinatal health services, child deaths, childhood diarrhoea, and whether young children are left alone for periods of time, to confirm whether the intervention alters the maternal and child health indicators which were observed to be associated with water carriage in this study. A clinical assessment, ideally performed by a trained health professional, should be used to evaluate pain location, severity, duration and its impact on the individual's movement, functioning and participation to gain more insight into the most likely causes of self-reported symptoms. Whilst general disability and self-reported problems with function of the limbs and body were evaluated in the cross sectional survey, the use of outcome measures designed to specifically capture pain related disability would be more appropriate. Better understanding of the prevalence, underlying cause and impact of health related symptoms and behaviours, could be used to identify and prioritise individuals or communities in urgent need of better access to drinking water based on their health status.

In the cross sectional survey, at-house water supply did not remove the need for people to carry water, indicating that in any intervention studies, monitoring the reliability and functionality of household water supply systems is important. Efficient ways to monitor, maintain and repair water services and supply systems over time are needed. Monitoring systems could also facilitate community participation in water supply management and provide enhanced communication between service users and service providers to improve services, and to reduce the need for water carriage during periods of water supply disruption. For example, a mobile phone app designed to gather water access and health data to improve communication between services users and providers has already been piloted in the South African study community (Geere et al., 2016).

Where the shift to household water supply is not possible, studies evaluating interventions or public health programmes to promote behaviour change for improved water access relevant to the local context should be conducted. Behaviour change interventions such as encouraging men to collect water, reducing gender based violence at shared water points and providing or expanding childcare support networks when women must collect water away from home, are warranted. The effectiveness of improving the safety of water point access pathways and/or provision of affordable equipment such as wheelbarrows as an alternative to head loading should also be investigated. Evaluation of whether such programmes improve maternal and child health outcomes and reduce pain experienced by water carriers is needed.

The cross sectional survey did not find an association between general disability and water carriage. However, this may have been due to the outcome measures used to capture functioning and disability. If the pain pattern found to be associated with water carriage in this study is due to an underlying musculoskeletal disorder, there may be long term and rare, but severely disabling sequelae, such as myelopathy related to cervical spondylosis. Such sequelae may therefore be better identified in longitudinal cohort studies incorporating a clinical assessment of pain related disability, rather than in a cross sectional survey.

5.7 Summary

For many people, water carriage is a regular chore which is essential for life. However, evidence derived from a systematic review, analysis of MICS data and a cross sectional survey mainly indicates that water carriage is associated with a range of negative health outcomes. This supports the view that water carriage is detrimental to the water carrier's health and as a consequence at the population level, is detrimental to public health. Overall the data support a conclusion that action should be taken now to reduce the need for water carriage, and to increase the number of people who can access water for household use in their own home or yard.

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Appendices

Appendix 1. Published paper

GEERE, J. L., CORTOBIUS, M., GEERE, J. H., HAMMER, C. C. & HUNTER, P. R. 2018. Is water carriage associated with the water carrier's health? A systematic review of quantitative and qualitative evidence. BMJ Global Health, 3 (3) available at https://gh.bmj.com/content/3/3/e000764 [accessed 19/03/19]

BMJ Global Health

Is water carriage associated with the water carrier's health? A systematic review of quantitative and qualitative evidence

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ABSTRACT

Introduction The work of carrying water falls mainly on women and children, particularly in sub-Saharan Africa and rural areas. While concerns have been raised, how water carriage is associated with health of the water carrier is not clear. The aim of this review is to summarise evidence on whether, and how, water carriage is associated with the water carrier's health.

Methods A systematic review of literature was conducted, searching Embase; Medline; Web of Science Social Sciences Citation Index; Web of Science Arts and Humanities Citation Index; International Initiative for Impact Evaluation website; WHO Virtual Health Sciences Library and WHO African index medicus, from inception to 8 November 2017.

Results Forty-two studies were included. Their ability to demonstrate cause and effect relationships was limited by study design and fair or poor methodological quality. Overall, the studies suggest that water carriage is associated with negative aspects of the water carriers' health. There is moderate quantitative and strong qualitative evidence that water carriage is associated with pain, fatigue, perinatal health problems and violence against vulnerable people, and inconclusive evidence of an association with stress or self-reported mental health and general health status.

Conclusion In many circumstances, water carriage is a potential barrier to Sustainable Development Goal (SDG) 6 target 'universal and equitable access to safe and affordable drinking water for all' and SDG 3 'ensure healthy lives and promote well-being for all at all ages'. Efforts should focus on providing water on premises, and where this is not possible, providing water close to home and reducing risk of gender-based violence.

Key questions

What is already known?

- Water carriage work falls mainly on women and children, particularly in sub-Saharan Africa and rural areas.
- Water is often carried in addition to other loads, and it may not be the heaviest or key porterage task leading to health issues.

What are the new findings?

- Moderate quantitative and strong qualitative evidence indicates that water carriage is associated with pain, fatigue, perinatal health problems and violence against vulnerable people, while the evidence that water carriage is associated with stress and general health is inconclusive.

What do the new findings imply?

- Efforts to improve access to safe drinking water should focus on achieving 'safely managed' water on premises.
- Where water fetching must continue, strategies to reduce risk of harm should focus on providing water close to home and reducing risk of gender-based violence.

INTRODUCTION

Historically, the focus of water and health research has been on management of water quality and risk or prevalence of infectious disease. However, health is defined more broadly as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'.[1] More recently, interest in the work of carrying water from sources located away from the home, or 'off-plot', has been raised by WHO, Unicef[2 3] and the International Labour Organisation.[4] Understanding how water carriage is associated with health is relevant to the United Nations Sustainable Development Goal (SDG) 6, target 1 'universal and equitable access to safe and affordable drinking water for all',[5] and SDG 3, which aims to ensure 'healthy lives and promote well-being for all at all ages'.[6] Adverse health impacts of water carriage are likely to have implications for SDGs 1 (end poverty in all its forms), 4 (quality education), 5 (gender equality), 8 (decent work and economic growth), 10 (reduced inequalities) and 16 (promote peaceful and

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inclusive societies).[7] They would also make water access inequitable for those obtaining water off-plot compared with people with safe water piped into their homes, and directly create inequity in relation to SDG 3.

Previous research has demonstrated an association between distance or time to water source and health of children in the home, as indicated by diarrhoeal disease, and child anthropometrics and mortality.[8–10] Stelmach and Clasen[11] reviewed the association between water quantity and health. In low-income countries, incidence of trachoma and gastrointestinal-related disease improved with increased quantity of water in the home, and in high-income countries, higher levels of water consumption were associated with renal and bladder cancer, but not type II diabetes. What is absent from these studies of distance to water source and increased household water quantity, is investigation of how these factors affect the health of the person who brings water into the home. It is clear that women and children most commonly collect and carry water home for household use,[3 12 13] often by carrying 20–25 L containers on their head[14] or by other methods such as loading a number of containers into a wheelbarrow.[15 16] While concerns have been raised, what remains unclear, is how the work of water carriage is associated with the health of the water carrier. With more attention focused on this issue in recent years, a review of the published literature to summarise what is currently known and identify gaps in the existing knowledge base is timely. Therefore, a systematic review of published literature was conducted with the aim of answering the review question: 'Is the work of water carriage associated with the health of individuals who fetch and carry water for household use?'

METHODS

A systematic review of literature was undertaken to identify research investigating the relationship between water carriage and health.

Search strategy and selection criteria

A search of electronic databases was conducted from inception to 8 November 2017 by one reviewer (JLG). Seven electronic databases were accessed: Embase; Medline; Web of Science Social Sciences Citation Index selecting public, occupational and environmental health themes; Web of Science Arts and Humanities Citation Index; grey literature databases provided by the International Initiative for Impact Evaluation (http://www.3ieimpact.org/), the WHO Virtual Health Sciences Library (www.emro.who.int/information-resources/vhsl/) and the WHO African index medicus. Experts in the field of water access and health were also contacted to identify relevant literature and reference lists of included papers were checked for relevant papers.

One researcher (JLG) independently exported titles and abstracts of all retrieved citations into endnote (X7) and removed duplicates. Retrieved titles and abstracts were evaluated against predefined inclusion criteria by two reviewers (JLG and PRH). Studies were included in the review if they reported quantitatively measured variables or qualitative reports related to the work of fetching water from an off-plot or out of home source and carrying it back home *and* included some measurement or qualitative appraisal of the health of the person who performed the water carriage work. Studies were excluded if they did not present any quantitative or qualitative analysis of the relationship between water carriage and health of people who perform water carriage work.

Inclusion criteria

- Quantitative research reporting the relationship between variables related to the physical work of carrying filled water containers *and* variables related to the health of the water carrier.
- Qualitative research where people who carry water report the effect of water carriage on their own health or the health of others who carry water.
- Studies reported in English, French, Spanish, Portuguese, Swedish or Turkish.

Exclusion criteria

- Studies reporting health only of children aged 5 or less, because children of this age are much less likely to carry significant water for household use.
- Studies reporting variables related to water access and water carrying, but not reporting health of the water carrier other than prevalence or indicators of infectious or vectorborne diseases.
- Article with a topic focus on sanitation, hygiene, water source type and water source or household water contamination or treatment, without data on the work of water carriage and health of water carriers.
- Article with information on 'water insecurity' and health, without any data about the association between physically carrying water containers (as an aspect of water security) and health, disaggregated from other aspects of water insecurity (such as limited water quantity or quality).

Advanced searches were conducted using key terms combined with boolean operators to maximise search sensitivity. Terms were also mapped to medical subject headings (MeSH) in Medline and Embase. Truncation terms and searches in all fields '.af' were used to maximise search sensitivity in each database where possible (online supplementary appendix 1).

Data analysis

Summary measures, statistics and qualitative themes reported in the studies were diverse, and findings are presented as reported in each study. Where studies separately presented analyses of multiple risk factors or independent variables, and multiple outcomes or dependent variables, only findings which reported the relationship between variables related to the work of water carriage and health outcomes of the water carrier were extracted.

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No studies were excluded on the basis of methodological quality, which was appraised independently by two reviewers: JLG and CH for qualitative aspects of studies, and JLG and JHG for quantitative aspects of studies. Where differences in quality scores could not be agreed, a third reviewer (PRH) was consulted to achieve consensus. The US Department of Health and Human Services, National Institutes of Health (NIH) Quality Assessment tool for observational cohort and cross-sectional studies[17] was used for 26 studies which reported quantitative data, and the Critical Appraisal Skills Programme (CASP) tool[18] was used for 21 studies which were qualitative or of mixed methods and reporting a qualitative component to the study.

Meta-analysis was planned. However, the studies included in the review were too heterogeneous to perform a meta-analysis, because of differences in the characteristics of study samples, and exposure variables or outcomes measured, therefore a narrative synthesis was completed. A wide variety of systems to grade the strength of evidence gathered in systematic reviews have been reported, however most place emphasis on a hierarchy of research design considered most robust for determining the effectiveness of a clinical intervention.[19] We therefore used a system reported by Hoogendoorn *et al*,[20] to rate the strength of evidence from observational cohort and case-referent studies, considering study quality, number and consistency of findings. We modified the approach by Hoogendoorn *et al* by applying it to the synthesis of cross-sectional and qualitative studies, and incorporating the NIH and CASP ratings of study quality, because we aimed to identify whether water carriage is associated with reported health problems, even if it were not possible to establish a cause and effect relationship. There was no funding source for this study.

RESULTS

Nineteen thousand, seven hundred and fifty-eight titles were retrieved through the electronic database searches (figure 1). Once duplicates were removed, 12 131 articles remained for further screening of abstracts and titles against the inclusion and exclusion criteria. Of these, 11 789 articles were excluded (305 remained), because the title and abstract clearly indicated that the content was irrelevant to the purpose of this review; or because health outcomes were reported only for children aged 5 years or less or for cases of infectious disease; or they reported only sanitation and hygiene practices or household water supply type without information about water source location (ie, does not indicate need for water fetching work). A further 37 papers were flagged electronically while retrieving full-text papers from the databases, identified in reference lists of retrieved papers or obtained from contacting water, sanitation and hygiene (WASH) experts.

In total, the full text of 342 articles was obtained for review against the inclusion and exclusion criteria. Of these, 300 were excluded because they did not include data on either the work of water fetching or health of water carriers or both. Articles which focused on the health impact of physical contact with water at the point of collection, for example, reporting prevalence of schistosomiasis infection and observed or reported water contact time during water fetching activities, were also excluded because such studies do not provide information on the association between health and the work of carrying water containers home. In total, 42 articles were included in the review, which reported associations with the health of water carriers and the work of water carriage.

Twenty-six studies collected quantitative data.[14 21–45] The overall methodological quality of the studies, in terms of their capacity to demonstrate a cause and effect relationship between the work of water carriage and health was rated as fair (6 studies) or poor (19 studies), only one was rated as good (table 1). The key reasons for low-quality ratings were the use of cross-sectional study design, lack of evidence to support the reliability and validity of exposure or outcome measures, lack of outcome assessor blinding and failure to include confounding factors in analyses.

Twenty-one studies reported qualitative data[23 26 31 32 34 35 44 46–59] (table 2). While almost all seemed to have appropriately chosen a qualitative research design to meet their aims and provided a clear statement of research findings, there was often insufficient information reported to determine whether recruitment, data collection and analysis were appropriate and sufficiently rigorous. The influence of the researcher and ethical issues were also not clearly reported in most of the studies. We rated studies as 'good' if six or more of the appraisal criteria scored a 'yes' response, fair if four or five criteria had yes responses and poor if three or fewer had yes responses. The scoring process resulted in 12 of the studies being rated as of good quality, 5 of fair quality and 4 rated as poor quality.

The articles reported health and social outcomes including bodily pain, energy expenditure or fatigue, stress or mental well-being, perinatal health and access to healthcare services, lack of safety or discrimination related to social vulnerability and general health status. The studies reporting social outcomes of safety and discrimination were included because of the clear and likely direct impact of the reported social factors on the water carrier's physical or psychological health. The reported health outcomes are grouped for comparison under key themes: bodily pain, energy expenditure and fatigue, stress and mental well-being, perinatal health, social vulnerability and general health.

There is moderate evidence from quantitative data and strong evidence from qualitative data of an association between water carriage and self-reported pain or injury (tables 3 and 4). Sixteen reports of 15 studies[14 26 28 29 31–33 39 43 46 47 52–54 58 59] included people within their study samples whose experience of water

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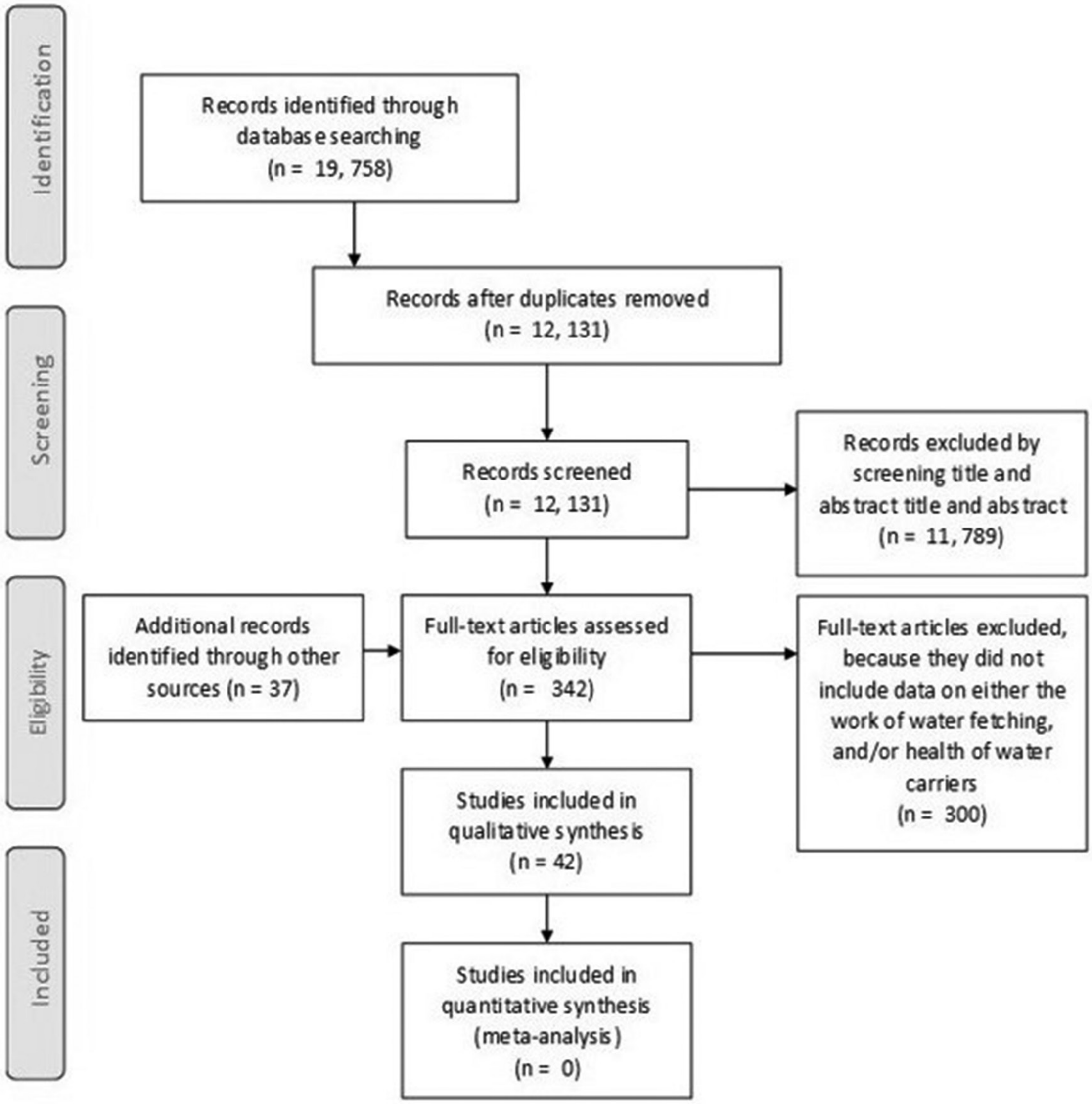

Figure 1 Study selection (Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2009).

carriage was associated qualitatively, or through quantitative analysis, with pain, injury or risk of injury (table 5). The significantly reduced distance walked and time spent for water fetching among head-loading water carriers who reported pain, compared with those who did not report pain, was interpreted by Geere *et al*,[14] as an indication of pain-related disability. They suggested that people who experienced pain during water fetching may reduce the length of time they are exposed to the loading force, while those without pain or with lower levels of pain may be able to collect water from greater distances. Although their study was limited by a small sample size, their findings are supported by the studies including qualitative data derived from people who collect water. They are also supported by the findings of Rauniyar *et al*,[29] who attributed a significant 5% reduction in the 'drudgery' of water fetching among the lowest socioeconomic group to water supply projects, and the findings of Porter *et al*,[60] who found high proportions of children reporting pain as a direct result of load-carrying, which particularly for girls, included water carriage by head loading. However, as highlighted by Porter *et al*,[60 61] individuals in low-income and middle-income countries carry diverse loads, and water may not be the heaviest load carried. Because none of the studies took this into account in their analyses, the effects of manual labour in addition to water carriage may confound the apparent associations between water carriage and pain.

In a recent study, Geere *et al*[43] did not find an association between pain in the previous 7 days and history of water carriage, but did find that among people reporting pain, the area of the body in which pain was experienced was associated with a history of water carriage. Ten studies[14 26 28 29 31–33 43 53 58] included some indication of the areas of the body in which water carriers experienced pain, with back and neck pain commonly reported. Geere *et al*[43] found that participants reported multiple areas of pain, and that pain areas were correlated. Principal component analysis explained 55% of the variance in pain locations and extracted two factors correlated

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Table 1 Quality appraisal cohort studies (National Institutes of Health critical appraisal tool)

First author and date (listed in chronological, then alphabetical order)	Was the research question or objective in this paper clearly stated?	Was the study population clearly specified and defined?	Was the participation rate of eligible persons at least 50%?	Were all the subjects selected or recruited from the same or similar populations?	Was a sample size justification, power description or variance and effect estimates provided?	For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?	Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?	For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome?	Were exposure measures (independent variables) clearly defined, valid, reliable and implemented consistently across all study participants?	Was the exposure(s) assessed more than once over time?	Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?	Were the outcome assessors blinded to the exposure status of participants?	Was loss to follow-up after baseline 20% or less?	Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?	Overall rating of study quality for determining cause and effect relationship
Buor 2004[21]	Y	Y	N	N	N	N	N	Y	N	NA	N	NR	NA	N	Poor
McCray 2004[22]	N	Y	N	Y	N	N	Y	Y	CD	N	N	N	NA	Y	Fair
Foggin 2006[23]	Y	Y	N	N	N	N	N	N	Y	NA	N	N	NA	N	Poor
Gibson 2006[24]	Y	Y	NR	N	N	Y	Y	N	Y	N	Y	NR	NR	N	Fair
Rao, 2006[25]	Y	Y	N	CD	N	N	N	Y	N	NA	N	N	NA	N	Poor
Hemson 2007[26]	N	Y	CD	CD	N	N	N	Y	N	NA	N	N	NA	N	Poor
BeLue 2008[27]	Y	Y	CD	Y	N	N	Y	Y	N	NA	CD	CD	NA	N	Poor
Borah 2010[28]	N	Y	NR	Y	N	N	N	N	N	N	N	N	NA	N	Poor
Geere 2010[46]	Y	Y	N	Y	N	N	N	Y	Y	NA	N	N	NA	N	Poor
Rauniyar 2011[29]	Y	Y	N	Y	N	N	N	N	N	N	N	CD	NA	Y	Poor
Devoto 2012[30]	N	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Good
Singh 2012[33]	Y	Y	CD	N	N	N	N	N	N	NA	N	CD	NA	N	Poor
Stevenson 2012[34]	Y	Y	NR	Y	N	N	N	N	N	N	N	NR	NR	Y	Poor
Yallew, 2012[35]	Y	Y	N	Y	N	N	N	Y	Y	NA	N	N	NA	N	Poor
Asaba 2013[31]	N	Y	N	Y	N	N	N	N	N	N	N	N	NA	N	Poor
Robson 2013[32]	Y	Y	CD	N	Y	N	N	Y	Y	NA	N	N	NA	N	Poor
Henley 2014[36]	Y	Y	N	N	N	N	N	N	N	NA	Y	NR	NA	Y	Fair
Mugambe 2014[37]	Y	Y	N	Y	Y	N	N	Y	N	NA	N	N	NA	Y	Fair
Ono 2014[38]	y	y	CD	y	N	N	N	Y	N	NA	Y	N	NA	Y	Fair
Berrian 2016[39]	Y	Y	Y	Y	Y	N	N	Y	N	NA	N	NR	NA	N	Poor
Cook 2016[40]	Y	Y	CD	Y	N	N	N	Y	CD	NA	N	CD	NA	N	Poor
Hennegan 2016[45]	Y	Y	N	Y	N	N	Y	NA	Y	Y	N	N	Y	N	Poor
Krumdieck 2016[41]	Y	Y	Y	Y	N	N	N	N	N	NA	N	NR	NA	N	Poor
Dapaah 2017[42]	Y	Y	N	Y	N	N	N	N	N	NA	N	N	NA	N	Poor
Geere 2018[43]	Y	Y	Y	N	Y	N	CD	Y	N	NA	Y	Y	NA	Y	Fair
Thomas 2018[44]	Y	Y	N	Y	N	N	N	Y	N	N	N	N	NA	Y	Poor

CD, cannot determine; N, no; NA, not applicable; NR, not reported; Y, yes.

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Table 2 Quality appraisal studies reporting qualitative data (CASP tool)

First author and date (listed in chronological, then alphabetical order)	Was there a clear statement of aims?	Is a qualitative method appropriate?	Research design appropriate to research aims?	Recruitment strategy appropriate to research aims?	Data collected to address research issue?	Relationship between researcher and participants considered?	Have ethical issues been considered?	Was the data analysis sufficiently rigorous?	Clear statement of findings?	Quality rating: Poor≤3 Fair=4–5 Good≥6
Foggin 2006[23]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Cannot tell	Cannot tell	No	Fair
Hemson 2007[26]	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Yes	Fair
Geere 2010 and [46]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Yes	Good
Domènech 2012[47]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Cannot tell	Cannot tell	Yes	Fair
Stevenson 2012[34]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Yallew, 2012[35]	Yes	Yes	Yes	Cannot tell	Yes	Cannot tell	Yes	Cannot tell	Yes	Good
Asaba 2013[31]	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	No	Cannot tell	No	Fair
Robson 2013[32]	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell	No	Cannot tell	Yes	Poor
House 2014[48]	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Yes	Poor
Isoke 2014[49]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Yes	Good
Mukhulani 2014[50]	Yes	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Cannot tell	Yes	Fair
Schatz 2014[51]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Yes	Yes	Good
Bisung 2015[52]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Sarkar 2015[53]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Good
Subbaraman 2015[54]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Good
Ghosh 2016[55]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Yes	Good
Mbereko 2016[56]	No	Yes	Cannot tell	Yes	Yes	Yes	Cannot tell	Yes	Yes	Good
Zolnikov 2016[57]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Cannot tell	Yes	Yes	Good
Ayoade 2017[58]	Yes	Yes	Cannot tell	Cannot tell	Yes	Cannot tell	No	Cannot tell	No	Poor
Mercer 2017[59]	Yes	Yes	Yes	Yes	Yes	Cannot tell	Yes	Yes	Cannot tell	Good
Thomas 2018[44]	Yes	Yes	Cannot tell	Cannot tell	Cannot tell	Cannot tell	No	Cannot tell	Cannot tell	Poor

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Table 3 Strength of evidence from quantitative data

Health domain	Quality*	Quantity†	Consistency‡	Strength of evidence§
Pain and injury	One fair, eight poor	9	Consistent: 100% associate WC and pain	Moderate
Fatigue and energy expenditure	One fair, six poor	7	Consistent: 100% associate WC and increased fatigue	Moderate
Stress, mental well-being or life satisfaction	One good, one fair, three poor	5	Inconsistent: 3 (60%) associate WC and increased stress; 2 (40%) found no significant effect of reduced water collection time on mental health or life satisfaction	Inconclusive
Perinatal health	Three fair	3	Consistent: 100% associate WC and reduced perinatal health or care access	Moderate
Social vulnerability	One good, one fair, five poor	7	Consistent: 100% associate WC and social vulnerability or risks	Moderate
General health	One fair, three poor	4	Inconsistent: 3 (75%) associate WC and poorer health	Inconclusive

*Quality score based on National Institutes of Health tool, qualitative and quantitative data of mixed methods studies rated separately, such that total number of rating scores can be greater than number of studies.
†Number of studies.
‡Inconsistent: if ≤75% of the available studies reported the same conclusion.
§Evidence based on quality, number and the outcome of studies: strong=provided by generally consistent findings in multiple high-quality quantitative studies; moderate=generally consistent findings in one high-quality quantitative study and one low-quality study, or in multiple low-quality studies; inconclusive evidence=only one study available or inconsistent findings in multiple studies.[20]
WC, water carriage.

with patterns of pain distribution. The factor ‘axial compression’ was correlated with head, upper back, chest/rib, hands and abdomen/stomach pain. The association was proposed to indicate detrimental impacts of axial spinal loading, because participants who had previously or currently carried water had a mean increase in axial compression factor score compared with people who had never carried water, and the association was stronger among head loaders compared with those using other methods of water carriage. The factor ‘soft tissue strain’ was correlated with neck, upper limb pain, lower back and lower limb pain, and was slightly negatively associated with those having history of water carriage. While these findings may seem to contradict earlier data reporting complaints of neck and back pain during water carriage, the ‘axial compression’ pain pattern associated with water carriage was interpreted as pain referral from an underlying neck disorder.

All studies relied on self-report of pain, which is appropriate and necessary as pain is a subjective and emotional experience.[62] Self-reported pain intensity scales have been shown to be valid and reliable for use in clinical trials to evaluate pain severity caused by a range of medical conditions,[63–65] however, only one of the studies reported findings based on a pain intensity scale,[33] and the scale was not clearly defined in the published report. No other studies qualified participants’ reports of pain in terms of its quality, severity or effect on functioning. Qualification of pain is important because it is a common phenomenon, and can range from mild intensity which does not affect functioning or quality of life to severe pain which is disabling and/or reduces quality of life. Studies should focus on whether the work of water carriage is associated with pain which is of a quality or intensity sufficient to impair functioning or reduce quality of life.[66]

Seven studies included qualitative reports from participants, in which they associated physical injury with water fetching,[31 32 46 47 53 58 59] and four described fear of injury due to water carriage along routes or from locations frequented by dangerous animals.[31 32 39 59] One study reported three cases of a child drowning at open wells or ponds,[31] participants in another study reported fear or risk of being swept away or drowning during floods[32] and a further study included participants who had witnessed people struck by moving vehicles while fetching water.[58]

There is moderate evidence of an association between fatigue or tiredness and water carriage from quantitative data (table 3) and strong evidence from qualitative data (table 4). Five of 11 studies (12 publications) reporting tiredness, fatigue or exhaustion affecting water carriers (table 6), described associations with worsened family relationships,[57] poorer health status[24 26] and reduced engagement with education.[32 58] Two studies measured energy expenditure.[25 28] As an index of total energy

Table 4 Strength of evidence from qualitative data

Health domain	Quality*	Quantity†	Consistency‡	Strength of evidence§
Pain and injury	Five good, two fair, two poor	9	Consistent: 100% associate WC and pain	Strong
Fatigue and energy expenditure	Three good, two fair, two poor	7	Consistent: 100% associate WC and increased fatigue	Strong
Stress	Two good, one poor	3	Inconsistent: 2 (66%) good quality studies associate WC and increased stress, one study found no effect	Strong
Perinatal health	Two good, one poor	3	Consistent: 100% associate WC and reduced perinatal health or care access	Strong
Social vulnerability	Five good, three fair, three poor	11	Consistent: 100% associate WC and worse social vulnerability	Strong
General health	Two good	2	Inconsistent: 1 (50%) associate WC and poorer health, 1 (50%) associate WC and better health	Inconclusive

*Quality score based on CASP tool, qualitative and quantitative data of mixed methods studies rated separately, such that total number of rating scores can be greater than number of studies.
†Number of studies.
‡Inconsistent: if ≤75% of the available studies reported the same conclusion.
§Evidence based on quality, number and the outcome of studies: strong=provided by generally consistent findings in multiple high-quality qualitative studies; moderate=generally consistent findings in one high-quality study and one low-quality qualitative study, or in multiple low-quality studies; inconclusive evidence=only one study available or inconsistent findings in multiple studies.[20]
WC, water carriage.

expenditure, Rao *et al*[25] described drawing water as moderate physical activity, and carrying two containers on the head as heavy physical activity, while Borah *et al*[28] categorised drawing and carrying water home as moderately to very heavy. However, the energy expenditure measurements were done on very small samples of women in India, and may not be generalisable to other populations. Together with other studies in this review, which found that rating of perceived exertion is correlated with weight of water carried and path incline,[14] that energy expenditure for water carriage may be most important in food scarce regions[47] and that water points which reduce water fetching increase birth rates,[24] current evidence highlights that the energetic cost of water carriage has potentially detrimental effects on health and well-being, manifesting as tiredness or fatigue.

We found inconclusive evidence that water carriage is associated with stress from quantitative data (table 3) and strong evidence from qualitative data (table 4). Two rigorous qualitative studies,[34 57] and one fair quality[36] and two poor quality[27 34] cross-sectional surveys, reported water carriage to be associated with stress (table 7). In these studies, psychosocial distress was identified as an effect of water carriage by thematic analysis, and measured using three different questionnaires and by quantification of hair cortisol content as a biomarker for chronic stress. Despite the different indicators of stress, all of the studies elucidated mechanisms by which water carriage might cause stress. These included feeling unsafe during water collection,[36] having insufficient time for family members to spend with each other or discuss household issues,[57] the physical difficulty of water carriage with a young child,[27] risk of physical assault or rape, extremes of temperature, queueing times and inability to complete household tasks triggering arguments between married couples.[34] Considering issues related to social vulnerability which are discussed below, it is plausible that water carriers experience stress related to fear of conflict or abuse.[48] However, one good quality cohort study failed to find any significant association with respondents' mental well-being or life satisfaction and connection to a piped water supply, among participants with above median time spent fetching water at baseline.[30] One mixed methods study failed to find an association between emotional distress and water fetching time, even though participants found water collection to be 'bothersome' because of having to collect water at night.[44] The findings of these studies are inconsistent with the others, however, they should be considered with some caution. The outcome measurement of mental well-being in the study by Devoto *et al*[30] was derived from a composite score and its validity and reliability for use with the study population was not reported, and while socioeconomic status was included, other potential confounding factors which might affect

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Table 5 Water carriage and pain or injury

First author and date	Population	Study type	Dates	Key findings	Quality
Hemson 2007[26]	South Africa: 1052 children aged 5–17 years from 366 households, in three villages with no piped water supply	Mixed methods	NR	96% of the children reporting that their health had worsened, reported that they had a sore neck or back.	Poor* Fair†
Borah 2010[28]	India: 30 rural women with normal blood pressure and temperature aged 21–40 years in Jorhat district of upper Brahmaputra Valley Zone of Assam	Observational study	NR	Incidence of pain during complete water fetching cycle, and with subactivities was mainly in low back region. Pain also reported in shoulder joints while drawing water and carrying it home.	Poor*
Geere 2010a[46]	South Africa: subgroup of 29 people interviewed, drawn from convenience sample of 39 adults and children fetching water in six rural villages of Limpopo Province	Mixed methods‡	2008	Prevalence of spinal (neck or back pain) among water carriers was 69% and back pain alone was 38%.	Poor*
Geere 2010a and b[46]	South Africa: 39 adults and children observed to fetch water in six rural villages of Limpopo Province	Qualitative‡	2008	Children linked water fetching to pain, spinal mobility problems and injury.	Good†
Rauniyar 2011[29]	Pakistan: 1301 'treatment' households of rural water and sanitation project villages and 1301 matched comparison households in non-project villages	Cross-sectional survey	2008	A significant 5% (p<0.001) reduction in 'drudgery' defined as pain from fetching water due to muscle strain, back ache or blisters, attributed to water and sanitation projects; remained highly significant for lowest socioeconomic group in subgroup analyses.	Poor*
Domènech 2012[47]	Nepal: 120 households of 10 communities (2 communities from each district) of Kaski, Syangja, Palpa, Gulmi and Doti districts	Mixed methods§	2008–2009	Rain water harvesting at the house reported to reduce 'numbers of accidents and injuries during water collection'.	Fair†
Singh 2012[33]	India: 100 agricultural workers (50 male and 50 female) engaged in agricultural tasks in last 10 years, from villages of Udaipur district of Rajasthan	Cross-sectional survey	NR	Male and female respondents reported severe neck and shoulder pain during water fetching; severe lower back pain felt by female respondents during water fetching.	Poor*
Asaba 2013[31]	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in four villages	Mixed methods	2011–2012	Three cases of a child drowning at open wells or ponds reported; accidental injury due to slips and falls while water fetching and fear of animal attacks also reported; among men and women, and male and female youths and children, carrying water was perceived to cause chest pain (33.3%–64.4%); headache (5.7%–23.1%); nasal bleeding (0.8%–4.0%); back pain (0.8%–1.9%); spinal problems (0.3%–0.8%) and no problem (11.1%–32.9%).	Poor* Fair†
Robson 2013[32]	Malawi: 1504 children aged 9–18 years from 12 field sites in each of 3 regions	Mixed methods	2006–2009	35% of children reported pains and health problems as their biggest difficulty in carrying water; headaches and neck aches most frequently cited (26%). Of children citing water carrying as their heaviest load, 5% more girls than boys reported bodily aches and pain in the last week. Supported by qualitative evidence from adults and children. Children (22%) reported hazards or risks of water fetching, such as rough terrain, stream/river crossings, snake or dog attacks, vehicles or risk of being swept away or drowning during floods.	Poor*†[1 2]
Bisung 2015[52]	Kenya: convenience sample of 8 women living in Usoma, 15 km from Kisumu	Qualitative (photovoice)	2013	Photograph used to illustrate that children fetch water bare footed and are exposed to injuries.	Good†
Sarkar 2015[53]	Canada: 37% of adults and 100% of high school students living in the sub-Arctic Inuit community Black Tickle-Domino, located on the remote Island of Ponds, off the coast of southern Labrador	Mixed methods§	2013	Study participants attributed chronic back and shoulder injuries to carrying heavy water buckets every day. Some men required surgery, but indefinitely postponed surgery due to 'the unavailability of alternative persons to retrieve water for their families'.	Good†
Subbaraman 2015[54]	India: interviews with 40 adults in Mumbai slum; 3 focus groups (FG) of 6–9 women; 3 FG of 6–9 men	Qualitative	2011	Physical strain occurs from water fetching, particularly impacting negatively the elderly, women and children.	Good†

Continued

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Table 5 Continued

First author and date	Population	Study type	Dates	Key findings	Quality
Berrian 2016[39]	South Africa: 256 surveys within four purposively selected villages of Mnisi study area, Bushbuckridge Local Municipality, Mpumalanga	Cross-sectional survey	2013	224 (85%) respondents believed that shared water sources among people, livestock and wild animals could be a health risk; 118 (45%) reported household water collection from places shared with animals. 'Most' survey participants dislike wildlife around their community, perceived as a threat to personal safety.	Poor*
Ayoade 2017[58]	Nigeria: 800 girls aged 5–15 years in periurban areas of Abeokuta, Ogun Stat	Qualitative	2013–2014	788 (95%) experienced neck and back pain from carrying an excessive load of water and most reported a belief that their back pains worsened during menstruation as a results of heavy water carrying; 90% have experienced some form of violence (fights or punishment) and injury (slips, stepping on nails/glass); 166 (21%) experienced injury from physical fights at water points; 345 (41%) witnessed friends or neighbours struck by moving vehicles while fetching water.	Poor†
Mercer 2017[59]	Canadian subarctic: seven purposively selected households (21 people) in Black Tickle-Domino Inuit community	Mixed methods¶	NR	40.92% reduction in water retrieval time with rain water harvesting, explained by participants to mean less lifting and carrying of heavy water containers and potentially fewer injuries. Reported fear and anxiety of polar bear attack during water retrieval.	Good†
Geere 2018[43]	South Africa, Ghana, Vietnam: 1 adult and 1 child from 673 households with at-house and off-plot water supply	Cross-sectional survey	2012–2013	People who previously carried water had increased risk of pain in hands (RR 3.62, 95% CI 1.34 to 9.75) and upper back (RR 2.27, 95% CI 1.17 to 4.40), as did people who currently carry water (RR hand pain 3.11, 95% CI 1.34 to 7.23; RR upper back pain 2.16, 95% CI 1.25 to 3.73) compared with people who never carried water. Mean 'axial compression' factor score (correlated with pain in head, upper back, chest/ribs, hands, feet and abdomen/stomach) associated with current (0.30, 95% CI 0.17 to 0.43) or previous (0.21, 95% CI 0.01 to 0.42) water carriage. Mean 'soft tissue strain' factor score (correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs), negatively associated with currently (−0.18, 95% CI −0.32 to −0.04) carrying water.	Fair*

*Methodological quality rating of cohort study or cross-sectional survey.
†Methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study.
‡Quantitative data reported by Sarkar *et al* and Domènech *et al* were water quality testing.
§No quantitative health data were collected for analysis against water retrieval time.
¶Small mount of qualitative data presented in Geere 2010a are drawn from study reported in Geere 2010b.
RR, relative risk.

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Table 6 Water carriage and energy expenditure or fatigue

First author and date	Population	Study type	Dates	Key finding	Quality
Gibson 2006[24]	Ethiopia: agropastoralist community, 1548 women aged 15–49 years in a demographic survey of 1976 HHs and subsample of 682 children (<15 years) and 264 women (15–49 years) in anthropometric survey in four villages	Cohort study	2003	Odds of a woman with 'energy saving' water points closer to home giving birth in any given month was three times greater than a woman without an improved water supply (OR 3.78, p=0.009).	Fair*
Hemson 2007[26]	South Africa: 1052 children aged 5–17 years from 366 households, in three villages with no piped water supply; two dry flat villages in Limpopo and one hilly village with natural springs in Kwazulu Natal	Mixed methods	NR	17% of children surveyed on recent illness reported fatigue for which 4% had sought treatment. Of children reporting worsened health, 96% described water carrying as tiring, 75% reported fatigue.	Poor* Fair†
Rao 2008[25]	India: 22 rural women aged 18–45 years from villages about 30–40 km from Pune city, Maharashtra	Cross-sectional survey	NR	PAL‡ of drawing water from a well and using hand pump were categorised as moderate; carrying two containers on the head was categorised as heavy.	Poor*
Borah 2010[28]	India: 30 rural women with normal blood pressure and temperature aged 21–40 years in Jorhat district of upper Brahmaputra Valley Zone of Assam	Observational study	NR	Compared with walking to water point and drawing water, the return journey with water-filled containers had maximum heart rate (HR) and energy expenditure (EE) for 21–30 age group (115 bpm and 9.56 kJ/min) and for 31–40 age group (113 bpm and 9.24 kJ/min); on basis of average HR and EE, workload for drawing water and return journey classified as moderately heavy; on basis of peak HR and EE, workload for drawing water and return was classified as heavy or very heavy; rating of perceived exertion was highest with the return journey while carrying water, and highly correlated with HR (r=0.84–0.92) for both age groups at all parts of the water fetching cycle.	Poor*
Geere 2010a[46]	South Africa: subgroup of 29 people interviewed, drawn from convenience sample of 39 adults and children fetching water in six rural villages of Limpopo Province	Mixed methods	2008	Rating of perceived exertion significantly correlated with container weight (r=0.52; p=0.011) and path incline (r=0.459; p=0.018) during water carriage.	Poor*
Geere 2010b[46]	South Africa: 39 adults and children observed to fetch water in six rural villages of Limpopo Province	Qualitative	2008	Children link water carriage to tiredness in qualitative interviews.	Good†
Domènech 2012[47]	Nepal: 120 households equally distributed among 10 selected communities and with at least 2 years of experience with rainwater harvesting	Mixed methods§	2008–2009	Rainwater harvesting reduced water fetching (6.4 hours/day less in the rainy season; 4 hours/day less in the dry season) and allowed energy (calorie) savings.	Fair†

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Table 6 Continued

First author and date	Population	Study type	Dates	Key finding	Quality
Asaba 2013[31]	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in four villages	Mixed methods	2011–2012	Over 70% of survey respondents highlighted 'tiresome' nature of water fetching. Many added that carrying water required 'a lot of physical energy'. Among men (22.9%) and women (13.6%), male youths (18.1%), female youths (19.1%), male children (23.7%) and female children (23.1%) carrying water was perceived to cause fatigue.	Poor* Fair†
Robson 2013[32]	Malawi: 1504 children aged 9–18 years from 12 field sites in each of 3 regions	Mixed methods	2006–2009	Of children citing water carrying as their heaviest load, 5% more girls than boys reported experiencing tiredness in the last week. Supported by qualitative data from adults and children, indicating that children suffer from tiredness and inability to concentrate at school, particularly from being woken at night or very early morning to fetch water.	Poor*†
Bisung 2015[52]	Kenya: convenience sample of 8 women living in Usoma, 15 km from Kisumu	Qualitative	2013	Children need a lot of energy to push wheelbarrows and carts used for carrying water.	Good†
Zolnikov 2016[57]	Kenya: 52 semi-structured interviews to examine relationships among primary water gatherers and their families after receiving nearby access to water, in Kitui.	Qualitative	NR	Primary water gatherer 'very tired and easily annoyed' prior to the implementation of interventions providing nearby water supply.	Good†
Ayoade 2017[58]	Nigeria: 800 girls aged 5–15 years in periurban areas of Abeokuta, Ogun State	Qualitative	2013–2014	Respondents reported that they experienced fatigue due to water carriage, which negatively affected their ability to participate in school.	Poor†

*Methodological quality rating of cohort study or cross-sectional survey.
†Methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study.
‡Index of total energy expenditure adjusted for basal metabolic rate (BMR).
§Quantitative data reported by Domènech *et al* were water quality testing.
HHs, households.

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Table 7 Water carriage and stress, mental well-being or life satisfaction

First author and date	Population	Study type	Date	Key findings	Quality
BeLue 2008[27]	South Africa: mothers, 9 months post partum aged 17–30 years, Khayelitsha, Western Cape	Cross-sectional survey	1999–2000	Piped water in the dwelling associated with significantly lower perceived stress (PSS); PSS 14.2, (SD 4.8) for piped into dwelling, 19 (SD 7.4) piped water to yard, 17 (SD 6.6) for public standpipe).	Poor*
Devoto 2012[30]	Morocco: 845 households in Tangiers, not connected to a city water network, comparing subgroup of households reporting above median baseline time fetching water	Cohort study	2007–2008	With subgroup analysis of households reporting above average median baseline water fetching time, no significant effect of allocation to water supply 'encouragement' project, or actual connection to piped water supply on (a) summary index averaging 3 scores of mental well-being (over past 7 days respondent felt more often than not, sad/worried/satisfied), and (b) respondent's rating of life satisfaction level being ≥5 (on 0–10 scale).	Good*
Stevenson 2013	Ethiopia: women from cluster sample of 104 households for free listing, convenience sample of 39 women from three kebeles for ranking exercise, three focus group discussions totalling 30 women form three kebeles, cluster sample of 324 women	Mixed methods	2009–2010	The 24-item water insecurity scale was correlated with time required to fetch water (r=0.52; p<0.0001), and was positively but weakly correlated with psychosocial distress (r=0.22, p<0.001), indicating that women who experienced more water insecurity also reported more symptoms of common mental disorders. Qualitative data indicate that social and environmental factors contribute to stress during water carriage.	Poor* Good†
Henley 2014[36]	Kenya: randomly selected subsample (200 of 1000 participants in health survey) from settlements in Naivasha and Mogotio	Cross-sectional survey	2011	Participants who reported feeling unsafe when they collected water or went to the toilet had increased mean hair cortisol content by 127 ng/g (yes (safe) 607±282 ng/g; no (not safe) 734±335 ng/g; p=0.0370).	Fair*
Zolnikov 2016[57]	Kenya: 52 semi-structured interviews to examine relationship experiences among primary water gatherers and their families after receiving nearby access to water, in Kitui.	Qualitative	NR	Primary water gatherers: before water interventions easily annoyed; after intervention additional time for discussions with spouse and of school-related achievements and issues with children. Household heads: before interventions angry at lack of water availability, challenged by lack of time for household discussions, unsatisfied with work; after water interventions time for discussions and planning with spouse, made additional money. Children: after intervention school fees available, time with mother and family more frequent, more time for friendships and schoolwork, no time outside of school spent gathering water.	Good†

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Table 7 Continued

First author and date	Population	Study type	Date	Key findings	Quality
Thomas 2018[44]	Ethiopia: survey and focus groups with 200 households in Welenchiti, Oromia region, and interviews with senior water utility staff	Mixed methods	NR	Most households (64%) felt 'bothered' by collecting water in the previous 7 days, mostly because of having to collect water at night; emotional distress was not significantly associated with accessibility (total water collection time in minutes) of the main water source (β =−0.03, p=0.677) indicating that a longer time spent collecting water did not increase the intensity of emotional distress.	Poor*†

*Methodological quality rating of cohort study or cross-sectional survey.
†Methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study.

mental health and life satisfaction were not included in the analyses. The average one way time to the water source in the case study by Thomas and Godfrey[44] was <3 min.

There is moderate quantitative evidence that perinatal health is associated with water carriage (table 3) and strong qualitative evidence (table 4). Six studies reported different aspects of perinatal health to be associated with water carriage (table 8). Two qualitative papers reported physical strain and non-specific 'health complications' from carrying 20 L water containers on the head during pregnancy[50 52] and one reported mothers' views that being forced to fetch water in late pregnancy led to malnourished children.[55] Quantitative studies reported reduced uptake of prenatal care services,[22] six times greater odds (our calculation) of giving birth in a health facility when a husband provided help with water fetching[38] and almost four times greater odds of giving birth in any given month, among women with an improved water supply closer to their home compared with those without improved water supply.[24] Gibson and Mace[24] described the improved water access as an 'energy saving' intervention which reduced distance to water and women's time spent water fetching. They concluded that the energy saved by the technology did not translate into an improved nutritional status for women, because it supported an increase in birth rates. While the study found a negative consequence of the increased birth rate to be increased childhood malnutrition, it nevertheless indicates a potentially detrimental impact of maternal health associated with water carriage; it suggests that prior to installation of taps the exertion of water carriage affected women's health enough to reduce birth rates, as compared with birth rates post-tap installation. While Gibson and Mace did not include nutritional interventions as possible confounding factors in their multivariable analysis, and McCray's[22] outcome measure could have been affected by recall and therefore misclassification bias, the six studies provide evidence that water fetching could be significantly associated with perinatal health outcomes through behavioural and physiological mechanisms.

There is moderate quantitative evidence and strong qualitative evidence that vulnerable people are at risk of discrimination or physical, sexual and psychological abuse while they collect water (tables 3 and 4). The studies in this review provide rich qualitative evidence in good,[49 51 54 55 57] fair[31 47 48] and poor quality studies[32 50 58] from 31 countries, and good,[30] fair[31 37] or poor[31 32 35 41 42] quantitative evidence from 6 countries (table 9). People may be vulnerable because of age, gender, disability, health status or ethnicity.

There is inconclusive evidence of a relationship between water carriage and self-rating of general health, because of inconsistent findings in the five studies (tables 3 and 4). There is an indication of a dose-response relationship between water carriage and self-rating of health in three[21 23 26] of the five studies reporting

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Table 8 Water carriage and perinatal health

First author and date	Population	Study type	Dates	Key finding	Quality
McCray 2004[22]	South Africa: 327 HH surveys: mothers of child aged 12–23 months in randomly selected household Kwazulu Natal	Cross-sectional survey	1998	Report that fetching water was daily activity affected by making a trip to the health clinic associated with level of prenatal care utilisation (^{2}=6.64, p=0.036); women two times more likely to use prenatal care services at low level than at an average level (1/OR=2.43).	Fair*
Gibson 2006[24]	Ethiopia: 1548 women (aged 15–49 years) in demographic survey of 1976 HHs; 682 children, 264 women in anthropometric study (four villages)	Cohort study	2003	Odds of woman with access to water points giving birth in any given month three times greater than a woman without an improved water supply (OR 3.78, p=0.009). Installation of taps did not improve or predict maternal health indicated by anthropometric measures of BMI and MUAC.	Fair*
Ono 2014[38]	Kenya: 306 mothers aged 18–49 years, who brought their babies to Sosiot Health Center for immunisation within their first year of life, in September to November 2011. Data from 303 respondents (99%) were analysed	Cross-sectional survey	2011	Unmarried women whose sisters helped them fetch water more likely to deliver at health facilities (HF) (p=0.042) and married women whose neighbours helped them fetch water less likely to deliver at HF (p=0.021) than those without support. Married women, borderline significant (p=0.054) association between birth at home and support from husband water fetching; of women who received help from their husband to fetch water, 1 of 20 (5%) gave birth at home, 19 of 20 (95%) gave birth in a HF; women who did not have help from their husband to fetch water, 50 of 211 (23.7%) gave birth at home, 161 of 211 (76.3%) gave birth in HF. Married women more likely to deliver at HF if they did not have the support of sisters-in-law fetching water (OR=2.2, 95% CI 1.0 to 4.7, n=245; husband helping not in logistic regression model).	Fair*
Mukhulani 2014[50]	Zimbabwe: respondents of three Bulawayo suburbs	Qualitative	NR	Physical strain and health complications from carrying 20 L container on head while pregnant highlighted in illustrative quote from qualitative data.	Poor†
Bisung 2015[52]	Kenya: convenience sample of eight women living in Usoma, 15 km from Kisumu	Qualitative (photovoice)	2013	Photograph of pregnant woman carrying 20 L of water on head and holding 10 L used to exemplify association of water carriage with maternal health.	Good†
Ghosh 2016[55]	India: 79 mothers from 8 groups of 8–10 mothers of at least 1 child under 6, in four villages in the Sundarbans of West Bengal	Qualitative	NR	Mothers did not get sufficient rest during pregnancy and perceived that this led to giving birth to malnourished children. 'The women have to fetch water from a distant source even in their last few months of pregnancy. They force themselves to do so to avoid the quarrels with the mother-in-law'.	Good†

*Methodological quality rating of cohort study/cross-sectional survey.
†Methodological quality of qualitative study or qualitative findings of mixed methods study.
BMI, body mass index; MUAC, middle upper arm circumference.

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Table 9 Water carriage and social vulnerability

First author and date	Population	Study type	Dates	Key finding	Quality
Devoto 2012[30]	Morocco: 845 households in Tangiers, not connected to a city water network, comparing subgroup of households reporting above median baseline time fetching water	Cohort study	2007–2008	Significant reduction in risk of being in conflict with people from his/her family on water matters with (a) allocation to water supply 'encouragement' project (–0.06, p=0.05), which remained significant and decreased further for households with above median baseline time fetching water (–0.09, p=0.10) or (b) actual connection to piped water supply (–0.12, p=0.05), which was similar but not significant for households with above average baseline water fetching time.	Good*
Domènech 2012[47]	Nepal: 120 households distributed among ten selected communities, with at least 2 years experience of rainwater harvesting	Mixed methods‡	2008–2009	Perceived benefits from rainwater harvesting reported as being particularly helpful to vulnerable groups, described as older people, disabled people and children.	Fair†
Yallew 2012[35]	Ethiopia: 296 home based care clients living with HIV/AIDS, drawn from two NGOs in Gondar city	Mixed methods	2009	Bivariate analysis indicated that being forced to go far distance associated with unimproved water status (crude OR 3.91, 95% CI 1.13 to 13.47, p<0.05); needing help with walking associated with improved water status (crude OR 0.11, 95% CI 0.01 to 0.89, p<0.05), but not significant in multiple logistic regression; adjusted OR for forced to go far 3.84 (95% CI 0.41 to 35.27); for needing help walking 0.13 (95% CI 0.01 to 1.44).	Poor* Good†
Asaba 2013[31]	Uganda: survey of 602 (~35%) households in Makondo Parish, and in-depth interviews, focus group discussions and participant observation in four villages	Mixed methods	2011–2012	Water points are sites of positive social interactions, however, fights resulting in verbal and physical attacks were also observed and reported to occur at 'improved' water points, particularly at those with queues.	Poor* Fair†
Robson 2013[32]	Malawi: 1504 children aged 9–18 years from 12 field sites in each of 3 regions	Mixed methods	2006–2009	Hazards of water fetching reported to be harassment, verbal abuse or attack from people, and 'meeting criminals'.	Poor*†
House 2014[48]	Various countries§	Qualitative	NR	Case studies indicate that gender-based violence occurs during water fetching in many countries. Violence may be sexual, psychological, physical or sociocultural.	Poor†
Isoke 2014[49]	Uganda: 127 survey respondents from Bwaise II and Kisenyi III parishes (informal settlements in Kampala). Semi- structured interviews with 10 NWSC staff. Three focus groups, 2 with 12 leaders of the parishes and 1 of 4 NGO members	Mixed methods¶	NR	Reasons cited for choice of tap included securing young children from being sexually abused and preventing children from 'picking up bad habits from bad company'.	Good†

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Table 9 Continued

First author and date	Population	Study type	Dates	Key finding	Quality
Mugambe 2014[37]	Uganda: 450 respondents, with 222 from HIV/AIDS affected, 228 from HIV/AIDS non-affected households of rural districts Mpigi and Gomba	Cross-sectional survey	NR	Bivariate analysis: perceptions that fetching water takes a lot of time (OR=2.44; 95% CI 1.65 to 3.61) and requires a lot of energy (OR=1.83; 95% CI 1.26 to 2.67) strongly associated with buying water from water vendors. Multivariable analysis: perception that fetching water takes lot of time (AOR=2.15; 95% CI 1.21 to 3.82), district location (AOR=1.92; 95% CI 1.25 to 2.95), presence of person living with HIV/AIDS in household (AOR=0.58; 95% CI 0.38 to 0.88) significant predictors of buying water from vendors.	Fair*
Mukhulani 2014[50]	Zimbabwe: respondents from three suburbs in Bulawayo affected by water scarcity	Qualitative	NR	Sexual assault and harassment reported at water points, during early morning queueing for water, or at night when travelling to boreholes 500 m–2 km away.	Fair†
Schatz 2014[51]	South Africa: 30 women aged 60–75 years and impacted by HIV in some way, from phase I of the ‘Gogo Project’, in rural subdistrict	Qualitative	NR	Fetching water is an activity associated with the respondents’ (older women) own health and level of family support.	Good†
Subbaraman 2015[54]	India: 40 adults of Mumbai slum; 3 focus groups (FGs) 6–9 women; 3 FGs 6–9 men	Qualitative	2011	Reports of social conflict and extortion when bringing water containers home.	Good†
Ghosh 2016[55]	India: 79 mothers from 8 groups of 8–10 mothers who had at least one child below 6 years of age across 4 villages in three blocks in the Sundarbans region of West Bengal	Qualitative	NR	Mothers did not get sufficient rest in pregnancy, perceived that this led to birth of malnourished children. 'The women have to fetch water from a distant source even in their last few months of pregnancy. They force themselves to do so to avoid the quarrels with the mother-in-law’. Some beaten by in-laws.	Good†
Cook 2016[40]	Kenya: 387 households near Kianjai, north-central Kenya	Cross-sectional survey	2013	Water sources are a cause of social conflict. Proportion of respondents who thought using water source would be 'somewhat' or 'very' likely to lead to conflict: public well 0.69, public borehole 0.51, public piped connection 0.56, surface, other public 0.62. Among well-owners, 85% reported allowing neighbours to use well, of these 28% said that sharing led to conflict with neighbours.	Poor*
Krumdieck 2016[41]	Kenya: 323 women at 33 weeks gestation, of mixed HIV status, recruited from seven clinics in Nyanza province	Quantitative	2014–2015	Water acquisition posed psychological stress and physical risk, 77.3% stating that they felt ‘somewhat or strongly concerned’ for their physical safety during trips for water.	Poor*
Zolnikov 2016[57]	Kenya: 52 semi-structured interviews among primary water gatherers and their families after receiving nearby water access	Qualitative	NR	Primary water gatherers report feeling ‘scared and fearful when gathering water, unhappy with water-gathering situation’	Good†

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Table 9 Continued

First author and date	Population	Study type	Dates	Key finding	Quality
Ayoade 2017[58]	Nigeria: 800 girls aged 5–15 years in periurban areas of Abeokuta, Ogun State	Qualitative	2013–2014	456 (55%) reported sexual assault and/or harassment; 99 (11%) reported physical punishment by parents or guardians when containers got lost or exchanged at water points; 184 (23%) reported punishment by parents or guardians who believed they were wasting water; 122 (14%) reported fear of returning home with empty containers.	Poor†
Dapaah 2017[42]	Ghana: 120 survey respondents in Ga-Mashie, Accra and 80 in Madina, Accra	Mixed methods**	NR	Incidence of fights at water collection points 102 (85.0%) in Ga-Mashie; 34 (42.5%) in Madina; 136 (68.0%) in total.	Poor*

*Methodological quality rating of cohort study or cross-sectional survey.
†Methodological rating of qualitative study or qualitative findings of a mixed methods study.
‡Quantitative data reported by Domènech *et al* were water quality testing.
§Sudan, DRC, Solomon Islands, Liberia, Guinea, Sierra Leone, Kenya, India, Cameroon, South Africa, Tanzania, Uganda, Zambia, Haiti, Afghanistan, Cambodia, Somalia, Philippines, Nigeria, Ghana, Mozambique, Pacific Islands, Pakistan, Angola, Malawi, Sudan, Iran, Nepal, Timor-Leste, Bangladesh, Sri Lanka.
¶Quantitative data reported by Isoke and Van Dijk were not analysed for association with health outcomes.
**Qualitative data were not about health outcomes.
AOR, adjusted OR; NGO, non-governmental organisation; NWSC, National Water and Sewerage Corporation.

general health of water carriers, with greater amounts of time spent water fetching linked with poorer health for both children and adults (table 10). These findings were inconsistent with those of Geere *et al*,[43] who found that adults who currently or previously carried water, had a better (lower=healthier) mean general health rating score than adults who never carried water, while children who currently carried water reported better, and children who previously carried water reported worse health, compared with children who had never carried water. In qualitative data from an earlier pilot study, Geere *et al*[46] found that some children linked water carriage to better health and stronger resilience to diseases such as 'influenza', others to meeting basic needs and some to experiencing unfair workloads.

The inconsistencies may be due to different methods used for participants to rate their general health, and differences in confounding factors incorporated into the analyses. In the three of four studies which attempted to scale or categorise health status,[21 23 26] recall of occasions of illness or comparison of current to previous health status was required of respondents. This may introduce bias or error to the classification of health status, weakening internal validity of the studies and rendering the findings inaccurate.[17] Self-rated health 'today' on a simple 5-point scale has been found to have high test-retest reliability and to be an excellent predictor of future health in some studies, however, reliability of self-rated health status has also been shown to be affected by age, income and occupation in some populations.[67] Hemson's[26] findings may therefore have been influenced by recall and confounding factors, because the statistics presented are descriptive and lack analysis of the effect of variables such as age, gender and socioeconomic status. These variables were considered in the regression analyses reported by Bour,[21] Foggin *et al*[23] and Geere *et al*,[43] with Foggin *et al* reporting a very strong association between increased time spent water fetching and poorer general health. However, other potential confounding factors which were not included in analyses, such as hygiene practices, access to healthcare or sanitation coverage, could have influenced the results in all studies. No studies used a longitudinal cohort design to determine a temporal relationship between water fetching and health status, and all could have been affected by confounding factors which were not included in analyses.

DISCUSSION

This is the first systematic review of the association of the work of water carriage with the health of water carriers. Forty-two studies were included in the review. Direct detrimental health impacts were mainly reported, such as increased pain, fatigue and stress. Indirect detrimental health impacts were also reported and were related to perinatal health and social vulnerability. These included serious health issues such as physical abuse and rape. The ability of the studies reporting quantitative data to

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Table 10 Water carriage and general health

First author and date	Population	Study type	Date	Key findings	Quality
Buor 2004[21]	Ghana: 210 females aged 12+ years in Kumasi; 90 from urban ‘core’, 120 form urban periphery	Cross-sectional survey	2001	During water scarcity: ill once every 2 weeks (fetching water≥4 hours 39.2%; 2–3 hours 19.3%; <2 hours 21.3%); ill once a month (fetching water≥4 hours 31.4%; 2–3 hours 26.6%; <2 hours 27.7%); ill once in 3 months (fetching water≥4 hours 19.6%; 2–3 hours 41.3%; <2 hours 31.9); ill rarely (fetching water≥4 hours 9.8%; 2–3 hours 12.8%; <2 hours 19.1%); multiple regression: beta-coefficients total sample (–0.255; p=0.000), core (–0.261; p=0.011), and periphery (–0.293; p=0.003). Type of regression model not stated. If multiple linear regression, for each extra hour of water fetching, health status score reduced by 26%–29%. However, health status measured on 4-point categorical scale (1=sick once every 2 weeks, 4=rarely sick), for which proportional odds regression is more appropriate. This would mean that for each hour spent water fetching, the likelihood of going from a lower level of the outcome variable (higher frequency of illness) to the next (lower frequency off illness) reduces by 25%–29%.	Poor*
Foggin 2006[23]	Tibet: herders in Sanjiangyuan region, Tibetan Plateau, southwest Qinghai Province; 50 families in Suojia Township, 49 in Zhahe Township	Cross-sectional survey and qualitative	2002	Tibetan pastoralists who spend>15 min collecting water are almost 10 times more likely to report being ill in the past month than those spending ≤15 min (OR=9.853; p≤0.001).	Poor* Good†
Hemson 2007[26]	South Africa: 1052 children aged 5–17 years from 366 households, in three villages with no piped water supply; two dry flat villages in Limpopo, one hilly village, with natural springs in Kwazulu Natal	Cross-sectional survey and qualitative	NR	Compared with children collecting water 0–13 hours per week, smaller proportions of children collecting water for ≥14 hours pw rated their health as ‘improved’ (0–13 hours 42%; ≥14 hours 37%) or the same (0–13 hours 53%; ≥14 hours 45%) and a greater proportion as worse (0–13 hours 5%; ≥14 hours 19%). Of children reporting worsened health, 77% spent≥14 hours pw collecting water and 87% stated that their health was worsened by collecting water. Of children who said their health had got worse 82% reported collecting water>once a day vs 18% collecting water once a day. Of children reporting their health as improved or the same, 56% collected water>once a day, 44% collected water once a day.	Poor* Fair†

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Table 10 Continued

First author and date	Population	Study type	Date	Key findings	Quality
Geere 2010b[46]	South Africa: 39 adults and children observed fetching water, six rural villages, Limpopo Province	Qualitative	2008	Children linked water carriage and health in various ways, including feeling 'better and healthy' or having greater resilience to diseases like influenza, as a result of the exercise required for water carriage. Children also related health to being able to participate in activities such as water fetching, as well as to having basic needs met and experiencing fair workloads.	Good†
Geere 2018[43]	South Africa, Ghana, Vietnam: 1 adult and 1 child from 673 households with at-house and off-plot water supply	Cross-sectional survey	2012–2013	Adults who previously carried water had a better (lower=healthier) mean general health score than adults who never carried water ($\beta=-0.58$, 95% CI −0.80 to −0.35, $p<0.001$) and adults who currently carried water had a better mean general health rating score than adults who had never carried water ($\beta=-0.91$, 95% CI −1.12 to −0.70, $p<0.001$). Children who currently carry water had a better mean score rating for general health than children who had never carried water ($\beta=-0.20$, 95% CI −0.37 to −0.31, $p=0.003$). Children who previously carried water had a worse mean score rating for general health ($\beta=0.39$, 95% CI 0.02 to 0.75, n=10).	Fair*

*Methodological quality rating of cohort study or cross-sectional survey.
†Methodological quality rating of qualitative study or reporting of qualitative findings as part of a mixed methods study.

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demonstrate a cause and effect relationship is limited because of study design and fair or poor methodological quality. The only cohort study in the review rated as good[30] was of limited value, as in the main analyses of the health effects of 'encouragement' and actual household connection to piped water supply, people carrying water by container were not disaggregated from those connected by hose to a public tap or neighbour, the health outcome measures reported for relevant subgroup analyses were limited and confounding factors did not include other forms of manual labour. A greater number of studies reporting qualitative data were rated as having good methodological quality, and while these provide insight into the lived experience of fetching water, they cannot provide strong evidence of a causal relationship, as the actual experience of pain or other health effects may be mediated by confounding factors and bias. Overall, the evidence in this review indicates that the work of water carriage is more often associated with harm rather than benefit to the water carriers' health. Our findings indicate that the health outcomes associated with water carriage create barriers to achieving the targets of many of the SDGs.

Qualitative studies clearly indicate that water carriers experience pain and feel exposed to risk of injury during water carriage, which is commonly performed by carrying containers on the head. The findings are supported by Lloyd *et al*,[68] who reported that discomfort in the neck was, in all cases, the cause of early termination of head-loading trials during a laboratory experiment. Geere *et al*[43] proposed that the pain pattern they observed to be associated with water carriage might indicate referred pain as a consequence of tissue deformation under compressive loading, or long-term structural changes such as cervical spondylosis. Evidence of advanced cervical spondylosis has been reported among porters and people who apply loads to the head (head loading),[69–71] suggesting that this common method of water carriage may be sufficient to cause structural changes in bone and the soft tissues of the spine. Such changes have been proposed in experimental studies to occur as a consequence of biomechanical stress and strain.[72] Particularly in the cervical spine, spondylosis may lead to neurological impairment, such as radiculopathy or myelopathy, and related disability.[73 74] However, none of the studies reporting pain or injury affecting water carriers were longitudinal cohort studies. Hence, it remains unknown whether the loading patterns typical of domestic water carriage, by head loading or other methods, are sufficient to have important long-term effects on the musculoskeletal system and to increase risk of neurological compromise. This question is particularly important for populations in sub-Saharan Africa, where other risk factors for myelopathy, including nutritional or infectious diseases such as HIV, tuberculosis or schistosomiasis, are also common[75–77] and may increase susceptibility to adverse impacts of head loading. It is also important to recognise that many people will carry diverse loads in addition to water,[60] and future studies should include detail of other head loading and manual labour as potential factors confounding the effects of water carriage.

No studies attempted to conduct any detailed clinical assessment of their study participants,[78] or reported excluding participants with long-term health conditions which might cause pain and modify an association between symptoms and water carriage. This may be due to the practical and ethical challenges of conducting clinical assessments in areas of limited health services coverage, the likely situation in many areas where water carriage studies would typically be conducted.[6] However, future studies would be strengthened by incorporating some aspects of clinical assessment to supplement self-reported health outcomes. For example, a medical history could be combined with evaluation of whether movement, compression stress or palpation of pain sensitive structures provokes symptoms comparable to those experienced during water carriage.[79] This would help to identify a likely cause of symptoms and could confirm whether mechanical loading during water carriage is a plausible mechanism of pain production in study participants.

This review has found moderate quantitative and strong qualitative evidence that tiredness or fatigue is associated with water carriage. Head loading by African women has been described as an energy efficient way of carrying loads.[80 81] However, one study tested the 'free ride' hypothesis for head loads compared with back loads, and found that it was not generalisable, with significant individual differences in energetic cost.[82] In larger households, or those caring for young children, aged parents or people living with disability or long-term conditions, their need for water may be high and water carriage may become a demanding daily chore, particularly if it falls on one woman or her children. Differences in the capacity of individuals to meet their household's need for water will influence water security and could exacerbate interhousehold and intercommunity inequalities of water access, a direct challenge to SDG 6 target 6.1 'universal and equitable access to safe and affordable drinking water for all'.[5]

We found inconclusive quantitative and strong qualitative evidence that stress is associated with water carriage. Qualitative evidence highlighted that the experience of stress associated with water carriage could be due to reduced family time and poorer interpersonal relationships, conflicts which arise in the community or at home over water use and domestic tasks, the physical challenges of collecting water and lack of safety. Water fetching is also indirectly linked to stress, by increasing water insecurity, and feelings of worry or shame from inability to keep oneself or one's children clean, or complete expected household chores such as laundry, cleaning and cooking. The one good quality cohort study in this review did not find a significant effect of connection to a piped water supply on respondents' mental health or life satisfaction, however, their mental health index was derived from the average of three separate measures of well-being, and its

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reliability and validity for use in the study population is not clear. While socioeconomic confounding factors were included in the analyses, other factors which may have also affected mental health and well-being in the population studied, were not included in the analysis. Overall, our findings are similar to a review of water insecurity and psychosocial stress,[83] and highlight that reducing the work of water carriage has potential to benefit women's and children's mental health in settings where water carriage is physically challenging, unsafe or exacerbates water insecurity. This aligns with SDG target 3.4 to 'promote mental health and well-being'[6] and further good quality cohort or intervention studies, using valid and reliable outcome measures of stress, mental health and well-being are warranted.

The moderate quantitative and strong qualitative evidence that water carriage can affect perinatal health and reduce uptake of health services is particularly relevant to SDG 3 targets 1 and 2, to reduce maternal and new born deaths, and 7, ensure access to reproductive healthcare services. Fetching water also sets the scene in which health risks due to social vulnerability are realised. Vulnerable people include women, children, displaced people, people with disability and people living with HIV AIDS. It is likely that cases of abuse are under-reported, due to shame and fear of further discrimination or reprisals against the victim or their family, and ineffective or inappropriate policing and support services.[48] Older adults are also vulnerable, as they may not be capable of collecting enough water from off-plot sources because of age-related health problems, and may lack support from younger family members for fetching water.[84 85] Future studies should investigate how to reduce social vulnerability and ensure *safe access* to safe water, and are needed to strengthen the existing evidence base and identify ways to meet the 'universal' aspect of SDG 6, target 6.1.

Study findings differ on the association between general health and water carriage. Apart from differences in study design, the perceived and reported general health impact of water carriage may also be mediated by whether the work is perceived as 'normal', whether it allows basic needs to be met and by how well the workload matches the water carrier's physical capacity for work and the comparative workload of other people.[46] In the study which reported a rating of health 'today',[43] the association of better health with current or past water carriage might indicate a selection process, whereby healthier people are allocated the task of fetching water. It may also indicate a beneficial health effect of regular physical activity undertaken since adolescence.[86] Overall, the findings on general health from studies in this review are inconsistent and therefore provide inconclusive evidence. However, in light of this review's findings in relation to other domains of health, further research with longitudinal cohort studies is warranted.

Our review has used a sensitive search strategy to identify published reports in academic and grey literature. While one good quality cohort study evaluating the impact of connection to piped water supply was found, its findings were of limited value for the review. A limitation of our review is that we did not contact study authors for additional information or data. All other studies were either qualitative or used cross-sectional surveys, and we therefore cannot make causal inferences. However, the qualitative studies included in this review provide insight into people's experiences of water fetching and the mechanisms by which it might affect their health, and together with the substantial number of cross-sectional studies reporting that water carriage is negatively associated with health outcomes, indicate that further good quality research is warranted.

The design of future studies should ideally evaluate the temporal relationship between water carriage (exposure) and health (outcome) to evaluate cause and effect, or use randomisation and control groups or villages to reduce risk of confounding and bias. They should also include multivariable analyses of important potential confounding factors, such as socioeconomic level, health status and comorbidities, manual labour and carriage of loads other than water.[87] Studies should incorporate standardised, valid and reliable methods of exposure and outcome measurement, including measured time spent carrying water, weight of water carried, frequency of water carriage, years of exposure and methods of water carriage. Health outcome measures should be piloted for reliability and validity of use in the study populations, and include severity, duration, location and functional impact of pain, as well as indicators of fatigue, stress, mental health and general health, social vulnerability and perinatal healthcare access. Clinical assessment by trained health workers could supplement self-reported outcome measures to support better evaluation of the health status of study participants against selection criteria, at baseline assessment and follow-up. While the challenges of limiting the effects of confounding and bias in WASH research are well recognised,[88] a stronger body of evidence derived from good quality studies with comparable health outcome measures will allow future reviews to better evaluate risk of bias, more precisely estimate measures of treatment or intervention effect and conduct sensitivity analyses to reduce risk of overall bias.

Through its association with pain, fatigue, stress and reduced access to perinatal healthcare services, the existing evidence suggests that water carriage is a potentially important barrier to achievement of many health targets set for SDG 3. Because in most households of low-income and middle-income countries, it is women and girls who fetch water for household use, it will also compromise SDGs related to gender equality, quality education for all and reducing inequalities. Because water is essential for life, but fetching it is often not safe, water carriage is also a barrier to ensuring safe and inclusive societies, and decent work for all, a further challenge to reducing poverty in all its forms. However, it is important to recognise that water may be carried in addition to other loads, and it may not be the heaviest or key

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porterage task leading to health issues. Combined, all of these factors reduce the likelihood of achieving SDG 6 target 1 by 2030: 'universal and equitable access to safe and affordable drinking water for all'.

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Contributors J-ALG conceived of the review, completed the electronic data base searches, selected papers to include in the review against selection criteria, extracted data, appraised articles reporting qualitative and quantitative data, wrote the first draft of the paper, reviewed subsequent drafts and reviewed and approved the final draft; MC conceived of the review, contacted experts in the field of water and health, provided translation of Swedish papers, reviewed drafts and reviewed and approved the final draft of the paper; JHG appraised articles reporting quantitative data, reviewed drafts and reviewed and approved the final draft of the paper; CCH appraised articles reporting qualitative data, reviewed drafts and reviewed and approved the final draft of the paper; PRH selected papers to include in the review against selection criteria, provided translation of French papers, appraised articles requiring consensus on quality rating, reviewed drafts and reviewed and approved the final draft of the paper.

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Appendix 2. Published paper

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Who Carries the Weight of Water? Fetching Water in Rural and Urban Areas and the Implications for Water Security

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ABSTRACT: The global burden of fetching water, particularly its effects on individuals and societies, is largely unknown because comparative analysis of the global data available is incomplete and scarce. To address this information gap, this article presents a synthesis of the data on water-fetching from households in 23 countries. In rural areas of the dataset almost 50% of the population still have to bring water from a source outside of their home or yard. Women generally carry the main responsibility for fetching water; however, in many countries and in particular in urban areas, men also take on a great share of this work. The mean single trip time to collect water ranges from 10 to 65 minutes in urban areas with an average increase or decrease of 2 to 13 minutes in rural areas. Further, up to 60% of children support the collection of wood and water, in some countries spending up to 11.3 hours per week. Water fetching continues to have the greatest impact on women and children in poorer rural areas and is likely to be a substantial barrier to household water security and sustainable development in regions most in need of sustainable development.

KEYWORDS: Water fetching, MICs surveys, global data, time, health impacts

INTRODUCTION

'Water security' is defined in this collection as 'the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable or tolerable level of water-related risks to people, environments and economies'. We argue in this paper that in many regions of the world, continued reliance on the manual labour of fetching water to obtain water for household use is substantial, and compromises water security. Consequently, opportunities for sustainable growth which are commonly expected to occur as a result of 'improved access' to safe drinking water are not likely to occur unless the burden of the work of fetching water is recognised and reduced. Whilst there are data to support that men contribute to this work in some regions and in urban areas, global regions most in need of sustainable growth and economic development, such as rural areas of sub-Saharan Africa, most commonly rely on women to obtain and carry household water from a source located away from their homes (UNICEF and WHO, 2012). Water fetching therefore remains a significant barrier to household water security and sustainable development, particularly for rural women in middle- and low-income regions.

Improving access to safe drinking water was a key target for Millennium Development Goal 7 (MDG 7) (Moe and Rheingans, 2006). Whilst the global MDG target of halving the proportion of people without improved drinking water was reported as met in 2010, some regions did not achieve the target and regional inequalities persist (UNICEF and WHO, 2015). Some 663 million people still lacked access to improved drinking water sources in 2015 (UNICEF and WHO, 2015) and most 'unsafe' drinking water sources are likely to be located away from a person’s home or 'off-plot' at shared public access or supply points. Importantly, even improved or 'safe' water sources are frequently located off-plot, highlighting that many people must continue to travel or walk some distance to access and bring home water for drinking and general household use (Pickering and Davis, 2012; Evans et al., 2013). Off premises or 'off-plot' access has been recognised as an important issue by the WHO/UNICEF Joint Monitoring Programme (JMP), which has incorporated the location of water source and water-fetching times into their 'ladder' for household drinking water services, to improve future monitoring of inequalities in access (WHO, 2017).

For many people, off-plot access means that the final steps of the water supply chain require manual labour to transfer water into containers from a publicly shared source, and carry water-filled containers to their house for storage at home, which will influence the quantity and quality of water available to household members (Jagals, 2006; Geere et al., 2010a; Baguma, et al., 2013). Therefore, when water is obtained by water-fetching, 'the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production' at the household level is dependent on the ability of household members to negotiate access to off-plot sources (Wutich, 2009; Stevenson et al., 2012; Diouf et al., 2014), carry sufficient quantities of water home (Geere et al., 2010a) and safely store it (Jagals, 2006).

Despite this crucial role in household water provision, the working conditions of carrying water and impact on the carrier have received little attention to date. Yet, with the 2013 Resolution of the International Conference of Labour Statisticians to recognise fetching water and other unpaid and informal service and production of goods as work, moving away from a sole focus on formal employment (ICLS, 2013) member states will be able to report water-fetching in the Labour Force Surveys. This would open up possibilities to look deeper into the working conditions of this female-dominated link in the water provision service chain.

The detrimental health impacts of regular water carrying are being increasingly recognised and have been investigated in small-scale studies (Geere et al., 2010a; Evans et al., 2013; Geere, 2015). The risks to personal safety that may occur in many areas have also been recognised (House et al., 2014). Any detrimental impact of water-fetching may be superimposed on other personal or household factors which limit capacity to access and carry water and exacerbate inequalities in water security and livelihoods. For example, older adults, orphans, people living with long-term conditions, disability or facing social stigma may be less able to access and carry water, and therefore particularly vulnerable to household water insecurity (Wrisdale et al., in press).

Comparison and analysis of reliable data on fetching water derived from multi-country surveys or datasets are limited, and mainly focus on countries of sub-Saharan Africa (Thompson, et al., 2000; Pickering and Davis, 2012; WHO, 2017). This article summarises descriptive data derived from a subset of 29 Multiple Indicator Cluster surveys (MICs) reported from 2010 to 2015, which included information on access to water and the work of carrying water. We focus on location of the water source, household member responsible for fetching water and time spent fetching water and use the data to illustrate and consider the implications of these specific factors for household water security. More complex analyses of relationships between water-fetching and health, utilising all MICs surveys containing relevant data and reported from 2010 to 2015, will be published elsewhere. This report answers the following questions

- What proportion of household respondents report their access to their main water supply as being from off-plot sources comparing different countries and regions?
- Who is typically responsible for water collection within households?
- How much time is spent fetching water in different countries and regions?

We then discuss the implications of water-fetching on household water security and opportunities for sustainable growth, highlighting water-fetching as a substantial challenge to both and to achievement of many of the Sustainable Development Goals (SDGs). We highlight the recently proposed JMP ladder for drinking water services, which incorporates location of water source and trip times for fetching water (WHO, 2017), and indices such as 'Percentage of population using safely managed drinking water services at home' as appropriate to monitor progress toward SDG 6 and to flag areas and regions vulnerable to household water insecurity between now and 2030.

BACKGROUND

Time spent fetching water and fuel reduces the time that can be devoted to generating livelihoods or in remunerated work, whether in the formal or informal economy. Poor households rely heavily on the time its members have for formal and informal work. As a result, time poverty due to the need for fetching water, firewood and other domestic chores cause trade-offs putting food security, child nutrition, health and education at risk (Kes and Swaminathan, 2006).

According to the JMP (UNICEF and WHO, 2012) about three quarters of households in sub-Saharan Africa bring water from a source located away from their home, with women and girls bearing the main responsibility for collecting water in 71% of the households. A recent JMP report highlights that in 61 DHS and MICs surveys, 73.5% of households reported women as responsible for collecting water, and in 53 out of 73 countries, over half of households without water on premises rely on women to collect water (WHO, 2017). In addition, the likelihood of a woman being the responsible person has been reported to increase as more time is needed per trip (Sorenson et al., 2011). In South Africa, in poor rural households, women who fetch water and fuelwood spend 25% less time in paid employment (Valodia and Devey, 2005).

The mean time needed to fetch water in sub-Saharan Africa is about 30 minutes per trip (UNICEF and WHO, 2012), but depending on the persons in a household and water carrying method, multiple trips per day may be required, substantially increasing the total time spent per day (Hemson, 2007; Geere et al., 2010a; Sorenson et al., 2011). Tanzanian time use data suggest that water-related infrastructure investments could free up time spent on water collection to the equivalent of, if converted into paid employment, more than half a million new full-time jobs for women (Fontana and Natali, 2008). Hutton et al. (2007) estimated that 4 billion working days would be saved by meeting the MDG target on water, equivalent of USD 15,330 million per year of global economic benefits.

Carrying water appears to have direct detrimental impacts on the physical health of the carrier (Geere, 2015), and his or her ability to participate in domestic, formal and informal work (Schatz and Gilbert, 2014). Both children and adults link persisting pain or movement problems with fetching water (Lloyd et al., 2010; Geere et al., 2010a, b) and the task may be an important factor in pain and disability linked to spinal musculoskeletal disorders and cervical compression syndromes (Evans et al., 2013).

In addition, water insecurity contributes to psychosocial and emotional distress (Wutich, 2009; Stevenson et al., 2012; Diouf et al., 2014). Stress can influence general health, disability related to musculoskeletal disorders and work performance or satisfaction. Incidents and fear of physical and sexual violence are widely reported by women and children in relation to water-fetching (Sorenson et al., 2011; House et al., 2014).

The effects of fetching water on women's health and abilities to work are likely to be more pronounced in low- and middle-income countries where a greater proportion of people are engaged in physically demanding, informal or poorly regulated work environments (Hoy et al., 2014). Furthermore, since economic, political and social inequalities are reflected in the access to drinking water (UNICEF and WHO, 2015), it is likely that marginalised groups suffer disproportionally from the negative economic and health impacts of fetching water.

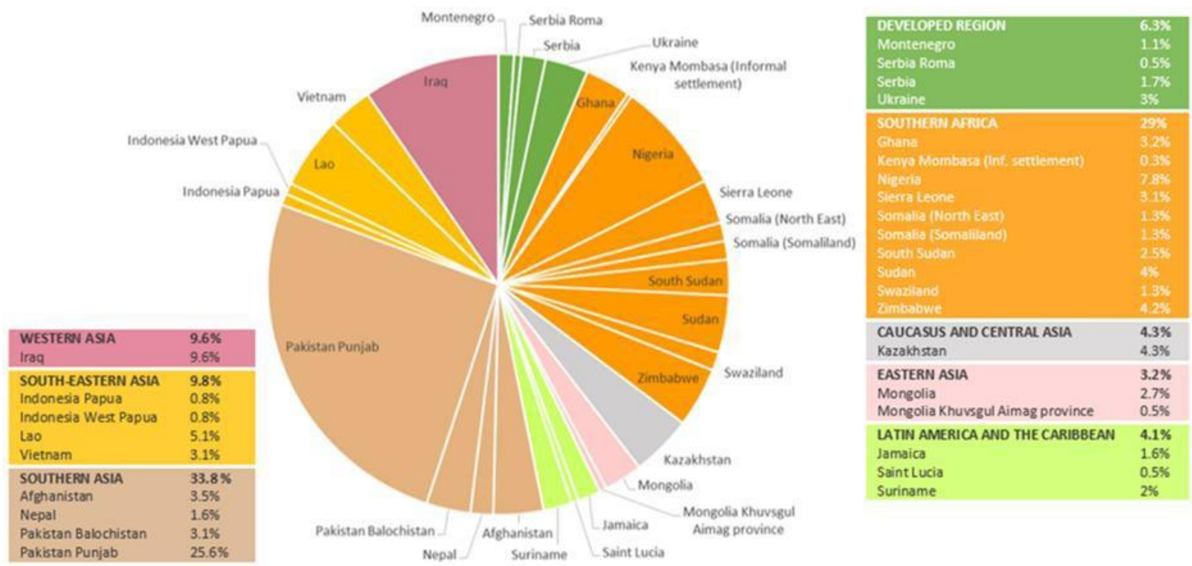
Reducing the time, distance and impact of water-fetching has a double effect: on the practical side, it can improve the quality and quantity of water supply, and on the strategic side, it has been demonstrated to have "an impact on gender/power relations both at the household and community levels and has also contributed towards greater gender equity in terms of women's decision-making and participation in local water management" (Mishra Panda, 2007). To develop effective processes and strategies for improving household water security, we must estimate the global burden of work involved in fetching water, and understand who is doing it.

METHODS

Datasets derived from 29 MICs[1] conducted in 23 countries were purposively selected as a subset of those reported and available through UNICEF in a five-year time span (2010-April 2015). The sample was chosen to ensure representation of countries classified in the UN MDG categories of 'developed countries' (n4) and 'developing' countries (n25), which include regions of sub-Saharan Africa (n10), as well as other regions (n15). The distribution of extracted survey responses per country and MDG region (UNICEF and WHO, 2015) is visualised in Figure 1.

Of these 29 surveys 20 were national surveys and 9 were limited to either a region of a country (8) or to a specific ethnic group within a country (1). A Table of the MICs questions derived for the analysis of this article can be found in Annex 1.

Figure 1. Multiple Cluster Indicator surveys (MICs); % households per region and survey.



The datasets of MICs were downloaded using the Statistical Package for the Social Sciences (SPSSv22) software and data files recording household-level variables related to access to water, women's health, and information on child health for each individual country or regional survey and were merged and prepared for analysis. All surveys were then merged for comparison.

In the household survey of the MICs the question WS3 'what is the location of the water source?' with response options 'house', 'yard', or 'elsewhere', is only asked of respondents without piped water to their house, yard, or neighbour (determined in question WS1). Therefore, variables WS1 and WS3

[1] The complete MICs survey tools can be accessed at http://mics.unicef.org/tools.

were merged to create a new variable, so that wherever possible any household without WS3 responses had their WS1 response re-categorised to indicate at-house, in yard, or 'elsewhere' location of water source. Respondents who had not answered WS3 but for WS1 reported their main drinking water source as a public standpipe, kiosk, tanker truck, cart with small tank/drum, filter plant, bottled or sachet water, or reverse osmosis and in Sudan and South Sudan as a 'water yard/hand pump' were deemed as getting their water from 'elsewhere' as these sources are unlikely to be accessed from within the house or yard. Other sources (protected/unprotected well or spring, rainwater, surface water or 'other') which could be accessed either on or off-plot were designated as 'missing'. However, most of these were wells or springs, many likely located outside of the house or yard to be situated 'elsewhere' or 'off-plot'.

In the original surveys of MICs, only respondents who did not report their main drinking water source as piped to their house, yard, or neighbour in question WS1 were asked about the location of their water source (question WS3) and only those responding 'elsewhere' to WS3 were asked about the person responsible for collecting water. As a result, because of the way in which the surveys are administered, the number of respondents to this question is reduced.

The mean time to get water and return home in minutes (question WS4) was asked of household respondents who reported obtaining their main drinking water from 'elsewhere' (i.e. neither in the house nor yard). In households with children aged 5-17 years, respondents were asked whether the child had fetched water or collected wood for household use in the previous week (question CL8), and the number of hours spent fetching water or firewood in the previous week (question CL9). IBM SPSS statistics v22 were used to establish statistical significance of mean difference in time taken to get water and return, and mean difference in hours spent fetching water or firewood, comparing urban versus rural households in the different surveys.[2]

RESULTS

Altogether 371,635 household surveys were completed in the 29 MICs, with 152,073 (41%) completed in urban areas and 219,562 (59%) completed in rural areas. Further, 6943 (1.9%) surveys were classified as missing mainly due to the uncertainty about the location of wells, springs, rainwater collection, surface water and 'other' sources of water. In all surveys, except Kenya Mombasa Informal Settlement (2.5%), Sudan (19.1%) and South Sudan (39.6%), the percent of answers with unknown location amounts to less than 1.0%. As a consequence, the number of households having to manually bring drinking water is most probably underestimated in areas where wells, springs, rainwater and surface water are common water sources.

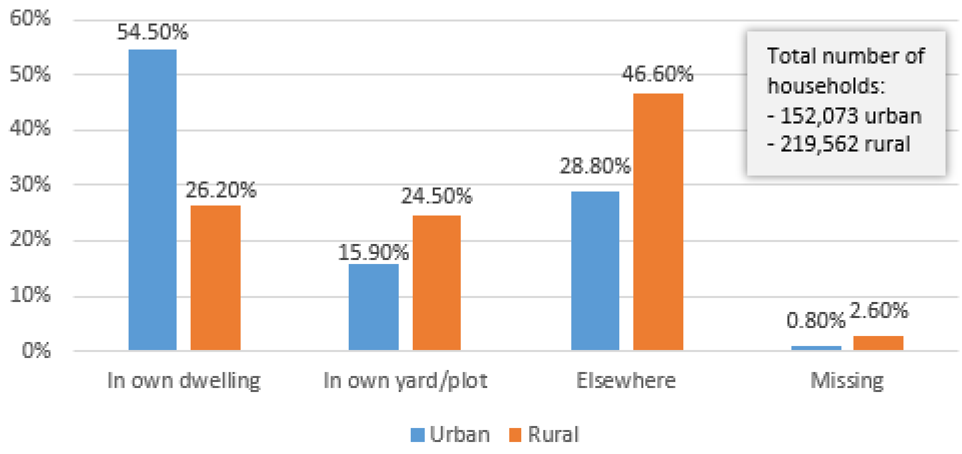
Location of main drinking water source

Of the 371,635 households, a greater proportion of urban households compared to rural households had a water supply within their house, while a smaller proportion of urban households reported a drinking water source in their yard (Figure 2). Consequently, of the urban dwellers, only a smaller share of those without water in their homes, can access it in their yard; those in the larger share (28.8%) have to look for it elsewhere.

In all surveys a greater percentage of urban compared to rural households reported having their main drinking water supply in their house. However, there was no such consistent trend regarding the proportions of urban versus rural households accessing drinking water in their yards. The combined findings overall will be influenced by the large proportion of data from Pakistan Punjab (Figure 1).

[2] The assumption of equal variances was assessed using Levene's test, to reduce the risk of a type I error. If Levene's test gave p>0.05, homogeneity of variance assumption was assumed; if Levene's test gave p< 0.05, equal variances are not assumed.

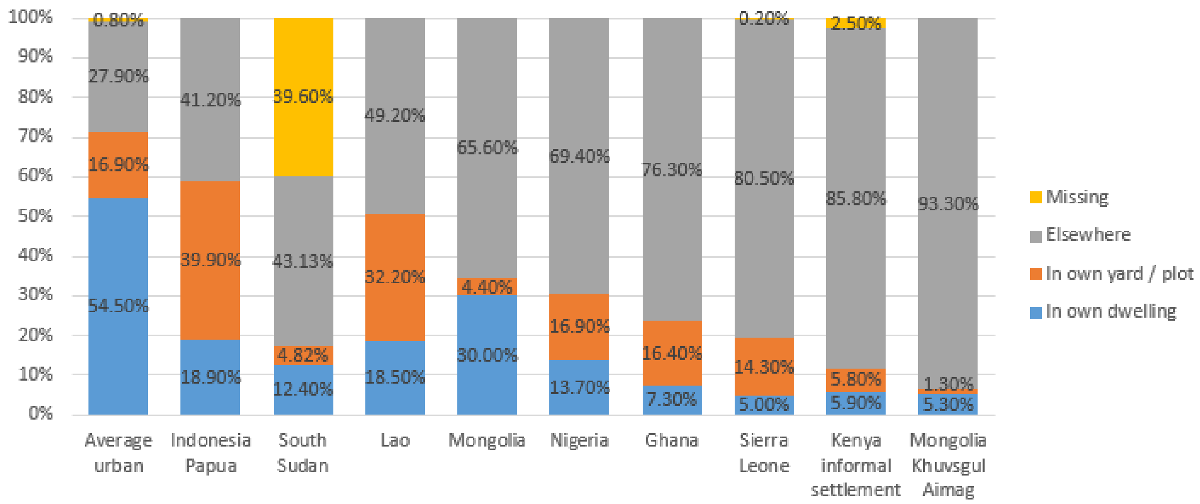
Figure 2. Location of water source urban versus rural.



In most surveys, proportionately fewer households in urban areas obtain their drinking water from 'elsewhere' compared to rural households. The exceptions are for Serbia, Pakistan Punjab and most noticeably in South Sudan. The South Sudan findings may be due to the greater proportion of rural data which had to be categorised as missing for the analysis due to the main water source being categorised as a spring or well, which could be located within the yard or elsewhere (see Figure 3). However, in some surveys (Indonesia West Papua, Lao PDR, Pakistan Punjab, Montenegro, and Serbia) the difference between percentage of urban versus rural households obtaining water from elsewhere is very small (Annex 2). In urban areas of countries of developed regions it is likely that a substantial proportion of water sourced from 'elsewhere' is bottled water, which may not require a household member to physically carry a container from a shared water source. For example, of households in urban areas of Montenegro obtaining water from elsewhere, 61.3% obtained their water from a protected spring and 35.4% had bottled water, compared to rural households where water was obtained from a greater range of sources with 46.9% using a protected spring and 30.5% using bottled water. In Serbia 80.8% of urban households obtaining water from elsewhere used bottled water, compared to 57.2% in rural areas.

Because fetching water from off-plot sources is generally accepted to be more common in rural areas, and a potentially neglected issue in urban areas, we compared location of water source in urban areas of different surveys, to highlight the extent to which water-fetching can be required in urban areas. Comparing the location of the main drinking water source in urban areas only, eight surveys (Ghana, Indonesia Papua, Kenya informal settlement, Lao, Mongolia Khuvsgul Aimag, Mongolia, Nigeria, and Sierra Leone), indicated that the largest proportion of urban households obtained their drinking water from elsewhere (i.e. outside of their own house or yard), with six of the surveys having the majority (>50%) of urban households obtaining their water from 'elsewhere' (Figure 3). In these surveys the proportion of urban households obtaining drinking water outside of their home or yard ranged from 41 to 93% of surveyed households (Figure 3).

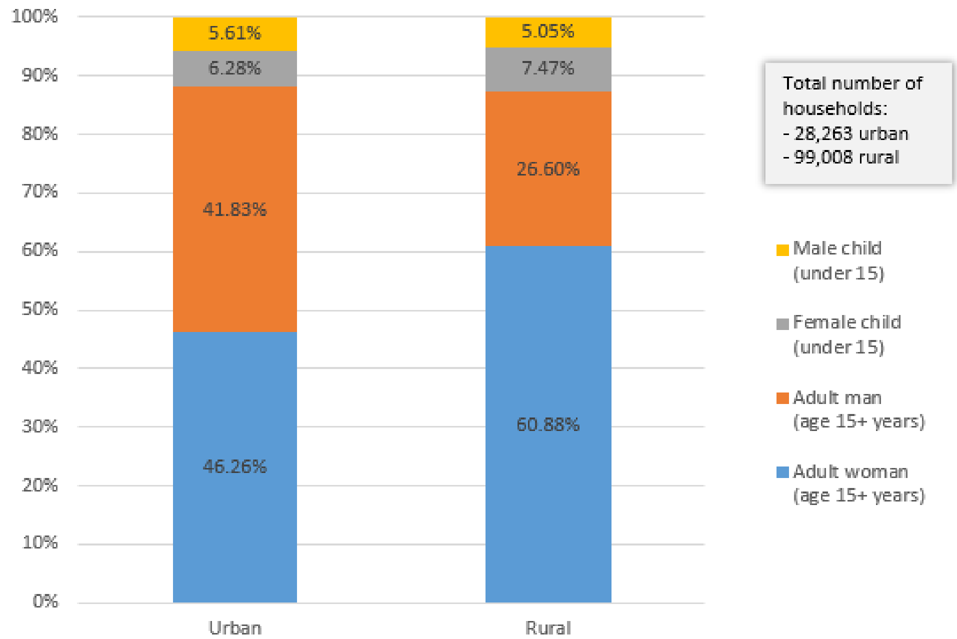
Figure 3. Surveys in which biggest proportion of urban households obtain water from elsewhere.



Person responsible for collecting water

From all surveys and in both the urban and rural areas of 127,271 households that provided information on the main person responsible for collecting water, the greatest proportion of households identified an adult woman as the main person responsible. In urban areas however, the proportion of households who identified men as the main person carrying water is almost equal to the proportion of households identifying a woman as the main person carrying water. In rural areas approximately twice as many households identify women as main carriers of water than men (Figure 4).

Figure 4. Person responsible for collecting water in percent, urban and rural areas.



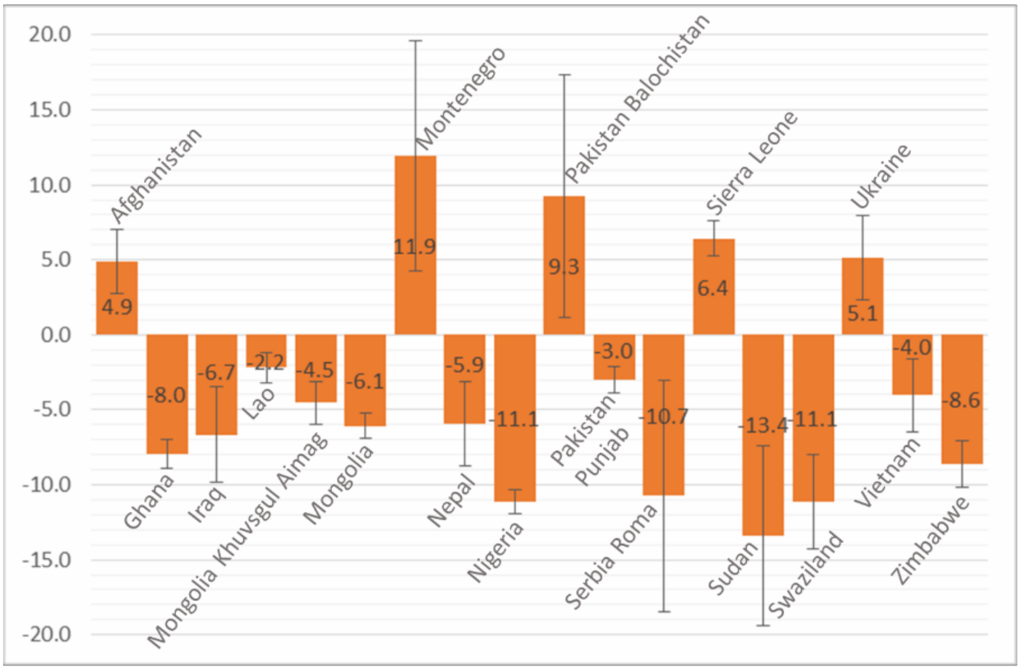
In all surveys adults were most often identified as the main person responsible for collecting water; however, the proportion of households reporting a woman or a man as that person varied between surveys, and in some regions differed between rural and urban areas. In 15 surveys (Ghana, Indonesia Papua, Lao PDR, Nepal, Nigeria, Sierra Leone, Serbia Roma, Somalia (North East), Somalia (Somaliland), Sudan, South Sudan, Suriname, Swaziland, Vietnam, and Zimbabwe) proportionately more households surveyed identified a woman as responsible in both urban and rural areas; in nine surveys (Iraq, Jamaica, Kazakhstan, Mongolia Khuvsgul Aimag, Mongolia, Montenegro, Saint Lucia, Serbia, and Ukraine) proportionately more households identified a man as responsible for collecting water in both rural and urban areas; and in four surveys (Pakistan Baluchistan, Pakistan Punjab, Indonesia West Papua, and Afghanistan) proportionately more households identified a man as responsible in urban areas and a woman in rural areas. The Mombasa informal settlement includes only urban households, and more households reported men as responsible for collecting water (Figure 5, Annex 5).

Figure 5. Person responsible for fetching water.

Time to fetch water

The mean time taken for urban households to get water from an off-plot water source (i.e. 'elsewhere') and return home ranged from 10 minutes in Lao PDR to 65 minutes in Somaliland (Annex 3). Significant differences in urban versus rural mean time to collect water and return occur in 18 of the 28 surveys with urban and rural households. Significant mean time difference between urban and rural water collection time within each survey ranges from 2-13 minutes and can be either increased or decreased in urban areas (Figure 6; Annexes 3 and 4). In Indonesia Papua, Indonesia West Papua, Jamaica, Kazakhstan, St Lucia, Serbia, Somalia (NE), Somalia (Somaliland), South Sudan and Suriname no significant difference was found.

Figure 6. Mean difference in minutes between rural and urban areas to get water and come back.



Notes: Only surveys with statistically significant difference. Negative value indicates more time taken in rural compared to urban areas.

Children and water collection

In 23 MIC surveys, children between 5 – 17 years of age were asked if they had worked to collect water or firewood in the previous week and in 22 surveys responses of children in rural versus urban households could be compared. Children who had worked fetching water or firewood in the previous week were asked how many hours they had spent working at that task. Disproportionately, children in rural rather than urban areas had spent time collecting firewood or water in the previous week. In urban areas the proportion of children engaged in this work ranged from 1% in Serbia to 60% in Mongolia Khuvsgul Aimag.

The mean number of hours spent collecting water or firewood in the previous week ranged from 1 (St Lucia) to 11.3 hours (Somalia NE). In St Lucia, Serbia Roma and Serbia the number of children reporting hours spent fetching water or firewood was small. There were significant differences in the mean number of hours spent fetching water or firewood in the previous week between children from urban and rural households in all survey responses except Jamaica, Montenegro, Saint Lucia, Serbia, Suriname, Ukraine and Vietnam. The significant mean differences in hours spent in the previous week ranged from 0.4 hours or 20 minutes in Sierra Leone (greater in rural areas) to 4.2 hours in Serbia Roma (greater in urban areas).

Discussion

Location of main drinking water source

Within MICs surveys, information about the location of water source is only asked of households reporting access to their main source of drinking water from public standpipes or other non-piped sources. However, within the MICs surveys included in this study, there was a large proportion of missing data in some areas. For example, with South Sudan and Sudan, types of water source commonly reported (well or spring) did not also indicate whether the source was on or off plot. If we had treated all such indeterminate data as off-plot rather than 'missing' data, we would have larger proportions of households accessing water 'elsewhere' and therefore likely to be engaged in the work of fetching water. Even with this potential underestimation, our findings are consistent with the 2015 update of progress on sanitation and drinking water (UNICEF and WHO, 2015) which highlights that despite important improvements in the last 15 years, rural-urban disparities persist. Our findings also highlight the importance of obtaining information about the on-plot or off-plot location of springs, wells and rainwater sources in household surveys to more accurately indicate the burden of work in fetching water.

While in most global regions urban coverage of piped water on premises remains higher than in rural areas (UNICEF and WHO, 2015), our findings highlight that coverage within urban areas may still be poor in developing regions, particularly in informal settlements. Informal settlements are a very specific type of urban space that generally does not have access to basic services because the settlement is 'illegal'. Although this makes it difficult to compare the situation of informal settlements with other urban areas that would include both informal and formal urban areas, our analysis indicates very clearly that there are stark differences even within cities. This finding is particularly important when considering the challenges of maintaining public health in urban areas of developing countries, which can be affected by high rates of rural-urban migration (Bieker et al., 2010), protracted armed conflict (ICRC, 2015), and epidemics of infectious diseases (Brainard et al., 2015).

Person responsible for collecting water

For both urban and rural areas the greatest proportion of households identified an adult woman as the main person responsible for collecting water and in all individual surveys an adult was most often identified as the main person responsible for collecting water. However, the gender of the person responsible for collecting water in most households varies between both countries and regions.

In 15 surveys, including all of those from sub-Saharan Africa except the informal settlement of Mombasa, Kenya, water collection is more commonly reported as a woman’s responsibility in both rural and urban areas. Surveys from the remaining 14 developed and developing regions had proportionately more households indicating a man as the main person responsible for collecting water in urban areas, and in rural areas of just four of these, proportionately more households identified a woman as responsible for collecting water. Thus, contrary to many reports (Ferguson, 1986; Crow, 2001; Buor, 2004; Sultana, 2009; Baguma et al., 2013), our findings indicate that in many regions, the majority of households do not report collecting water is a woman’s responsibility.

There are several possible explanations for our findings. Traditional cultural and religious practices may determine who is tasked with fetching water at locations away from home, and traditional practices may change over time, or with migration or urbanisation. Rural-urban migration for employment may mean that in urban areas there are more households comprising only men, or that 'traditional' gender roles for household chores typical of rural areas are not observed by younger generations living in urban areas. Increasing access to vehicles or other equipment to bring home more water more easily may also be a factor, particularly where men are more likely to have learned the skills required to drive vehicles or operate equipment. An increase in informal water vending may lead men to take responsibility for obtaining water if they control or manage household monetary transactions. In areas of armed conflict, men may replace or escort women during water collection for safety reasons, and therefore be seen as the ultimate person responsible for water collection. Alternatively, it is possible that the image of the female water carrier is simply not true in many parts of the world, and was extrapolated from observations in sub-Saharan Africa.

However, in sub-Saharan African countries water collection is most often a responsibility of women, and in rural areas of other regions (e.g. Afghanistan and Suriname), women play an important role in accessing and securing household water. In these regions, the inclusion of women's perspectives is likely to be particularly important to voice community needs for household water security against the competing demands of other groups (Baguma et al., 2013). This is especially so, since case studies from Panama, Philippines, and Senegal indicate that as service provision is formalised and institutionalised men tend to take the lead, making skills training and affirmative actions in employment and water management intrinsic components of policies to include women in formal water work (Reyes, 2014). Since research has shown that women tend to prioritise investments in drinking water more than men and that equal participation in water and sanitation increase efficiency and sustainability (WSP and IRC, 2000; Chattopadhyay and Duflo, 2004), promoting gender equality in water management can also be a way to lift the water issue on the political agenda and to catalyse lasting improvements in access to water and sanitation services.

Time to get water and come back

Combining all surveys, the mean time taken to get water and come back is 28 minutes. Statistically significant differences were found in urban versus rural mean time to collect water and return in 19 surveys. However, the actual mean time differences are not large (ranging from 2 to 13 minutes) and indicate that once water must be sourced from out of the home or yard, return trip water collection times are similar in rural and urban areas. The data cannot demonstrate whether this is due to similar distances to off-plot water sources in rural and urban areas, or other factors. For example, it is possible that crowding and queueing times may be longer in urban areas, even if actual distances to water points are reduced. It is probable that people in rural areas also need to collect firewood or perform other types of informal reproductive or manual labouring work that takes up their time and energy. Particularly if combined with poorer health, limited access to health services and poverty, as is often the case in low-income households of rural areas and some urban areas, fetching water may exacerbate water insecurity and be a barrier to sustainable development. These differences are likely to cement existing inequalities or poverty and increase the risk of them being transferred across generations.

The data are also limited in that they indicate only the time taken for one trip for water collection. The surveys do not account for the number of trips required to obtain sufficient water for household needs or differences which create barriers to access for vulnerable people. Household needs are likely to vary greatly according to the number of people in the household, activities performed in the household, and the health of household members. Barriers to access can be due to environmental factors affecting safety or physical exertion required for water collection (Geere et al., 2010a; Geere, 2015; ICRC, 2015) and in many regions create particular challenges for people with disability (Groce et al., 2011). The number and timing of trips for water collection may also be influenced by the reliability of water supplies. A strategy which has been reported in regions where household water supplies are unreliable, is to collect as much water as possible over many trips for storage at home to cover periods when a public service has broken down (Geere, 2015). These differences in household needs and service reliability may create substantial inequalities in access to safe drinking water which are not reflected by the mean time taken for one trip for water collection (Geere, 2015).

Children and water collection

In all of the 22 surveys with rural-urban comparisons, proportionately more children in rural areas had spent time collecting firewood or water (Annex 6). There were statistically significant differences in the mean number of hours spent fetching water or firewood in the previous week between children from urban and rural households in 15 surveys.

The marked differences in time spent fetching water and firewood between countries may influence the impact which this activity has on childhood growth, health and development. The data cannot indicate how well matched the work of water-fetching is to a child's capacity to safely perform the task, which may vary greatly depending on the child's age, health, and circumstances (Geere et al., 2010a). In some regions, it may take up important opportunities to spend time on other activities, such as completing school work or doing sports activities, and expose children to environmental hazards, physical jeopardy, or physical strain and pain (Hemson, 2007; Geere et al., 2010b). Alternatively, it may be seen as a valuable use of time which makes life better through participation in physical activity and household tasks, or through remuneration (Geere et al., 2010b). Nevertheless, given their greater vulnerability and reduced physical strength compared to adults, it is hard to understand how reliance on children as a labour force to obtain sufficient water for household needs and development can be deemed secure, safe or sustainable.

Monitoring and evaluation of access to water and fetching water

MIC surveys provide a valuable source of basic information about access to water and time per trip in fetching water in many countries. However, it is clear that more detailed information is needed to understand the true impact of the work of fetching water on household resources and individuals and to understand which regions, communities and households face water insecurity. In particular, the following information would provide more insight into the impact of this work:

- Usual number of trips in fetching water per day or week, to estimate total time required for work on fetching water.
- Measured distance to water source or time taken for water-fetching, as self-reported travel time for fetching water may be influenced by recall and has been shown to be an inaccurate indicator of distance to water source (Ho et al., 2014).
- Method of carrying water, as access to equipment which would reduce the strain of carrying water is likely to be affected by poverty and gender (Geere et al., 2010a).
- Health and disability status of individuals in the household and of those who carry water, as this may influence capacity to obtain sufficient water for household needs and effect quantities of water required to maintain household health (Geere, 2015).
- Safety of individuals engaged in fetching water from off-plot sources, which can indicate quality of work and highlight risks related to the working environment.

Disaggregation by social categories, such as ethnicity, race, capabilities, and economic quintile, would enable a better understanding of how different social and cultural groups are affected. This would greatly support efforts to develop differentiated strategies focused on the most marginalised groups in society, in line with the intent of SDG 7 and the Human Rights to Water and Sanitation. Issues related to the working conditions of carrying water could also be strengthened or integrated in the MICs, but considering the recognition of water-fetching as work by the International Conference of Labour Statisticians, the Labour Force Surveys could also provide a suitable framework to look at aspects such as method of fetching, health and safety issues and use of time. In such a case harmonisation of methods to enable comparability will be key.

New approaches to data collection are needed to supplement the information gathered in MIC surveys if we are to better understand the impact of fetching water on water security and sustainable development. Improved data collection could also reduce the overall burden of work due to carrying water, by facilitating improved levels of water service provision and maintenance. Mobile devices and networks have revolutionised communication globally, particularly in sub-Saharan Africa. Researchers have begun to explore their potential to improve monitoring, evaluation and maintenance of water services, and to leverage improved access to water. For example, mobile devices have been used to support operational management of water distribution in Colombia, monitor data on water level in The Netherlands, advise farmers in Ethiopia and provide urban flood warnings to citizens in Dhaka, Bangladesh (Jonoski et al., 2012) and also to monitor WaSH services in some areas (Tomlinson et al., 2009; Kumpel et al., 2015; Van-Ess et al., 2015).

Mobile devices and networks may provide ways to improve water service provider and user communications for better information-sharing and strengthened partnerships. They may also enhance local capacity to identify and voice community needs for household water security against competing demands of other groups, particularly by engaging water carriers in service monitoring. Improved service monitoring could substantially mitigate detrimental effects of carrying water, by improving reliability and maintenance of water supply systems, and through better communication, enabling households to choose appropriate coping strategies during service disruptions.

Finally, if we are to meet the SDGs and reduce inequalities, estimating the scale of global work on fetching water, and the proportion of households accessing water off-plot to identify who has what he or she needs will be crucial; thus, the importance given to the development of indicators for the 17 goals. With better information and understanding of the constraints under which different groups live we can move forward to SDG 5 on gender, SDG 6 on water and SDG 8 on decent work and economic growth by reducing the global need for fetching water. In particular, proposed changes to monitoring and reporting incorporated in the JMP's 'ladder' for household drinking water (WHO, 2017) which will identify the 'Percentage of population using safely managed drinking water services at home' are appropriate and important strategies to monitor the extent of water-fetching, progress toward SDGs and to flag areas and regions vulnerable to household water insecurity because of location of source of water between now and 2030.

LIMITATIONS

The data represented in figures with combined information from all surveys included in this study were not weighted, and will be influenced by differences in proportional representation of surveys within this dataset. The summary figures are used to indicate the unadjusted data from the surveys included in this report and cannot be generalised to indicate a global picture. However, individual MICs surveys are conducted to a rigorous standard and provide data representative of the country or region of the survey indicated by the survey title, such that it is appropriate for comparisons between surveys to be made.

CONCLUSIONS

The synthesis of MICs data demonstrates that, even if the MDG target on access to safe drinking water has been met, large populations globally still have to physically bring water to their homes. In most countries, this responsibility is predominantly carried by women, particularly in rural areas, yet in urban areas men also take on a substantial share of the burden. The detrimental health and security implications that arise from this informal water provision work highlight an often overlooked dimension related to the definition of 'access to safe drinking water' and one which is a substantial barrier to household water security, sustainable development and achievement of the SDGs. Our findings support the implementation of the JMP's drinking water services ladder and use of 'Percentage of population using safely managed drinking water services at home' as appropriate indicators to monitor progress toward SDGs and to flag areas and regions with substantial numbers of households vulnerable to water insecurity between now and 2030.

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ANNEXES

Annex 1. MICs questions used for the analysis

WS1. What is the main source of drinking water for members of your household?	Piped water Piped into dwelling.................................11 Piped into compound, yard or plot ....12 Piped to neighbour................................13 Public tap/standpipe ....14 Tube Well, Borehole.................................21 Dug well Protected well ....31 Unprotected well....................................32 Water from spring Protected spring.....................................41 Unprotected spring ....42 Rainwater collection.................................51 Tanker-truck ....61 Cart with small tank/drum ....71 Surface water (river, stream, dam, lake, pond, canal, irrigation channel) ....81 Bottled water ....91 Other (*specify*)________________________96	 11⇨WS6 12⇨WS6 13⇨WS6 14⇨WS3 21⇨WS3 31⇨WS3 32⇨WS3 41⇨WS3 42⇨WS3 51⇨WS3 61⇨WS3 71⇨WS3 81⇨WS3 96⇨WS3
WS3. Where is that water source located?	In own dwelling...1 In own yard/plot...2 Elsewhere 3	1⇨WS6 2⇨WS6
WS4. How long does it take to go there, get water, and come back?	Number of minutes .... Don't know 998	
WS5. Who usually goes to this source to collect the water for your household? *Probe:* Is this person under age 15? What sex?	Adult woman (age 15+ years) ....1 Adult man (age 15+ years) ....2 Female child (under 15) ....3 Male child (under 15) ....4 Don't know 8	
CL8. Since last (day of the week), did (name) fetch water or collect firewood for household use?	Yes ....1 No 2	 2⇨ CL10
CL9. In total, how many hours did (name) spend on fetching water or collecting firewood for household use, since last (day of the week)?	Number of hours................................______	

Annex 2. Location of main drinking water source rural vs. urban

Country				Location of the water source: In own dwelling	In own yard / plot	Elsewhere	Missing	Total
UN MDG Developed Region								
Montenegro	Area	Urban	Count	2287	19	210	1	2517
			% within area	90.9	0.8	8.3	0.0	100.0
		Rural	Count	1149	260	126	0	1535
			% within area	74.9	16.9	8.2	0.0	100.0
	Total		Count	3436	279	336	1	4052
			% within area	84.8	6.9	8.3	0.0	100.0
Serbia Roma	Area	Urban	Count	892	167	75	0	1134
			% within area	78.7	14.7	6.6	0.0	100.0
		Rural	Count	303	158	145	3	609
			% within area	49.8	25.9	23.8	0.5	100.0
	Total		Count	1195	325	220	3	1743
			% within area	68.6	18.6	12.6	0.2	100.0
Serbia	Area	Urban	Count	3023	43	636	0	3702
			% within area	81.7	1.2	17.2	0.0	100.0
		Rural	Count	1900	232	353	4	2489
			% within area	76.3	9.3	14.2	0.2	100.0
	Total		Count	4923	275	989	4	6191
			% within area	79.5	4.4	16.0	0.1	100.0
Ukraine	Area	Urban	Count	5879	795	666	4	7344
			% within area	80.1	10.8	9.1	0.1	100.0
		Rural	Count	1123	2401	453	0	3977
			% within area	28.2	60.4	11.4	0.0	100.0
	Total		Count	7002	3196	1119	4	11321
			% within area	61.8	28.2	9.9	0.0	100.0
UN MDG Developing Region sub-Saharan Africa								
Ghana	Area	Urban	Count	332	744	3469		4545
			% within area	7.3	16.4	76.3		100.0
		Rural	Count	59	206	7115		7380
			% within area	0.8	2.8	96.4		100.0
	Total		Count	391	950	10584		11925
			% within area	3.3	8.0	88.8		100.0
Kenya Mombasa Informal	Area	Urban	Count	60	59	872	25	1016
			% within area	5.9	5.8	85.8	2.5	100.0
	Total		Count	60	59	872	25	1016
			% within area	5.9	5.8	85.8	2.5	100.0
Sierra Leone	Area	Urban	Count	193	552	3103	8	3856
			% within area	5.0	14.3	80.5	0.2	100.0
		Rural	Count	99	392	7022	25	7538
			% within area	1.3	5.2	93.2	0.3	100.0
	Total		Count	292	944	10125	33	11394
			% within area	2.6	8.3	88.9	0.3	100.0
Somalia (North East)	Area	Urban	Count	1213	967	899	18	3097
			% within area	39.2	31.2	29.0	0.6	100.0
		Rural	Count	137	384	1136	23	1680
			% within area	8.2	22.9	67.6	1.4	100.0
	Total		Count	1350	1351	2035	41	4777
			% within area	28.3	28.3	42.6	0.9	100.0

Somalia (Somaliland)	Area	Urban	Count	1016	580	796	1	2393
			% within area	42.5	24.2	33.3	0.0	100.0
		Rural	Count	277	447	1684	7	2415
			% within area	11.5	18.5	69.7	0.3	100.0
	Total		Count	1293	1027	2480	8	4808
			% within area	26.9	21.4	51.6	0.2	100.0
South Sudan	Area	Urban	Count	41	45	1603	731	2420
			% within area	1.7	1.9	66.2	30.2	100.0
		Rural	Count	26	24	3922	2977	6949
			% within area	0.4	0.3	56.4	42.8	100.0
	Total		Count	67	69	5525	3708	9369
			% within area	0.7	0.7	59.0	39.6	100.0
Sudan	Area	Urban	Count	736	1552	1948	243	4479
			% within area	16.4	34.7	43.5	5.4	100.0
		Rural	Count	367	1680	5679	2573	10299
			% within area	3.6	16.3	55.1	25.0	100.0
	Total		Count	1103	3232	7627	2816	14778
			% within area	7.5	21.9	51.6	19.1	100.0
Swaziland	Area	Urban	Count	770	871	453	1	2095
			% within area	36.8	41.6	21.6	0.0	100.0
		Rural	Count	219	654	1864	2	2739
			% within area	8.0	23.9	68.1	0.1	100.0
	Total		Count	989	1525	2317	3	4834
			% within area	20.5	31.5	47.9	0.1	100.0
Zimbabwe	Area	Urban	Count	2170	1545	1414	5	5134
			% within area	42.3	30.1	27.5	0.1	100.0
		Rural	Count	267	1767	8504	14	10552
			% within area	2.5	16.7	80.6	0.1	100.0
	Total		Count	2437	3312	9918	19	15686
			% within area	15.5	21.1	63.2	0.1	100.0
Other								
Afghanistan	Area	Urban	Count	792	1657	1096	0	3545
			% within area	22.3	46.7	30.9	0.0	100.0
		Rural	Count	1155	1867	6542	7	9571
			within area	12.1	19.5	68.4	0.1	100.0
	Total		Count	1947	3524	7638	7	13116
			% within area	14.8	26.9	58.2	0.1	100.0
Indonesia Papua	Area	Urban	Count	194	410	423	0	1027
			% within area	18.9	39.9	41.2	0.0	100.0
		Rural	Count	114	588	1135	2	1839
			% within area	6.2	32.0	61.7	0.1	100.0
	Total		Count	308	998	1558	2	2866
			% within area	10.7	34.8	54.4	0.1	100.0
Indonesia West Papua	Area	Urban	Count	221	380	237	2	840
			% within area	26.3	45.2	28.2	0.2	100.0
		Rural	Count	279	1143	548	6	1976
			% within area	14.1	57.8	27.7	0.3	100.0
	Total		Count	500	1523	785	8	2816
			% within area	17.8	54.1	27.9	0.3	100.0
Iraq	Area	Urban	Count	14091	1288	6027	0	21406

			% within area	65.8	6.0	28.2	0.0	100.0
		Rural	Count	6217	3441	4636	1	14295
			% within area	43.5	24.1	32.4	0.0	100.0
	Total		Count	20308	4729	10663	1	35701
			% within area	56.9	13.2	29.9	0.0	100.0
Jamaica	Area	Urban	Count	2358	768	491	3	3620
			% within area	65.1	21.2	13.6	0.1	100.0
		Rural	Count	922	781	637	0	2340
			% within area	39.4	33.4	27.2	0.0	100.0
	Total		Count	3280	1549	1128	3	5960
			% within area	55.0	26.0	18.9	0.1	100.0
Kazakhstan	Area	Urban	Count	8043	536	1050		9629
			% within area	83.5	5.6	10.9		100.0
		Rural	Count	1532	2202	2437		6171
			% within area	24.8	35.7	39.5		100.0
	Total		Count	9575	2738	3487		15800
			% within area	60.6	17.3	22.1		100.0
Lao PDR	Area	Urban	Count	876	1525	2328	1	4730
			within area	18.5	32.2	49.2	0.0	100.0
		Rural	Count	1324	5834	6952	3	14113
			% within area	9.4	41.3	49.3	0.0	100.0
	Total		Count	2200	7359	9280	4	18843
			% within area	11.7	39.1	49.2	0.0	100.0
Mongolia Khuvsgul Aimag	Area	Urban	Count	24	6	419		449
			% within area	5.3	1.3	93.3		100.0
		Rural	Count	4	22	1507		1533
			% within area	0.3	1.4	98.3		100.0
	Total		Count	28	28	1926		1982
			% within area	1.4	1.4	97.2		100.0
Mongolia	Area	Urban	Count	1429	208	3123	0	4760
			% within area	30.0	4.4	65.6	0.0	100.0
		Rural	Count	157	294	4877	4	5332
			% within area	2.9	5.5	91.5	0.1	100.0
	Total		Count	1586	502	8000	4	10092
			% within area	15.7	5.0	79.3	0.0	100.0
Nepal	Area	Urban	Count	151	632	437	8	1228
			% within area	12.3	51.5	35.6	0.7	100.0
		Rural	Count	106	1227	3326	12	4671
			% within area	2.3	26.3	71.2	0.3	100.0
	Total		Count	257	1859	3763	20	5899
			% within area	4.4	31.5	63.8	0.3	100.0
Nigeria	Area	Urban	Count	996	1223	5031	1	7251
			% within area	13.7	16.9	69.4	0.0	100.0
		Rural	Count	1604	2509	17701	12	21826
			% within area	7.3	11.5	81.1	0.1	100.0
	Total		Count	2600	3732	22732	13	29077
			% within area	8.9	12.8	78.2	0.0	100.0
Pakistan Balochistan	Area	Urban	Count	2045	275	302	4	2626
			% within area	77.9	10.5	11.5	0.2	100.0
		Rural	Count	2684	1742	4508	52	8986
			% within area	29.9	19.4	50.2	0.6	100.0
	Total		Count	4729	2017	4810	56	11612
			% within area	40.7	17.4	41.4	0.5	100.0

Pakistan Punjab	Area	Urban	Count	27538	5041	5683	113	38375
			% within area	71.8	13.1	14.8	0.3	100.0
		Rural	Count	32526	16866	7450	21	56863
			% within area	57.2	29.7	13.1	0.0	100.0
	Total		Count	60064	21907	13133	134	95238
			% within area	63.1	23.0	13.8	0.1	100.0
Saint Lucia	Area	Urban	Count	404	73	201	0	678
			% within area	59.6	10.8	29.6	0.0	100.0
		Rural	Count	590	123	325	2	1040
			% within area	56.7	11.8	31.3	0.2	100.0
	Total		Count	994	196	526	2	1718
			% within area	57.9	11.4	30.6	0.1	100.0
Suriname	Area	Urban	Count	2280	721	171	4	3176
			% within area	71.8	22.7	5.4	0.1	100.0
		Rural	Count	1206	2035	978	12	4231
			% within area	28.5	48.1	23.1	0.3	100.0
	Total		Count	3486	2756	1149	16	7407
			% within area	47.1	37.2	15.5	0.2	100.0
Vietnam	Area	Urban	Count	2795	1493	708	5	5001
			% within area	55.9	29.9	14.2	0.1	100.0
		Rural	Count	1235	4611	764	3	6613
			% within area	18.7	69.7	11.6	0.0	100.0
	Total		Count	4030	6104	1472	8	11614
			% within area	34.7	52.6	12.7	0.1	100.0
Total	Area	Urban	Count	82849	24175	43871	1178	152073
			% within area	54.5	15.9	28.8	0.8	100.0
		Rural	Count	57581	53890	102326	5765	219562
			% within area	26.2	24.5	46.6	2.6	100.0
	Total		Count	140430	78065	146197	6943	371635
			% within area	37.8	21.0	39.3	1.9	100.0

ANNEX 3. TIME TO GET WATER AND RETURN (IN MINUTES)

Country		Area	N	Mean	Std. Deviation	Std. Error Mean
Afghanistan	Time (in minutes) to get water and return	Urban	911	28.12	31.119	1.031
		Rural	6262	23.25	26.050	.329
Ghana	Time (in minutes) to get water and return	Urban	2185	20.36	18.846	.403
		Rural	6974	28.32	22.066	.264
Indonesia Papua	Time (in minutes) to get water and return	Urban	140	20.44	19.504	1.648
		Rural	1096	18.80	17.547	.530
Indonesia West Papua	Time (in minutes) to get water and return	Urban	130	18.05	12.045	1.056
		Rural	484	19.15	16.486	.749
Iraq	Time (in minutes) to get water and return	Urban	740	26.71	38.612	1.419
		Rural	2603	33.38	39.286	.770
Jamaica	Time (in minutes) to get water and return	Urban	123	21.16	24.117	2.175
		Rural	469	23.68	27.102	1.251
Kazakhstan	Time (in minutes) to get water and return	Urban	756	18.77	18.086	.658
		Rural	2319	19.47	15.883	.330
Kenya Mombasa Informal	Time (in minutes) to get	Urban	805	12.65	20.317	.716

	water and return	Rural	0[a]	.	.	.
Lao PDR	Time (in minutes) to get water and return	Urban	417	10.12	10.278	.503
		Rural	6472	12.31	13.341	.166
Mongolia Khuvsgul Aimag	Time (in minutes) to get water and return	Urban	419	15.11	10.547	.515
		Rural	1504	19.65	19.043	.491
Mongolia	Time (in minutes) to get water and return	Urban	3110	19.08	13.180	.236
		Rural	4852	25.16	25.551	.367
Montenegro	Time (in minutes) to get water and return	Urban	117	38.97	26.200	2.422
		Rural	83	27.04	28.217	3.097
Nepal	Time (in minutes) to get water and return	Urban	439	21.76	28.140	1.343
		Rural	3315	27.69	30.202	.525
Nigeria	Time (in minutes) to get water and return	Urban	4599	19.36	19.508	.288
		Rural	17296	30.49	36.347	.276
Pakistan Baluchistan	Time (in minutes) to get water and return	Urban	207	50.76	58.271	4.050
		Rural	3751	41.51	38.414	.627
Pakistan Punjab	Time (in minutes) to get water and return	Urban	4140	23.56	19.698	.306
		Rural	6364	26.52	26.023	.326
Saint Lucia	Time (in minutes) to get water and return	Urban	26	14.62	13.526	2.653
		Rural	35	21.57	21.360	3.611
Serbia Roma	Time (in minutes) to get water and return	Urban	17	13.35	6.557	1.590
		Rural	98	24.08	35.185	3.554
Serbia	Time (in minutes) to get water and return	Urban	109	47.84	47.596	4.559
		Rural	136	42.07	54.465	4.670
Sierra Leone	Time (in minutes) to get water and return	Urban	2622	23.80	29.552	.577
		Rural	6749	17.39	14.346	.175
Somalia (North East)	Time (in minutes) to get water and return	Urban	746	53.36	60.642	2.220
		Rural	1088	58.18	76.209	2.310
Somalia (Somaliland)	Time (in minutes) to get water and return	Urban	424	65.44	79.154	3.844
		Rural	1564	62.66	77.086	1.949
South Sudan	Time (in minutes) to get water and return	Urban	2105	38.47	58.513	1.275
		Rural	6721	38.74	47.860	.584
Sudan	Time (in minutes) to get water and return	Urban	625	38.94	71.042	2.842
		Rural	5382	52.34	82.683	1.127
Suriname	Time (in minutes) to get water and return	Urban	27	37.59	44.938	8.648
		Rural	776	20.29	23.097	.829
Swaziland	Time (in minutes) to get water and return	Urban	286	24.02	23.851	1.410
		Rural	1794	35.14	31.530	.744
Ukraine	Time (in minutes) to get water and return	Urban	275	21.07	21.169	1.277
		Rural	430	15.94	13.502	.651
Vietnam	Time (in minutes) to get water and return	Urban	87	10.86	9.196	.986
		Rural	572	14.90	17.927	.750
Zimbabwe	Time (in minutes) to get water and return	Urban	1268	20.91	25.869	.726
		Rural	8429	29.55	27.831	.303

[a] Rural value cannot be computed for Kenya Mombasa Informal settlement

ANNEX 4. TIME TO GET WATER AND RETURN (IN MINUTES)

Country		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Afghanistan	Yes	42.093	.000	5.132	7171	.000	4.867	.948	3.008	6.727
	No			4.497	1103.331	.000	4.867	1.082	2.744	6.991
Ghana	Yes	80.607	.000	-15.206	9157	.000	-7.956	.523	-8.982	-6.931
	No			-16.506	4219.265	.000	-7.956	.482	-8.902	-7.011
Indonesia	Yes	4.955	.026	1.027	1234	.304	1.639	1.596	-1.491	4.770
Papua	No			.947	169.000	.345	1.639	1.731	-1.779	5.057
Indonesia	Yes	3.672	.056	-.712	612	.477	-1.101	1.546	-4.138	1.937
West Papua	No			-.850	273.015	.396	-1.101	1.295	-3.650	1.449
Iraq	Yes	4.507	.034	-4.085	3341	.000	-6.661	1.630	-9.858	-3.464
	No			-4.125	1208.274	.000	-6.661	1.615	-9.829	-3.493
Jamaica	Yes	2.021	.156	-.937	590	.349	-2.515	2.686	-7.790	2.759
	No			-1.003	210.191	.317	-2.515	2.509	-7.461	2.430
Kazakhstan	Yes	.200	.654	-1.020	3073	.308	-.703	.689	-2.054	.648
	No			-.955	1158.525	.340	-.703	.736	-2.146	.741
Lao PDR	Yes	19.152	.000	-3.292	6887	.001	-2.191	.666	-3.496	-.886
	No			-4.135	510.832	.000	-2.191	.530	-3.233	-1.150
Mongolia	Yes	37.859	.000	-4.680	1921	.000	-4.537	.969	-6.438	-2.636
Khuvsgul A.	No			-6.374	1238.062	.000	-4.537	.712	-5.933	-3.140
Mongolia	Yes	275.984	.000	-12.268	7960	.000	-6.082	.496	-7.053	-5.110
	No			-13.937	7655.915	.000	-6.082	.436	-6.937	-5.226
Montenegro	Yes	.141	.708	3.075	198	.002	11.938	3.882	4.282	19.594
	No			3.036	168.439	.003	11.938	3.932	4.176	19.700
Nepal	Yes	17.381	.000	-3.898	3752	.000	-5.934	1.522	-8.918	-2.949
	No			-4.115	580.045	.000	-5.934	1.442	-8.765	-3.102
Nigeria	Yes	422.187	.000	-20.012	21893	.000	-11.129	.556	-12.219	-10.039
	No			-27.898	13863.816	.000	-11.129	.399	-11.911	-10.347
Pakistan	Yes	29.770	.000	3.265	3956	.001	9.253	2.834	3.697	14.809
Baluchistan	No			2.258	215.992	.025	9.253	4.098	1.175	17.331
Pakistan	Yes	106.759	.000	-6.246	10502	.000	-2.960	.474	-3.889	-2.031
Punjab	No			-6.617	10265.354	.000	-2.960	.447	-3.837	-2.083
Saint Lucia	Yes	1.157	.286	-1.456	59	.151	-6.956	4.777	-16.515	2.603
	No			-1.553	57.735	.126	-6.956	4.480	-15.925	2.013
Serbia Roma	Yes	5.681	.019	-1.249	113	.214	-10.729	8.589	-27.745	6.288
	No			-2.755	112.412	.007	-10.729	3.894	-18.443	-3.014
Serbia	Yes	.271	.603	.872	243	.384	5.778	6.624	-7.270	18.826
	No			.885	241.154	.377	5.778	6.526	-7.078	18.634
Sierra Leone	Yes	316.227	.000	14.065	9369	.000	6.413	.456	5.519	7.306
	No			10.635	3112.758	.000	6.413	.603	5.230	7.595
Somalia	Yes	1.820	.178	-1.445	1832	.149	-4.830	3.342	-11.383	1.724
(North East)	No			-1.507	1791.931	.132	-4.830	3.204	-11.114	1.455
Somalia	Yes	3.956	.047	.654	1986	.513	2.775	4.245	-5.550	11.100
(Somaliland)	No			.644	656.740	.520	2.775	4.310	-5.688	11.238
South Sudan	Yes	.082	.774	-.215	8824	.829	-.272	1.264	-2.750	2.205

	No			-.194	3036.353	.846	-.272	1.403	-3.022	2.478
Sudan	Yes	11.650	.001	-3.888	6005	.000	-13.399	3.446	-20.155	-6.643
	No			-4.383	833.362	.000	-13.399	3.057	-19.400	-7.399
Suriname	Yes	29.540	.000	3.664	801	.000	17.300	4.722	8.032	26.569
	No			1.991	26.480	.057	17.300	8.688	-.542	35.143
Swaziland	Yes	14.906	.000	-5.710	2078	.000	-11.121	1.948	-14.941	-7.301
	No			-6.974	460.241	.000	-11.121	1.595	-14.255	-7.987
Ukraine	Yes	28.865	.000	3.923	703	.000	5.121	1.306	2.558	7.685
	No			3.574	417.098	.000	5.121	1.433	2.304	7.938
Vietnam	Yes	5.335	.021	-2.058	657	.040	-4.035	1.961	-7.885	-.184
	No			-3.258	203.900	.001	-4.035	1.238	-6.477	-1.593
Zimbabwe	Yes	25.469	.000	-10.394	9695	.000	-8.636	.831	-10.264	-7.007
	No			-10.970	1738.695	.000	-8.636	.787	-10.180	-7.092

a. No statistics are computed for one or more split files; yes = Equal variances assumed; no = Equal variances not assumed.

ANNEX 5. PERSON COLLECTING WATER – URBAN VERSUS RURAL.

				Person collecting water				
Country				Adult woman (age > 15)	Adult man (age > 15)	Female child (under 15)	Male child (under 15)	Total
UN MDG Developed Region								
Montenegro	Area	Urban	Count	21	97			118
			% within area	17.8	82.2			100.0
		Rural	Count	32	57			89
			% within area	36.0	64.0			100.0
	Total		Count	53	154			207
			% within area	25.6	74.4			100.0
Serbia Roma	Area	Urban	Count	9	7	0	1	17
			% within area	52.9	41.2	0.0	5.9	100.0
		Rural	Count	57	35	2	0	94
			% within area	60.6	37.2	2.1	0.0	100.0
	Total		Count	66	42	2	1	111
			% within area	59.5	37.8	1.8	0.9	100.0
Serbia	Area	Urban	Count	17	87	0		104
			% within area	16.3	83.7	0.0		100.0
		Rural	Count	26	106	2		134
			% within area	19.4	79.1	1.5		100.0
	Total		Count	43	193	2		238
			% within area	18.1	81.1	0.8		100.0
Ukraine	Area	Urban	Count	81	192		2	275
			% within area	29.5	69.8		0.7	100.0
		Rural	Count	187	232		0	419
			% within area	44.6	55.4		0.0	100.0
	Total		Count	268	424		2	694
			% within area	38.6	61.1		0.3	100.0
UN MDG Developing Region Sub-Saharan Africa								
Ghana	Area	Urban	Count	1422	433	227	107	2189
			% within area	65.0	19.8	10.4	4.9	100.0
		Rural	Count	5274	860	561	279	6974

			% within area	75.6	12.3	8.0	4.0	100.0
	Total		Count	6696	1293	788	386	9163
			% within area	73.1	14.1	8.6	4.2	100.0
Kenya Mombassa Informal	Area	Urban	Count	358	437	9	4	808
			% within area	44.3	54.1	1.1	0.5	100.0
	Total		Count	358	437	9	4	808
			% within area	44.3	54.1	1.1	0.5	100.0
Nigeria	Area	Urban	Count	2320	1595	463	296	4674
			% within area	49.6	34.1	9.9	6.3	100.0
		Rural	Count	8823	5729	1711	1233	17496
			% within area	50.4	32.7	9.8	7.0	100.0
	Total		Count	11143	7324	2174	1529	22170
			% within area	50.3	33.0	9.8	6.9	100.0
Sierra Leone	Area	Urban	Count	1521	719	280	156	2676
			% within area	56.8	26.9	10.5	5.8	100.0
		Rural	Count	4529	961	936	511	6937
			% within area	65.3	13.9	13.5	7.4	100.0
	Total		Count	6050	1680	1216	667	9613
			% within area	62.9	17.5	12.6	6.9	100.0
Somalia (North East)	Area	Urban	Count	466	196	63	37	762
			% within area	61.2	25.7	8.3	4.9	100.0
		Rural	Count	713	236	97	51	1097
			% within area	65.0	21.5	8.8	4.6	100.0
	Total		Count	1179	432	160	88	1859
			% within area	63.4	23.2	8.6	4.7	100.0
Somalia (Somaliland)	Area	Urban	Count	251	192	28	13	484
			% within area	51.9	39.7	5.8	2.7	100.0
		Rural	Count	1062	445	97	43	1647
			% within area	64.5	27.0	5.9	2.6	100.0
	Total		Count	1313	637	125	56	2131
			% within area	61.6	29.9	5.9	2.6	100.0
South Sudan	Area	Urban	Count	1744	154	192	17	2107
			% within area	82.8	7.3	9.1	0.8	100.0
		Rural	Count	5753	300	617	51	6721
			% within area	85.6	4.5	9.2	0.8	100.0
	Total		Count	7497	454	809	68	8828
			% within area	84.9	5.1	9.2	0.8	100.0
Sudan	Area	Urban	Count	318	213	68	63	662
			% within area	48.0	32.2	10.3	9.5	100.0
		Rural	Count	2812	1410	751	552	5525
			% within area	50.9	25.5	13.6	10.0	100.0
	Total		Count	3130	1623	819	615	6187
			% within area	50.6	26.2	13.2	9.9	100.0
Swaziland	Area	Urban	Count	160	114	6	7	287
			% within area	55.7	39.7	2.1	2.4	100.0
		Rural	Count	1265	345	112	66	1788
			% within area	70.7	19.3	6.3	3.7	100.0
	Total		Count	1425	459	118	73	2075
			% within area	68.7	22.1	5.7	3.5	100.0
Zimbabwe	Area	Urban	Count	959	291	28	9	1287
			% within area	74.5	22.6	2.2	0.7	100.0
		Rural	Count	6859	1202	265	108	8434
			% within area	81.3	14.3	3.1	1.3	100.0

	Total		Count	7818	1493	293	117	9721
			% within area	80.4	15.4	3.0	1.2	100.0
Other								
Afghanistan	Area	Urban	Count	129	488	106	218	941
			% within area	13.7	51.9	11.3	23.2	100.0
		Rural	Count	2922	1864	754	893	6433
			% within area	45.4	29.0	11.7	13.9	100.0
	Total		Count	3051	2352	860	1111	7374
			% within area	41.4	31.9	11.7	15.1	100.0
Indonesia Papua	Area	Urban	Count	75	59	6	2	142
			% within area	52.8	41.5	4.2	1.4	100.0
		Rural	Count	694	261	95	55	1105
			% within area	62.8	23.6	8.6	5.0	100.0
	Total		Count	769	320	101	57	1247
			% within area	61.7	25.7	8.1	4.6	100.0
Indonesia West Papua	Area	Urban	Count	61	64	0	4	129
			% within area	47.3	49.6	0.0	3.1	100.0
		Rural	Count	271	210	10	5	496
			% within area	54.6	42.3	2.0	1.0	100.0
	Total		Count	332	274	10	9	625
			% within area	53.1	43.8	1.6	1.4	100.0
Iraq	Area	Urban	Count	230	499	10	43	782
			% within area	29.4	63.8	1.3	5.5	100.0
		Rural	Count	1136	1497	30	41	2704
			% within area	42.0	55.4	1.1	1.5	100.0
	Total		Count	1366	1996	40	84	3486
			% within area	39.2	57.3	1.1	2.4	100.0
Jamaica	Area	Urban	Count	41	82	3	6	132
			% within area	31.1	62.1	2.3	4.5	100.0
		Rural	Count	159	304	10	10	483
			% within area	32.9	62.9	2.1	2.1	100.0
	Total		Count	200	386	13	16	615
			% within area	32.5	62.8	2.1	2.6	100.0
Kazakhstan	Area	Urban	Count	194	556	1	9	760
			% within area	25.5	73.2	0.1	1.2	100.0
		Rural	Count	651	1616	14	47	2328
			% within area	28.0	69.4	0.6	2.0	100.0
	Total		Count	845	2172	15	56	3088
			% within area	27.4	70.3	0.5	1.8	100.0
Lao PDR	Area	Urban	Count	290	91	20	21	422
			% within area	68.7	21.6	4.7	5.0	100.0
		Rural	Count	4804	970	585	185	6544
			% within area	73.4	14.8	8.9	2.8	100.0
	Total		Count	5094	1061	605	206	6966
			% within area	73.1	15.2	8.7	3.0	100.0
Mongolia KA	Area	Urban	Count	163	192	28	35	418
			% within area	39.0	45.9	6.7	8.4	100.0
		Rural	Count	536	823	74	71	1504
			% within area	35.6	54.7	4.9	4.7	100.0
	Total		Count	699	1015	102	106	1922
			% within area	36.4	52.8	5.3	5.5	100.0
Mongolia	Area	Urban	Count	997	1709	116	295	3117
			% within area	32.0	54.8	3.7	9.5	100.0

		Rural	Count	1549	2830	152	330	4861
			% within area	31.9	58.2	3.1	6.8	100.0
	Total		Count	2546	4539	268	625	7978
			% within area	31.9	56.9	3.4	7.8	100.0
Nepal	Area	Urban	Count	382	24	23	10	439
			% within area	87.0	5.5	5.2	2.3	100.0
		Rural	Count	3035	137	110	36	3318
			% within area	91.5	4.1	3.3	1.1	100.0
	Total		Count	3417	161	133	46	3757
			% within area	91.0	4.3	3.5	1.2	100.0
Pakistan Balochistan	Area	Urban	Count	78	138	6	11	233
			% within area	33.5	59.2	2.6	4.7	100.0
		Rural	Count	2461	1347	198	176	4182
			% within area	58.8	32.2	4.7	4.2	100.0
	Total		Count	2539	1485	204	187	4415
			% within area	57.5	33.6	4.6	4.2	100.0
Pakistan Punjab	Area	Urban	Count	699	3145	90	216	4150
			% within area	16.8	75.8	2.2	5.2	100.0
		Rural	Count	3591	2257	192	241	6281
			% within area	57.2	35.9	3.1	3.8	100.0
	Total		Count	4290	5402	282	457	10431
			% within area	41.1	51.8	2.7	4.4	100.0
Saint Lucia	Area	Urban	Count	12	17		0	29
			% within area	41.4	58.6		0.0	100.0
		Rural	Count	6	31		1	38
			% within area	15.8	81.6		2.6	100.0
	Total		Count	18	48		1	67
			% within area	26.9	71.6		1.5	100.0
Suriname	Area	Urban	Count	19	9	2	2	32
			% within area	59.4	28.1	6.3	6.3	100.0
		Rural	Count	678	105	12	4	799
			% within area	84.9	13.1	1.5	0.5	100.0
	Total		Count	697	114	14	6	831
			% within area	83.9	13.7	1.7	0.7	100.0
Vietnam	Area	Urban	Count	63	22	1	1	87
			% within area	72.4	25.3	1.1	1.1	100.0
		Rural	Count	390	168	13	6	577
			% within area	67.6	29.1	2.3	1.0	100.0
	Total		Count	453	190	14	7	664
			% within area	68.2	28.6	2.1	1.1	100.0
Total	Area	Urban	Count	13080	11822	1776	1585	28263
			% within area	46.3	41.8	6.3	5.6	100.0
		Rural	Count	60275	26338	7400	4995	99008
			% within area	60.9	26.6	7.5	5.0	100.0
	Total		Count	73355	38160	9176	6580	127271
			% within area	57.6	30.0	7.2	5.2	100.0

ANNEX 6. MEAN HOURS SPENT FETCHING WATER OR FIREWOOD IN PREVIOUS WEEK (CHILDREN AGED 5-17)

Country		Area	N	Mean	Std. Deviation	Std. Error Mean
Afghanistan	Hours to fetch water or collect firewood	Urban	1242	6.71	6.527	.185
		Rural	8107	9.27	7.784	.086
Indonesia Papua	Hours to fetch water or collect firewood	Urban	353	2.84	3.637	.194
		Rural	1385	5.39	4.094	.110
Indonesia West Papua	Hours to fetch water or collect firewood	Urban	190	2.82	3.114	.226
		Rural	937	3.68	4.302	.141
Iraq	Hours to fetch water or collect firewood	Urban	1087	3.99	4.120	.125
		Rural	1789	6.53	5.178	.122
Jamaica	Hours to fetch water or collect firewood	Urban	197	1.57	2.832	.202
		Rural	283	1.20	1.345	.080
Mongolia Khuvsgul Aimag	Hours to fetch water or collect firewood	Urban	226	7.37	7.315	.487
		Rural	929	10.10	9.705	.318
Mongolia	Hours to fetch water or collect firewood	Urban	1678	5.88	5.876	.143
		Rural	2587	8.69	9.088	.179
Montenegro	Hours to fetch water or collect firewood	Urban	138	1.58	3.189	.272
		Rural	159	2.10	2.361	.187
Nepal	Hours to fetch water or collect firewood	Urban	720	5.52	5.571	.208
		Rural	4579	7.82	6.609	.098
Nigeria	Hours to fetch water or collect firewood	Urban	5890	4.05	4.416	.058
		Rural	23516	5.00	5.383	.035
Pakistan Balochistan	Hours to fetch water or collect firewood	Urban	537	7.63	7.635	.329
		Rural	4609	6.77	7.216	.106
Pakistan Punjab	Hours to fetch water or collect firewood	Urban	1483	4.56	4.337	.113
		Rural	7652	5.94	5.278	.060
Saint Lucia	Hours to fetch water or collect firewood	Urban	22	1.09	2.022	.431
		Rural	38	.74	.828	.134
Serbia Roma	Hours to fetch water or collect firewood	Urban	20	8.60	7.910	1.769
		Rural	23	4.39	3.751	.782
Serbia	Hours to fetch water or collect firewood	Urban	13	1.85	1.772	.492
		Rural	27	2.56	3.080	.593
Sierra Leone	Hours to fetch water or collect firewood	Urban	3516	3.83	4.647	.078
		Rural	8815	4.19	4.881	.052
Somalia (North East)	Hours to fetch water or collect firewood	Urban	1580	11.34	10.505	.264
		Rural	1390	12.37	11.063	.297
Somalia (Somaliland)	Hours to fetch water or collect firewood	Urban	785	11.03	9.853	.352
		Rural	1802	12.46	10.721	.253
Suriname	Hours to fetch water or collect firewood	Urban	115	1.46	2.433	.227
		Rural	826	1.77	3.210	.112
Swaziland	Hours to fetch water or collect firewood	Urban	352	2.05	1.914	.102
		Rural	3025	2.91	2.584	.047
Ukraine	Hours to fetch water or collect firewood	Urban	59	2.14	1.727	.225
		Rural	229	2.69	2.558	.169
Vietnam	Hours to fetch water or collect firewood	Urban	101	7.28	7.765	.773
		Rural	821	7.09	6.199	.216

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Appendix 3. Published paper

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The association of water carriage, water supply and sanitation usage with maternal and child health. A combined analysis of 49 Multiple Indicator Cluster Surveys from 41 countries

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ABSTRACT

Background: Millions of people carry water home from off-plot sources each day and lack improved sanitation. Research on the health outcomes associated with water fetching is limited, and with usage of improved sanitation is inconclusive.
Objectives: To analyse the association of water fetching, unimproved water supplies, and usage of improved sanitation facilities with indicators of women's and children's health.
Methods: 49 Multiple Indicator Cluster Surveys from 41 countries were merged, creating a data set of 2,740,855 people from 539,915 households. Multilevel, multivariable analyses were conducted, using logistic regression for binary outcomes, negative binomial regression for count data and ordinary linear regression for linear data. We adjusted for confounding factors and accounted for clustering at survey, cluster and household level.
Results: Compared to households in which no-one collects water, water fetching by any household member is associated with reduced odds of a woman giving birth in a health care facility (OR 0.88 to 0.90). Adults collecting water is associated with increased relative risk of childhood death (RR 1.04 to 1.05), children collecting water is associated with increased odds of diarrheal disease (OR 1.10 to 1.13) and women or girls collecting water is associated with reduced uptake of antenatal care (β-0.04 to −0.06) and increased odds of leaving a child under five alone for one or more hours, one or more days per week (OR 1.07 to 1.16). Unimproved water supply is associated with childhood diarhhoea (OR 1.05), but not child deaths, or growth scores. When the percentage of people using improved sanitation is more than 80% an association with reduced childhood death and stunting was observed, and when more than 60%, usage of improved sanitation was associated with reduction of diarhhoea and acute undernutrition.
Conclusion: Fetching water is associated with poorer maternal and child health outcomes, depending on who collects water. The percentage of people using improved sanitation seems to be more important than type of toilet facility, and must be high to observe an association with reduced child deaths and diarhhoea. Water access on premises, and near universal usage of improved sanitation, is associated with improvements to maternal and child health.

1. Introduction

Target 6.1 of the UN Sustainable Development Goal on clean water and sanitation is to 'achieve universal and equitable access to safe and affordable drinking water for all', and target 6.2 is to 'achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations', by 2030 (UN, 2015). Equitable or fair access implies that different levels of water supply and sanitation services, or usage of different types of water source and toilet facilities, should not or will not disadvantage specific individuals or households.

In 2017, 785 million people still lacked even a basic drinking water service, defined as one requiring less than a 30 min round trip to fetch water from an improved source. Out of the people lacking a basic service, 206 million people spent over 30 min per round trip to collect water from an improved source (defined as a limited drinking water service) and the remainder relied on unimproved (435 million) or surface water sources (144 million), which most often also require more

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than 30 min to walk to, collect water and return home (WHO and UNICEF, 2019). In the same year, 2 billion people lacked a basic sanitation service (WHO and UNICEF, 2019). Off-plot access to water, even as part of a basic service, commonly requires a household member to complete multiple water fetching trips per day or week, with time spent walking to the source, queuing and physically carrying home enough water filled containers to meet their own needs and the needs of other household members (Evans et al., 2013; Geere, 2015). It therefore creates an immediate challenge to obtaining equitable access in comparison to households with water piped into their home, or which is accessible in the yard. It may also disadvantage individuals tasked with fetching water, usually the poorest women and children in low income regions (UN, 2016; WHO and UNICEF, 2017a, WHO and UNICEF, 2019). Many of these women and children also contend with a complete lack of, or unimproved sanitation facilities, which may further challenge their ability to maintain their own and their families' hygiene, health, safety and dignity (WHO and UNICEF, 2017b).

Different levels of access to safe water and sanitation may impact upon individuals and households through a variety of mechanisms or disease transmission pathways. However, epidemiological evidence of the health benefits of access to safe water and sanitation remains equivocal, at least in Low and Middle-Income Countries. For example, recent large scale multi-country randomised controlled trials have not reported clear associations between improvements in water or sanitation provision and either childhood diarrhoea or indicators of malnutrition (Clasen et al., 2014; Luby et al., 2018; Null et al., 2018). Even when randomised controlled trials of water and sanitation interventions have reported improved health outcomes, concerns were raised that such impact may be explainable largely by reporting bias as a result of lack of blinding of participants and investigators (Hunter, 2009; Schmidt and Cairncross, 2009). Equivocal or unclear findings may also be due to the confounding or mediating effects of other pathways leading to poor health, which have not been evaluated or adequately studied.

One aspect of water supply provision that has not been adequately studied, and may confound or mediate any benefits from improved water supply and sanitation interventions, is the impact that having to carry water home from off the site, or 'off-plot' water sources, may have on public health. Studies suggest that the work of water fetching may directly affect the health and wellbeing of the water carrier because it is associated with pain, fatigue and emotional distress (JA Geere et al., 2010; JL Geere et al., 2010 ; Geere et al., 2018; Wutich and Ragsdale, 2008). Through time and opportunity costs, water fetching might also indirectly lead to poorer health. For example, it might limit uptake of health services (Geere et al., 2018), or a person's capacity to engage with occupations which would otherwise enhance personal and family wellbeing, such as paid employment, vending or caring for young children (Wrisdale et al., 2017).

Because women and girls in the poorest families are most often tasked with fetching water (Geere and Cortobius, 2017; Graham et al., 2016; Hopewell and Graham, 2014; WHO and UNICEF, 2017a), it is likely that a differential burden from different levels of water access and the work of water fetching will become apparent as poorer maternal and child health outcomes (Geere et al., 2018; Pickering and Davis, 2012; Porter et al., 2012; Wang and Hunter, 2010), which might occur through a variety of pathways. For example, the time and energy taken for water carriage might reduce women's opportunities to also spend time and energy attending antenatal clinics (McCray, 2004), and antenatal clinic attendance has been shown to be associated with a woman giving birth in a health care facility (Seraphin et al., 2015). Women who lack social support for household water collection may not feel able to spend time away from home to give birth and recover in a health care facility, particularly if they have very young children to care for (Ono et al., 2013). Improved water supply and sanitation within the home might enable a woman to ask for and receive social support in the perinatal period (Subbaraman et al., 2015), which could then facilitate her access to antenatal care, or to travel to and give birth in a health care facility. Alternatively, communities where people have to fetch their own water may not have heath care facilities, or those that do exist may also lack adequate water supply and sanitation services, which could dissuade women from using them (Bouzid et al., 2018). Furthermore, the energy expenditure required for water carriage might exacerbate under-nutrition. During pregnancy or postnatally, insufficient maternal nutrition may impact upon intrauterine growth or breast feeding, to increase risk of child mortality, or children under five having reduced weight for age (WAZ) and height for age (HAZ) z-scores (Black et al., 2008). Unimproved water supply and low levels of improved sanitation usage may also impact on individuals and households through a variety of mechanisms leading to faecal contamination of the environment and within the home, with subsequent transmission of infectious disease (Clasen et al., 2014).

Analysis of existing data to establish whether water carriage, adjusted for unimproved water supply and low levels of use of sanitation, is independently associated with poorer maternal and child health outcomes, is an important step prior to further research into which causal pathways operate in specific contexts. Large scale demographic and health surveys (DHS) and Multiple Indicator Cluster Surveys (MICS) are regularly conducted in many countries and have been used to provide data on access to water and sanitation (Graham et al., 2016; Hopewell and Graham, 2014; Sorenson et al., 2011). However, they have not been used to test hypotheses about associations between water fetching, water supply and sanitation use, and the health and wellbeing of household members. We report an analysis of 49 MICS to test the hypotheses that inadequate access to drinking water and low levels of sanitation use are associated with indicators of poorer maternal and child health.

2. Methods

The primary hypotheses were that adverse maternal and child health outcomes are associated with.

1. Having to carry water
2. Use of unimproved drinking water supplies, and
3. Living in communities with low levels of use of improved sanitation

The key variables linked to the primary hypotheses were age and sex of the person in the household identified as usually responsible for collecting water, whether or not people reported use of an improved water supply, category of toilet/latrine usually used in the house and the proportion of homes in a cluster using improved sanitation.

We analysed data on seven health related indicators or outcome measures. The following health outcomes were tested against all three hypotheses.

1. An increase in the risk of child deaths
2. Higher 2 week prevalence of diarrhoea in children under 5 years of age
3. Decreased WHO weight for age z scores (WAZ)
4. Decreased WHO height for age z scores (HAZ)

In addition, the following indicators of health were tested only for having to carry water (hypothesis 1).

5. Reduced likelihood of giving birth in a health care facility (HCF)
6. Reduced uptake of antenatal care
7. Increased likelihood of a child under 5 being left alone for more than 1 h, for one or more days per week

Data sets from 41 countries derived from 49 MICS conducted between 2009 and 14 and with results reported and publicly available in April 2015, were downloaded after obtaining permission from UNICEF,

Table 1
MICs surveys merged for analysis.

Survey Country (region)	Year	N (households)	N (Individuals)	% sample
Afghanistan	2011	13116	101671	3.7
Argentina	2012	23791	89799	3.3
Barbados	2012	2872	8148	.3
Belarus	2012	8284	23650	.9
Belize	2011	4424	17538	.6
Bhutan	2010	14676	68351	2.5
Bosnia and Herzegovina (Roma Settlements)	2012	1544	5864	.2
Bosnia and Herzegovina	2012	5778	20248	.7
Central African Republic	2010	11756	54281	2.0
Chad	2010	16386	88564	3.2
Congo DR	2010	11393	61543	2.2
Costa Rica	2011	5561	21322	.8
Cuba	2011	9183	35454	1.3
Ghana (Accra)	2010–11	1409	4878	.2
Ghana	2011	11925	54228	2.0
Indonesia (Selected Districts of Papua)	2011	2866	12112	.4
Indonesia (Selected Districts of West Papua)	2011	2816	11533	.4
Iraq	2011	35701	238327	8.7
Jamaica	2011	5960	19277	.7
Kazakhstan	2010–11	15800	54316	2.0
Kenya (Mombasa Informal Settlements)	2009	1016	3216	.1
Kenya (Nyanza Province)	2011	6828	30763	1.1
Lao PDR	2012	18843	98440	3.6
Lebanon (Palestinians)	2011	4747	20983	.8
Madagascar (South)	2012	2968	15556	.6
Mauritania	2011	10116	59993	2.2
Moldova	2012	11354	28852	1.1
Mongolia (Khuvsgul Aimag)	2012	1982	6975	.3
Mongolia	2010	10092	35747	1.3
Montenegro	2013	4052	14691	.5
Nepal (Mid and Far Western Regions)	2010	5899	31753	1.2
Nigeria	2011	29077	150810	5.5
Pakistan (Baluchistan)	2010	11612	88427	3.2
Pakistan (Punjab)	2011	95238	599617	21.9
Saint Lucia	2012	1718	4922	.2
Serbia (Roma Settlements)	2014	1743	9014	.3
Serbia	2014	6191	22194	.8
Sierra Leone	2010	11394	66571	2.4
Somalia (North East Zone)	2011	4777	28604	1.0
Somalia (Somaliland)	2011	4808	30777	1.1
South Sudan	2010	9369	55973	2.0
Sudan	2010	14778	83510	3.0
Suriname	2010	7407	28783	1.1
Swaziland	2010	4834	19843	.7
Togo	2010	6039	30948	1.1
Tunisia	2012	9171	38861	1.4
Ukraine	2012	11321	33761	1.2
Vietnam	2011	11614	44831	1.6
Zimbabwe	2014	15686	65336	2.4
Total		539915	2740855	100.0

using the Statistical Package for the Social Sciences (SPSSv22) software. Separate files recording household level variables related to water access, women's health and child health for each survey were merged by creating unique identity numbers for each case in the spreadsheet, derived from survey, cluster, household and individual line numbers. All surveys were then merged producing a total of 2,740,855 people from 539,915 households included in the final data set (Table 1). All dependent (Appendix A) and independent (Appendix B) variables relevant to this study were checked to ensure that value labels were consistent and transformed if necessary prior to merging surveys and in preparation for analysis.

Health indicators or outcomes included in each survey differed and not all households had members who were relevant cases for each indicator, for example only women of child bearing age were asked about birth history, and only those reporting a live birth can provide data on child deaths. Cases with implausible values or missing data for the dependent or any of the independent variables were omitted from the analyses. The independent variable 'times received antenatal care' was highly skewed and so we used a square root transformation. Several new variables were created by combining or transforming the original MICS variables (Appendix A, Table A7).

SPSS data files were uploaded to MLwiN (v3.01) software (Charlton et al., 2017) to conduct multilevel, multivariable regression analyses of the associations between the key independent variables and maternal and child health outcomes. Where the dependent variable was binary we used logistic regression, where count data we used negative binomial regression and where linear we used ordinary linear regression (Appendix B, table B.8). We conducted four-level analyses in which individual survey respondents (level 1) were nested in households (level 2), which were nested in 'clusters' (level 3: a number of households randomly selected from within an enumeration area, or segment of an enumeration area of the survey), which were nested in surveys (level 4: country and/or surveyed region within a country). Our research aim was to determine the effect of the four key household level variables on health outcomes, as described above. Maternal and child health varies between countries, geographic areas or 'clusters' within countries and households (Black et al., 2008; Dangour et al., 2013; Goudet et al., 2015). It is therefore likely that contextual factors existing at these levels, but not represented by questions included in MIC surveys and therefore variables in the data set, could be associated with the health outcomes of interest. It is also likely that within clusters, respondents are more similar than people from different clusters, due to shared characteristics and contextual factors. Therefore, the four-level analyses allowed for random effects due to unmeasured contextual factors associated with the clusters in which an individual was situated (at household, enumeration cluster and survey level), and correlations within clusters (individuals within clusters are likely to be more similar than those from different clusters), and adjusted for the effects of individual and household level variables included as covariates in the models (factors known or hypothesised to be associated with the outcomes). To check the robustness of the models we ran fixed effects models for each outcome with country as an explanatory variable. We obtained similar results, but with the random effects models having slightly more conservative parameter estimates and a smaller deviance value indicating a better fit of the models (Appendix C). The analyses enabled us to provide an estimate of the independent association of four key modifiable household level variables with the maternal and child health outcomes of interest in this study.

3. Results

Table 1 (and Appendix A, Table A1-6) list the 49 surveys included in this analysis. The results of the seven regression analyses are shown in Tables 2 and 3. Table 2 shows the results of the regression analyses for child mortality, diarrhoea, and WHO WAZ and HAZ scores. Table 3 shows the results of regression analyses for likelihood of giving birth in a health care facility, uptake of antenatal care, and likelihood of leaving a child under five years of age alone for one or more hours, one or more days per week.

Relative risk of child death was greater in households that fetched water (Table 2). In households where women carried the water the relative risk of child death was 1.05 (95% confidence intervals 1.02–1.08). Where men carried the water, the risk was similar (1.04, 95%CI 1.00–1.07). Where children primarily collected water, there was no increased risk of death. Using an unimproved drinking water source was not independently associated with increased risk of child death. Living in a household where members did not usually use a flush toilet was associated with 9–12% greater relative risk of child death than living in a household where members usually used flush toilets. However, there was little obvious difference in mortality rates between those households using non-flush improved sanitation, unimproved sanitation or practicing open defecation. As the percentage of households in a cluster using improved sanitation increased in communities, the association with child deaths declined. Those children born into communities with > 90% improved sanitation usage were 12% less likely to die than those born into communities with ≤20% usage (Fig. 1).

An increase in the odds of a child under five years of age being reported to have had diarrhoea in the previous two weeks (10–13%) was associated with children collecting water, but not with adults collecting water, when compared to households in which no one collects water (Table 2). Using unimproved drinking water supply compared to improved drinking water supply was associated with an increase in the odds of diarrhoea by 5%. Use of an improved or unimproved toilet and open defecation in comparison to a flush toilet was also associated with an increase in the odds of diarrhoea, with improved toilets associated with a greater comparative increase (16%) than unimproved toilets (11%) or open defecation (5%). Improved sanitation usage was associated with the odds of childhood diarrhoea reducing by 8%, 13% and 21% in the > 60–80, > 80–90 and > 90% categories of coverage respectively (Fig. 2).

A small decrease in children's WHO WAZ scores, which indicate acute undernutrition, was associated with water carriage performed by women, men or boys when compared to non-water fetching households (Table 2). No association was observed between WAZ scores and use of an improved compared to unimproved water supply. The use of non-flush toilets (improved or unimproved) or open defecation compared to flush toilets, was associated with a decrease in WHO WAZ scores. A gradual increase in WAZ score was associated with each higher level of improved sanitation coverage beyond 60% (Fig. 3).

No association between children's WHO HAZ scores, which indicate childhood stunting, and household water fetching or improved water supply was observed (Table 2). Use of non-flush toilets (improved or unimproved) or open defecation compared to flush toilets was associated with a decrease in HAZ scores, and when more than 80% of people within a cluster used improved sanitation an association with increased HAZ scores was observed (Fig. 4).

Water fetching was associated with reduced odds of a woman giving birth in a health care facility (10–12% reduction), compared to non-water fetching households, with little difference according to the age and gender of the person responsible for collecting water (Table 3). A reduction in uptake of antenatal care was observed in households where a girl or woman usually collected water, however, when men or boys usually collected water, the odds ratio for antenatal care uptake was not significantly different from that of women living in non-water fetching households (Table 3). The odds of a child under five years of age being left alone for an hour or more, on one or more days of the week, was increased in households where a woman or female child was responsible for collecting water, but not in those where a man or boy collects water, when compared to households where no one collects water (Table 3).

4. Discussion

We believe that ours is the first study to utilize data from a large number of MICS, and analyse the relationships between water carriage, use of improved drinking water and sanitation, and maternal and child health. We have been able to control for a range of possible confounding factors and allow for random effects at the household, cluster and survey level. We have found that having to carry water home is independently associated with a range of adverse child and maternal health outcomes. In comparison to households where no one must collect and carry water, adults carrying water is associated with increased risk of child death, children carrying water with increased odds of childhood diarrhoea, and adults or boys carrying water with reduced WHO WAZ scores. Women of water fetching households are less likely to give birth in a health care facility, and women or girls collecting water, is associated with reduced antenatal care up-take and children under five being much more likely to be left alone at home. In addition, we report the largest study to date on the associations between toilet facility usage and percentage of households using improved sanitation within a cluster, with a range of health outcomes. Our findings suggest that health benefits are associated with a high percentage of households within a geographic area using improved sanitation. More than 60% usage is associated with reduced diarrhoea and acute undernutrition, and more than 80% usage is associated with reduction of the more severe outcomes of childhood death and stunting. This evidence supports the view that to be effective, WaSH interventions should aim toward sanitation provision and usage for all, and provision of safe water on premises.

Of note in our study, is that whilst use of unimproved water supply, an indicator of water quality, was not associated with risk of childhood death, the need for an adult to collect water from an off-plot source was independently associated with an increased risk of child death. When adults must fetch water, it is likely that in many households children are left unsupervised for the time it takes to walk to a water source, wait in a queue for water and return. Unsupervised children may be at more risk of death from accidental injury, or simply from reduced parental

Table 2
Risk of childhood death, odds of diarrhoea affecting a child under 5 years of age in the previous 2 weeks, and regression parameters for WHO weight for age and height for age z-scores by socio-economic characteristics, demographic variables, water supply, sanitation type, sanitation usage and water carriage.

Independent Variable	Child death RR (95% CI)	p-value	Diarrhoea OR (95% CI)	p-value	WAZ β (95% CI)	p-value	HAZ β (95% CI)	p-value
Fixed part of model								
Person collecting water								
No one	1.00		1.00		0		0	
Male child (< 15 years)	0.99 (0.94, 1.05)	0.828	1.13 (1.02, 1.25)	0.022	−0.05 (−0.09, −0.01)	0.021	−0.03 (−0.09, 0.02)	0.185
Man (15 + years)	1.04 (1.00, 1.07)	0.051	0.98 (0.92, 1.05)	0.602	−0.03 (−0.05, −0.01)	0.012	−0.02 (−0.05, 0.01)	0.139
Female child (< 15 years)	1.00 (0.95, 1.04)	0.871	1.10 (1.02, 1.20)	0.016	−0.00 (−0.04, 0.03)	0.857	−0.01 (−0.05, 0.03)	0.582
Woman (15 + years)	1.05 (1.02, 1.08)	0.001	1.05 (1.00, 1.10)	0.069	−0.02 (−0.04, −0.00)	0.028	−0.01 (−0.03, 0.01)	0.345
Water supply								
Improved	1.00		1.00		0		0	0.729
Unimproved	1.00 (0.98, 1.03)	0.926	1.05 (1.01, 1.10)	0.014	0.02 (0.00, 0.03)	0.055	0.00 (−0.02, 0.02)	
Toilet facility								
Flush toilet	1.00		1.00		0		0	
Other improved	1.10 (1.07, 1.13)	< 0.001	1.16 (1.10, 1.22)	< 0.001	−0.03 (−0.05, −0.01)	0.003	−0.10 (−0.12, −0.07)	< 0.001
Unimproved	1.12 (1.08, 1.16)	< 0.001	1.11 (1.04, 1.18)	0.002	−0.03 (−0.06, −0.01)	0.021	−0.09 (−0.12, −0.06)	< 0.001
Open defecation	1.09 (1.06, 1.13)	< 0.001	1.05 (0.99, 1.11)	0.147	−0.06 (−0.08, −0.04)	< 0.001	−0.08 (−0.11, −0.05)	< 0.001
Improved sanitation usage [c]								
≤20	1.00		1.00		0		0	
> 20 to 40	1.02 (0.98, 1.06)	0.323	0.96 (0.90, 1.03)	0.281	−0.02 (−0.05, 0.01)	0.186	−0.04 (−0.07, −0.00)	0.032
> 40 to 60	1.01 (0.97, 1.05)	0.776	0.93 (0.86, 1.00)	0.056	−0.01 (−0.04, 0.02)	0.441	−0.02 (−0.05, 0.02)	0.368
> 60 to 80	0.98 (0.93, 1.02)	0.251	0.92 (0.86, 1.00)	0.046	0.04 (0.01, 0.07)	0.007	0.03 (−0.00, 0.07)	0.079
> 80 to 90	0.92 (0.87, 0.97)	0.001	0.87 (0.79, 0.95)	0.002	0.07 (0.03, 0.10)	< 0.001	0.07 (0.03, 0.11)	0.001
> 90	0.88 (0.85, 0.93)	< 0.001	0.79 (0.73, 0.86)	< 0.001	0.08 (0.05, 0.12)	< 0.001	0.07 (0.03, 0.10)	< 0.001
Wealth index								
Poorest	1.00		1.00		0		0	
Second	0.96 (0.94, 0.99)	0.004	0.91 (0.87, 0.95)	< 0.001	0.08 (0.06, 0.10)	< 0.001	0.08 (0.06, 0.10)	< 0.001
Middle	0.89 (0.87, 0.91)	< 0.001	0.82 (0.78, 0.85)	< 0.001	0.16 (0.14, 0.18)	< 0.001	0.16 (0.14, 0.18)	< 0.001
Fourth	0.81 (0.78, 0.84)	< 0.001	0.77 (0.73, 0.81)	< 0.001	0.25 (0.23, 0.27)	< 0.001	0.27 (0.25, 0.30)	< 0.001
Richest	0.66 (0.63, 0.68)	< 0.001	0.62 (0.58, 0.66)	< 0.001	0.44 (0.42, 0.47)	< 0.001	0.49 (0.46, 0.51)	< 0.001
Education of household head								
Primary/none	1.00		1.00		0		0	
Secondary +	0.85 (0.83, 0.86)	< 0.001	0.89 (0.86, 0.92)	< 0.001	0.11 (0.10, 0.12)	< 0.001	0.13 (0.12, 0.15)	< 0.001
Area								
Urban	1.00		1.00		0		0	
Rural	0.99 (0.97, 1.02)	0.663	0.92 (0.88, 0.97)	0.001	0.02 (0.00, 0.04)	0.036	0.01 (−0.01, 0.03)	0.476
Sex of household head								
Male	1.00		1.00		0		0	
Female	0.99 (0.97, 1.01)	0.424	0.99 (0.94, 1.03)	0.495	0.06 (0.04, 0.07)	< 0.001	0.05 (0.04, 0.07)	< 0.001
Sex of child								
Male	n/a		1.00		0		0	
Female	n/a		0.92 (0.90, 0.94)	< 0.001	0.06 (0.05, 0.07)	< 0.001	0.08 (0.07, 0.09)	< 0.001
Age in years [a,b]	1.02 (1.02, 1.02)	< 0.001	0.75 (0.74, 0.76)	< 0.001	−0.08 (−0.08, −0.08)	< 0.001	−0.17 (−0.18, −0.17)	< 0.001
β_0 (S.E.)	−3.08 (0.10)		−1.71 (0.13)		−0.72 (0.09)		−0.72 (0.09)	
Random part of model								
Country level variance (S.E.)	0.34 (0.08)		0.60 (0.14)		0.33 (0.08)		0.25 (0.06)	
Cluster level variance (S.E.)	0.17 (0.01)		0.58 (0.02)		0.10 (0.00)		0.12 (0.00)	
Household level variance (S.E.)	0.28 (0.03)		1.23 (0.03)		0.26 (0.01)		0.27 (0.01)	
Individual level variance (S.E.)	0.78 (0.03)		1.00 (0.00)		0.98 (0.01)		1.47 (0.01)	

Note: Number of women reporting child deaths once individuals with missing data excluded = 299, 084 (86.6% of original MICs data), households = 274 145, clusters = 26519, MIC surveys = 40.
Number of women reporting diarrhoea affecting child under 5 years of age in the previous 2 weeks, once individuals with missing data excluded = 290, 176 (78.8% of original MICs data), households = 190 641, clusters = 27 030, MIC surveys = 43.
Number of WHO WAZ scores once individuals with missing data excluded = 230, 406 (84.8% of original MICs data), households = 154 742, clusters = 24 367, MIC surveys = 36.
Number of WHO HAZ scores once individuals with missing data excluded = 217, 210 (80.2% of original MICs data), households = 148 670, clusters = 24, 262, MIC surveys = 36.
RR, relative risk; OR, odds ratio; β, regression parameter; WHO WAZ, World Health Organisation weight for age z-score; WHO HAZ, World Health Organisation height for age z-score; β_0, Y intercept; S.E. = standard error.
[a] For children dead 'age' = age of mother.
[b] For diarrhoea, HAZ and WAZ 'age' = age of child.
[c] % with improved sanitation within cluster.

care when it is needed, for example during illness or when they are very young. In Ethiopia, Gibson and Mace (2006) found that when women's work of water fetching was substantially reduced because of access to tap stands much closer to home, the monthly risk of child death was 50% lower among children of the women with access to the new taps. They suggested that the increase in child survival was most likely due to increased quantity and improved quality of water available for household use, but also greater opportunities for mothers to care for their young children. If the association observed in our study was due to a larger quantity of water being available in non-water fetching households, it is difficult to explain why adults, but not children collecting water, who would be likely to carry even less water than adults, should be associated with an increase in the child death rate. Whilst the increase in risk is not as large as that associated with being in the higher three wealth quintiles, in countries where the under 5 mortality is high a 5% increase in risk independently associated with a modifiable risk

Table 3
Odds of a woman giving birth in a health care facility, uptake of antenatal care and odds of leaving a child under 5 alone > 1 h on 1 or more days per week by socio-economic characteristics, demographic variables and water carriage.

Independent variable	Birth in a health care facility OR (95% CI)	P value	Times received antenatal care β (95% CI)	P value	Child left alone OR (95% CI)	P value
Fixed part of model						
Person collecting water						
No one collects water	1.00		0		1.00	
Male child (< 15)	0.88 (0.79, 0.99)	0.032	−0.02 (−0.07, 0.02)	0.285	0.99 (0.91, 1.08)	0.878
Adult man (15 + years)	0.90 (0.84, 0.96)	0.001	−0.01 (−0.04, 0.01)	0.29	0.98 (0.93, 1.05)	0.605
Female child (< 15)	0.89 (0.82, 0.98)	0.015	−0.06 (−0.09, −0.03)	< 0.001	1.16 (1.08, 1.25)	< 0.001
Adult woman (15 + years)	0.89 (0.84, 0.93)	< 0.001	−0.04 (−0.05, −0.02)	< 0.001	1.07 (1.02, 1.13)	0.003
Wealth index						
Poorest	1.00		0		1.00	
Second	1.33 (1.27, 1.40)	< 0.001	0.06 (0.05, 0.08)	< 0.001	1.02 (0.97, 1.06)	0.459
Middle	1.76 (1.67, 1.85)	< 0.001	0.12 (0.10, 0.13)	< 0.001	1.02 (0.97, 1.07)	0.496
Fourth	2.34 (2.21, 2.48)	< 0.001	0.15 (0.14, 0.17)	< 0.001	0.99 (0.93, 1.04)	0.58
Richest	3.74 (3.47, 4.03)	< 0.001	0.25 (0.23, 0.27)	< 0.001	0.90 (0.85, 0.97)	0.003
Education of household head						
Primary/none	1.00		0		1.00	
Secondary +	1.22 (1.18, 1.27)	< 0.001	0.05 (0.04, 0.06)	< 0.001	0.99 (0.95, 1.02)	0.427
Area						
Urban	1.00		0		1.00	
Rural	0.84 (0.80, 0.87)	< 0.001	−0.05 (−0.07, −0.04)	< 0.001	1.08 (1.02, 1.14)	0.01
Sex of household head						
Male	1.00		0		1.00	
Female	1.15 (1.10, 1.21)	< 0.001	0.02 (0.00, 0.03)	0.012	1.02 (0.98, 1.07)	0.298
Age in years[a]	0.99 (0.99, 1.00)	< 0.001	0.001 (0.00, 0.002)	0.004	1.44 (1.42, 1.45)	< 0.001
β_0 (S.E.)	1.61 (0.43)		2.33 (0.08)		−4.12 (0.26)	
Random part of model						
Country level variance (S.E.)	7.22 (1.63)		0.25 (0.06)		2.78 (0.62)	
Cluster level variance (S.E.)	0.26 (0.01)		0.07 (0.00)		0.87 (0.02)	
Household level variance (S.E.)	0.00 (0.00)		0.06 (0.01)		0.30 (0.02)	
Individual level variance (S.E.)	1.00 (0.00)		0.19 (0.01)		1.00 (0.00)	

Note: Number of women reporting place of birth 100, 505 (85.4% of original MICs data), households = 95 890, clusters = 22 784, MIC surveys = 44.
Number of women reporting times received antenatal care 52, 696 (80.0%), households = 50 689, clusters = 14 904, MIC surveys = 40.
Number of women reporting whether a child under 5 years of age is left alone for an hour or more, on 1 or more days per week = 228, 307 (84.9%), households = 154 705, clusters = 21 617, MIC surveys = 43.
OR, odds ratio; β, regression parameter; β_0, Y intercept; S.E., standard error.
[a] For birth in health care facility and uptake of antenatal care, 'age' = age of woman, for child left alone, 'age' = age of child.

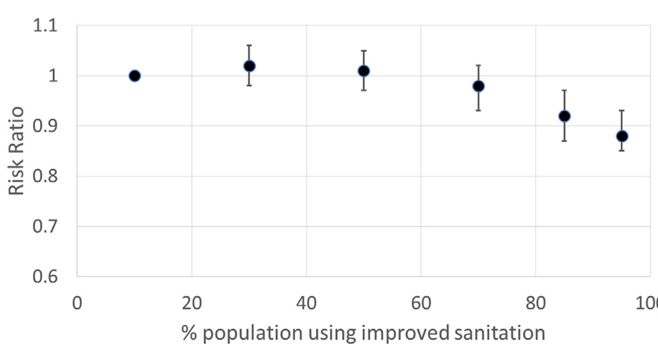

Fig. 1. Relative risk of child mortality by percentage of population using improved sanitation (reference category ≤20% using improved sanitation) Model: negative binomial regression. Covariates: wealth index, education of household head, urban/rural area, sex of household head, age of mother, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

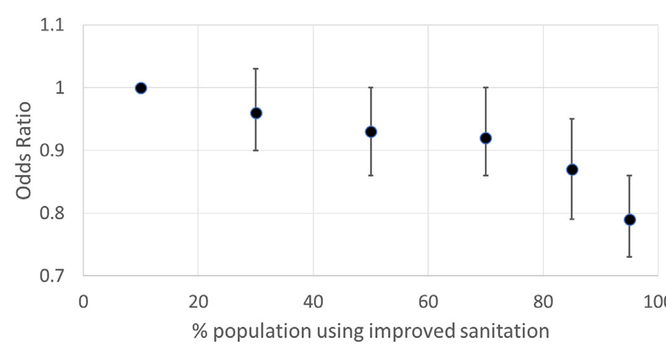

Fig. 2. Odds ratio for childhood diarrhoea by percentage of population using improved sanitation (reference category ≤20% using improved sanitation) Model: logistic regression. Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

factor is potentially important. For example our data set includes two surveys from Somalia conducted in 2011, when the under 5 mortality rate for the whole country was reported to be 153.5 deaths/1000 live births or 15.4% (UNICEF, 2019).

Compared to flush toilets, the use of any other type of toilet or open defecation was associated with increased risk of child death. Non-flush toilets of any type had higher relative risk than open defecation, indicating that they may have no benefit or create even greater risk of harm to young children than open defecation. This could occur if toilets are unhygienic, structurally unsafe for a small child to use, or situated in locations which are unsafe for children under five to access (Govender, 2014). Inequitable sanitation access within geographic areas, even where only 20% of households use unimproved sanitation or open defecation, was not significantly associated with a reduction in the risk of child death. This indicates that even a small percentage of households using unimproved sanitation may lead to increased disease transmission through person to person contact or environmental contamination.

The increased odds (10–13%) of children under five having

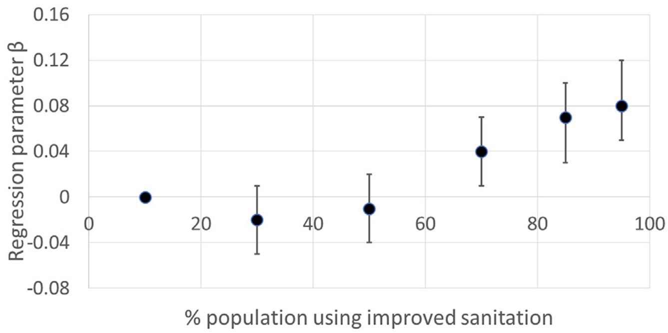

Fig. 3. WHO weight for age z-score by percentage of population using improved sanitation (reference category ≤20% using improved sanitation) Model: linear regression. Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/ unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

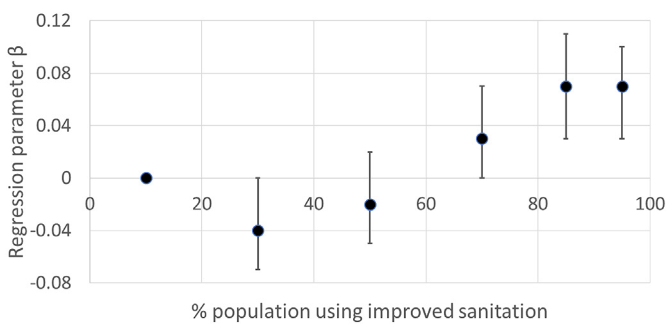

Fig. 4. WHO Height for age z-score by percentage of population using improved sanitation (reference category ≤20% using improved sanitation) Model: linear binomial regression. Covariates: wealth index, education of household head, urban/rural area, sex of household head, sex of child, age of child, improved/ unimproved water supply, toilet facility, coverage (%) improved sanitation usage, and person collecting water.

diarrhoea in households where children fetch water compared to households that do not, could simply reflect differing water quality from different source types as reported by Esrey (1996), and that children fetching water away from their home are more likely to be using an unimproved source, and therefore at more risk of diarrheal disease through consumption of contaminated drinking water. However, our analysis adjusted for the 5% increase in diarrhoeal risk from using an unimproved water supply. Furthermore, if use of an unimproved water source were the only reason for the observed association, one would not expect to see significant increases in diarrhoeal disease when children but not when adults collect water, after adjusting for differences in household toilet facilities and sanitation usage. It is known that water quality can deteriorate after collection from a shared source and during storage (Diouf et al., 2014; Jagals et al., 2003) and it's possible that children may be less likely or able to maintain hygienic practices, such as handwashing or cleaning containers adequately prior to refilling them. They may also be more likely to play in or drink untreated water at the source point than adults, and therefore more vulnerable to water borne disease.

Our results showed borderline significance of an association between a woman fetching water and increased risk of diarhhoea (RR 1.05, $p = 0.067$), whilst men showed no significant association with any increased risk of diarhhoea (0.98, $p = 0.602$) compared to non-water fetching households. It is possible that by fetching water, adults, and particularly men, may bring larger quantities of water to the house, either because they are simply stronger (Marras et al. 2002, 2003; Stemper et al., 2008) and therefore able to carry more water, or because they are more likely to use equipment or vehicles to collect more water (Geere, 2015). Men are also more likely to collect water when it is located closer to home, and women when it is located further away, such that men may collect larger quantities of water due to proximity of the supply point (WHO and UNICEF, 2017a). A larger quantity of water may enable all household members to improve cleanliness and hygiene practices such as handwashing to reduce the incidence of diarrhoea (Esrey et al., 1989; Hunter et al., 2010). By fetching water, an adult man or woman may also enable other family members, particularly other women but also children, to have more time and energy to engage in household management and chores, including hygiene practices related to washing, cooking and cleaning (Domenech et al., 2012; Rao et al., 2007; Zolnikov and Blodgett Salafia, 2016).

The association of an increased risk of diarrhoea with use of both improved and unimproved toilets, but not with open defecation, when compared to use of flush toilets is surprising. However, 'improved' toilets may not be used by all household members and may not remain functional over time (Clasen et al., 2014), and for these or other reasons may not be effective in preventing faecal contamination of water supplies or the environment (Patil et al., 2014). For example, the difficulties of cleaning, maintaining and emptying 'improved' toilets in which faecal matter is essentially stored near to homes, but not flushed away by water, might mean that it is hard to prevent disease transmission from person to person contact or environmental contamination. Certainly, many latrines, even improved latrines, are not maintained in a hygienic state with faecal smearing especially around the pit (Nakagiri et al., 2015; Simiyu et al., 2017; Sonego and Mosler, 2014). It is highly likely that such filthy latrines add to the risk of enteric pathogens.

Our findings that more than 60% coverage of households using improved sanitation in associated with a significant reduction of childhood diarrhoeal disease, might explain the lack of effectiveness of sanitation programmes reported in the literature. For example Clasen et al. (2014) found that a rural sanitation programme in India, which resulted in a mean 63% of households in the intervention villages having a latrine, had only 11 of 50 intervention villages with ≥50% functional latrine coverage at follow up. The programme was not effective in reducing exposure to faecal contamination or childhood diarrhoea and the authors felt that insufficient coverage and use of latrines were the most plausible explanations for their findings. Their findings are similar to those reported by others in India where there was no difference in household or source levels of *E. coli* contamination between intervention and control groups, and only 41% improved sanitation coverage was achieved in the intervention group (Patil et al., 2014). In Kenya, Null et al. (2018) also found no effect of interventions including improved sanitation on childhood diarhhoea. Whilst adherence to interventions which included improved sanitation was high in their study (78–82% of households), only 33–37% of the same households safely disposed of children's faeces. However, Luby et al. (2018) found that children receiving sanitation, handwashing, nutrition, and combined interventions (but not drinking water chlorination) had less reported diarrhoea. In their study adherence indicated by a functional latrine was very high (96–97%). Further support for this observation that community improved sanitation coverage and usage is more important than individual toilet ownership comes from a recent meta-regression analysis conducted by the World Health Organization (Wolf et al., 2018). This reported larger reductions in diarrhoea in those studies that achieved very high to 100% coverage. Another recent study from Mali also provides strong evidence for this observation (Harris et al., 2017).

Energy expenditure due to the work of water fetching may be important for nursing mothers, and if it affects breast feeding behaviour, might influence childhood nutrition and therefore children's weight for age (WAZ) or height for age (HAZ) scores (Goudet et al., 2015; Keino et al., 2014). WAZ and HAZ scores indicate acute undernutrition and chronic undernutrition or 'stunting' respectively (Dangour et al., 2013). Despite this potential effect, we found a significant but only small reduction in mean WAZ score in water fetching households associated with adults or boys collecting water, and did not find any association of water fetching with HAZ scores. In contrast to our findings of little to no effect, Gibson and Mace (2006) found that in an area of rural Ethiopia, children under 5 of women with access to water points which reduced the distance and time to fetch water, had significantly increased risk of being malnourished and stunted compared to children of women fetching water in the same area prior to the installation of labour saving taps. They proposed that reduced energy expenditure on water collection supported an observed increase in birth rate (OR 3.78, $p = 0.009$), which as a consequence, meant that smaller, low birth-weight babies were coming to full term and surviving early childhood. Inconsistent findings between studies such as ours and that reported by Gibson and Mace, might be due to contextual factors mediating the effects of water carriage on maternal health and therefore childhood growth.

Others have reported the energy costs of fetching water as moderate to high (Rao et al., 2007) and highlighted that the energy expenditure required for water fetching may become important in ‘food-scarce’ environments (Domenech et al., 2012). Several other studies also reported fatigue and tiredness affecting water carriers (JA Geere et al., 2010; JL Geere et al., 2010; Hemson, 2007; Porter et al., 2012; Zolnikov and Blodgett Salafia, 2016), and one study (Evans et al., 2013) reported that people who carried water had significantly less (40 min) ‘inactivity’ time (defined as sleep, resting or watching television) than those who did not carry water. Therefore, whilst findings from a range of studies indicate that the energy expenditure of water fetching may impact detrimentally on pregnant women and mothers, and that reducing the work of water carriage is likely to benefit them, other factors related to maternal or child nutritional intake (Luby et al., 2018; Stewart et al., 2018) and availability of family planning services (Dangour et al., 2013) may determine whether any impact on perinatal or maternal health leads to further impacts on under five weight for age and stunting. We were not able to include any indicators of food intake, nutritional status, feeding programs, birth rates or illness affecting mothers in the analyses, and therefore cannot exclude other possible confounding factors which may have influenced our results.

Dangour et al. (2013) conducted a meta-analysis including 4627 children and found no evidence of an effect of WaSH interventions on WAZ score (mean difference 0.05; 95% CI -0.01 to 0.12) and a borderline statistically significant but small effect of WaSH interventions on HAZ score (mean difference 0.08; 95% CI 0.00 to 0.16). The recent study by Clasen et al. (2014) focusing on a sanitation intervention in India found evidence for small increases in WAZ scores in villages with coverage of ≥50% and households with functional latrines, but no effect on HAZ scores. Our findings that any type of sanitation other than a flush toilet was associated with reduced WAZ and HAZ scores, together with the association of > 60% improved sanitation usage to achieve increased WAZ sores and > 80% usage to achieve increased HAZ scores, support Clasen et al.,’s (2014) recommendations to aim for full latrine coverage and use, and to end open defecation. However, in studies conducted in Kenya (Null et al., 2018), Bangladesh (Luby et al., 2018) and India (Patil et al., 2014), WaSH interventions alone did not improve child growth, and did not add to the improvements observed with nutrition interventions. In our analysis of observational surveys, the effects of water fetching, water supply and sanitation usage were small in comparison to the effects of wealth, which may enable families to secure enough food to optimize maternal and child nutrition. Overall this suggests that sufficient nutrition is of key importance (Black et al., 2008), which may explain why WaSH interventions alone are insufficient to achieve meaningful improvements in childhood growth.

We found that being from a water fetching household was associated with a reduction in the likelihood of a woman giving birth in a health care facility, but with little difference according to who was responsible for collecting water in the household. Ono et al.’s (2013) findings in Western Kenya indicate that decisions about giving birth at home or in a health care facility are complex, may differ according to which family member provides support with water fetching, and is significantly influenced by other factors in addition to social support. These are similar to our findings that wealth, higher education level of the household head, rural location and sex of the household head had the largest odds ratios associated with place of birth. However, our study provides evidence that as a modifiable risk factor, providing water on premises may independently increase the odds of women giving birth in health care facilities, which may be particularly important for women from lower socio-economic groups living in rural areas.

We found that uptake of antenatal care is likely to be lower for women from water fetching households, when a woman or girl is responsible for collecting water. This supports the findings of McCray (2004) who conducted a cross sectional survey of mothers of a child aged 12–23 months, from 327 randomly selected households in Kwazulu Natal, South Africa. They found that if a woman reported fetching water to be a daily activity affected by making a trip to the clinic, she was twice as likely to utilize prenatal care services at a low level, than an average level. Their conclusion was that making water more easily accessible would facilitate access to health care facilities for antenatal care (McCray, 2004). The added perspective from our research, is that where the location of a water source is not likely to change during a woman's pregnancy, help from her husband or sons to fetch water might enable her to receive antenatal care more times, because there was no decrease in uptake of antenatal care when men or boys collect water, compared to up-take of antenatal care in non-water fetching households. This suggests that by fetching water for household use, men and boys can make an important contribution to their family's health, as increased utilisation of antenatal care has been shown to be associated with better maternal and child health outcomes (Lincetto et al., 2006).

The association of an increased odds that a child under five is left alone for more than 1 h, for one or more days per week when women or girls collect water, highlights the challenges of providing child care and supervision when water is not accessed on premises. Qualitative research has highlighted the ‘Hobson's choice’ that carers face when they must obtain water from off-plot sources, and then choose to either leave their child alone, or take (often carrying) the child with them along what may be an unsafe route (JA Geere et al., 2010; Schatz and Gilbert, 2014; Wrisdale et al., 2017). The lack of change in the odds that a child is left alone when a man or boy collects water may indicate that the woman in the household is relieved of a task which would require her to leave children alone, and that she utilises the additional time to engage in household tasks that allow her to be with her children. When a woman collects water, it is possible that in some households, there may not be another adult at home and available to supervise children. It is also possible that even when living at home, men will prioritise time for income generating or other activities which take place away from home over child minding, and assume that a woman will manage to combine child minding with water fetching.

4.1. Limitations

MIC surveys are cross-sectional studies, which therefore prevent us from being able to confirm causal relationships between variables. The use of completed MICs questionnaires also limits the extent to which we were able to control for bias or confounding in our analyses. The variable ‘person collecting water’ is indicated by mutually exclusive response categories for the question ‘who usually goes to this source to collect the water for your household?’ A response option is not available to indicate that multiple people collect water. Therefore data from households where water carriage is performed by multiple people, for example as work shared by women and children, might introduce bias and have a mediating or confounding effect on the association between the person usually carrying water and the outcomes observed in this study. However, this is likely to reduce the strength of association observed and so our findings may underestimate the association. Time

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spent finding a place for open defecation (WSP, 2018) might have been a confounding factor affecting the relationship between water fetching and place of birth, up-take of antenatal care, and leaving a child alone. However, inadequate sanitation has been estimated to have much greater economic impacts through direct health costs such as premature death, diarhhoea and stunting than through time costs (WSP, 2018), and it is likely that fetching water for the household is much more time consuming than finding a place to defecate. Several of the outcome variables rely on self-reported information which may introduce reporting bias, however, outcomes such as number of children who have died are likely to be well remembered by respondents, with little gain to be had from intentional misreporting. Considering these limitations, the associations we observed remain plausible, unlikely to have occurred by chance, are strong in some analyses and consistent with the results of other studies, with some evidence of a 'dose-response' relationship for sanitation coverage (Bonita et al., 2006). Therefore, whilst our study cannot demonstrate causal relationships because the data lacks a clear temporal relationship with exposure preceding outcome, and the possibility of bias and confounding cannot be eliminated, it does contribute to the body of evidence supporting causal relationships between the predictor and outcome variables we analysed (Bonita et al., 2006). Further longitudinal cohort studies are required to allow firmer judgements on causation to be made.

The data set included a large number of studies from different countries, which were not conducted at the same time. However, the studies were all conducted within a five year timespan (2009–2014), and utilizing data from all 49 MICS of 41 countries which were available in April 2015 maximizes the generalizability of our results, and the relevance of our findings to global health. The surveys were not designed to specifically test the hypotheses which we have tested, however MICS and DHS data sets from multiple countries conducted at different times have been used to generate descriptive statistics (Graham et al., 2016; Hopewell and Graham, 2014; Sorenson et al., 2011) and to analyse associations between improved water supplies and sanitation usage and incidence of childhood diarrhoea, height and weight (Esrey, 1996). Utilizing a large set of surveys from different countries may increase the risk of variation in study design across surveys, however MICS are conducted after training enumerators to use standardized data collection tools and methods, and with population sampling which is either nationally representative, or representative of a target group or region within a country (UNICEF, 2017). The variables used for analysis in this study were checked and transformed if necessary to ensure that they had identical response options and value labels before data sets were merged for analyses.

5. Conclusion

Data from 49 surveys in 41 countries indicate that the work of fetching water when it is not located in the home or yard is associated with poorer maternal and child health outcomes. Our study is the first to report associations between maternal and child health and the age and gender of the person responsible for collecting water. Water fetching by any household member is associated with reduced odds of a woman giving birth in a health care facility. Adults collecting water is associated with increased risk of childhood death, children collecting water with increased risk of diarrheal disease and women or girls collecting water, with reduced uptake of antenatal care and increased odds of leaving a child under five alone for an hour or more, one or more days per week. We have found that sanitation usage must reach high levels to be associated with a reduction of childhood death and diarrhoea. Our results demonstrate that water access on premises, and high levels of improved sanitation usage, are associated with improvements in maternal and child health and safety.

Acknowledgements and declaration of interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijheh.2019.08.007.

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Appendix 4. Published report

EVANS, B., BARTRAM, J., HUNTER, P. R., RHODERICK WILLIAMS, A., GEERE, J., MAJURU, B., BATES, L., FISHER, M., OVERBO, A. & SCHMIDT, W.-P. 2013. Public Health and Social Benefits of at-house Water Supplies. Final Report. University of Leeds.

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Public Health and Social Benefits of at-house Water Supplies

Final Report

21st June, 2013

Barbara Evans, Jamie Bartram, Paul Hunter, Ashley Rhoderick Williams, Jo-Anne Geere, Batsi Majuru, Laura Bates, Michael Fisher, Alycia Overbo, Wolf-Peter Schmidt

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UEA

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List of abbreviations

CFU	Colony-forming Unit
CI	Confidence interval
DFID	UK Government Department for International Development
DRC	Democratic Republic of Congo
E.Coli	Escherichia coli
GH	Ghana
GLAAS	UN-Water Global Analysis and Assessment of Sanitation and Drinking Water
JMP	Joint Monitoring Programme for Water Supply and Sanitation
km	Kilometre
L95%CI	Lower 95% confidence Interval
l	Litre
lpcd	Litres per capita per day
m	Metre
min	Minute
ml	Millilitre
SA	South Africa
SD	Standard deviation
U95%CI	Upper 95% confidence interval
UNICEF	United Nations Children's Fund
V	Vietnam
WHO	World Health Organisation

Executive summary

We carried out a mix of secondary and primary research to examine the hypothesis that access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply. Our research was based on a mix of literature review and field-base case studies. Fieldwork was carried out in three countries; Ghana, South Africa and Vietnam and used a mix of data collection methods, specifically a three-part household questionnaire, which included anthropometric measures and the measurement of water collection journeys, natural group discussions, and contextual checklists.

The relationship between water source, water usage and health and social outcomes is complex and mitigated by a range of contextual and intermediate factors. A fundamental challenge in comparing outcomes of at-house supplies with shared supplies lies with wealth as a confounder. In our analysis we were able to account for wealth effects to some extent because of the detailed household information we were able to collect. Nonetheless these challenges are significant.

In our research we focused on a two-step approach, looking at the relationship between distance to source and volumes of water consumed followed by an analysis of volumes of water carried/consumed and the health and social outcomes including hygiene practices. In this way we reduced the effect of wealth and other broader social contextual factors in the analysis. This was supplemented by the analysis of the relationship between source-type and water quality.

From our field data a strong theme was that households often used multiple water sources. This dimension of water usage has received only limited attention from researchers. It is likely that the use of multiple sources of water for different activities is a significant confounder and one of the reasons why research into the relationships between health outcomes and use of specific water sources has been inconclusive.

We found a strong link between volumes of water consumed and the at-home-off-plot break point in services, but limited evidence of a distance-volume relationship once households were using off-plot supplies. We also found some evidence to suggest that where reliability of services is poor, the location of the water source may be less significant than its performance characteristics. In our study locations we found some evidence of households who access water from both private and public wells collecting higher quantities of water than users who access water from taps. Similarly we found strong evidence of a 'break point' in health outcomes between those who carried or who had previously carried water from outside the house and those who did not, relating to musculo-skeletal effects. Water quality was significantly better for those with piped water at home than those who carried water from elsewhere and stored it at home. The evidence on social benefits was limited but points to possible advantages to families who do not have to spend time carrying water but can spend time in leisure activities.

Overall the results from our research indicate that evidence for the detailed water quantity versus distance to source curve previously suggested is tenuous. The conclusion that at-house supplies are associated with higher consumption and health and social benefits is supported, but there is no evidence for the secondary drop in consumption at a fixed distance from home. In reality it seems most likely that the relationship between distance to source and volumes of water consumed is highly mediated by social and geographical factors. This suggests the quantity-distance curve is likely to be 'displaced' upwards or downwards in different contexts.

The headline conclusion from our research is that at-home water supply has significant, measurable benefits when compared with shared water supply outside the home provided that the service provided is reliable enough to ensure access to adequate quantities of water when required. Reliable at-home water supply results in higher volumes of water consumed, greater practice of key hygiene behaviours, a reduction in musculo-skeletal impacts associated with carrying water from outside the home, and improved water quality. This suggests a logical policy shift towards the promotion of reliable household access as the international benchmark for water supply.

For many governments, the implications of this are relatively simple. Where most people have access to reasonable quantities of water close to the home, there is a strong and compelling argument to focus investment in getting reliable water supplies into the home. In such cases, the outstanding challenges relate to improving our understanding of the relative risks associated with different dimensions of levels of service. For example, under what circumstances does a tap in the house have significant benefits over a tap in the yard? What is the relative risk associated with intermittent supply or low pressure of at-house piped supplies compared with private wells or shared supplies, if the latter can provide a more reliable service? A pressing gap in the literature relates to the water resources and cost implications of providing 24 hour supply in piped systems.

For some countries however, the challenge of moving to household supply as the benchmark level of service is more significant and will take time. In these locations (typically arid regions with limited water resources and limited access to capital funds) the policy emphasis may change more slowly. The clear policy message is that investments in water supply should be designed to enable a progressive move towards provision of household supplies even if this level of service cannot be achieved immediately. This might mean for example, designing point-source systems in such a way as to facilitate the addition of networks and house connections at a later date.

In the post-2015 era, the available evidence suggests that access to reliable water supply at home should be the benchmark for water supply.

1. Background

1.1. Research aims and objectives

This research project aimed to test the hypothesis that an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply.

Three primary research questions drove the research to test this hypothesis:

1. What are the patterns of water usage including quantities used and purposes in relation to a range of source types, reliability of service and distance?
2. What health outcomes are associated with different levels of water supply provision?
3. What are the socio-economic benefits derived from different levels of water supply provision?

1.2. The team

The project team comprised researchers in water and health from five Universities:

- the water@leeds team at the University of Leeds;
- the Water Institute at the University of North Carolina;
- the University of East Anglia
- the London School of Hygiene and Tropical Medicine; and
- the University College London.

The team benefited greatly from collaborations with numerous colleagues who supported out work in the field in Ghana, South Africa and Vietnam. Their contributions have been significant and they will play a major role and be fully acknowledged in the publication of the findings from this study.

1.3. The approach

The project utilised several methods to test the study hypothesis. Broadly these can be defined as:

- a review of both scientific and grey literature;
- a review of existing analysis of secondary global data to explore associations between levels of water service, quality of service and health outcomes;
- Field studies utilising qualitative and quantitative fieldwork, data collection and analysis in three countries.

1.4. This report

This report is the final report and summarises the results of both the secondary literature-based research and the field work. Further publications that will appear in open access Journals are planned on the basis of this work. A summary publication plan is included at the end of the report.

2. Methodology

2.1. Literature reviews

We carried out four reviews of the existing literature. The first was a systematically-organised review of the relationship between distance to source and quantities of water consumed. The results are described in Section 3.3.1. The second was a systematically-organised review of the health benefits of at-house water supplies. The results are described in section 3.4.1. We also carried out two brief reviews of the impacts of at-house water supplies on hygiene activities in the home, and the impact of water carrying on musculo-skeletal health impacts. These results are reported in sections 3.4.2 and 3.5.1. One of our team members (UNC) also conducted, at the time of this work, and primarily funded by WaterAid, a review of literature concerning the water quality of different facility types including at-home and off-plot supplies. We summarise that work in Section 3.6.23.6.2.

2.2. Field-based studies

2.2.1. Selection of field research locations

We carried out field research in three countries; South Africa, Ghana and Vietnam. Details of the field studies are given in **Appendices 1,2 and 3**. Case studies were selected to provide a range of contexts but are not representative of the countries in which they were carried out or designed to be globally representative. This research project was not large enough to accommodate representative sampling; our approach was to identify a range of cases which would provide insights into household behaviours and outcomes associated with a range of types of water source, quality of water services and topography.

In Ghana our research was conducted in four communities near Kumasi in the Ashanti region. All four communities were centred around a main road, stretching out densely along the road and less densely outward from the road on either side and could broadly be defined as urban or peri-urban. Water was supplied through a combination of private taps, public taps and private boreholes. The purchase of 'sachet' water was relatively common.

In Vietnam our research was conducted in the remote rural Lao Cai province. Lao Cai is a mountainous area. The communities in Lao Cai were generally small scattered rural hamlets and ethnically heterogeneous. Most households accessed water from several sources, some including piped water supply to the home, private boreholes and dug wells, and public springs.

In South Africa we carried out fieldwork in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province. Two communities were located in the dry, flat area west of Makhado/ Louis Trichardt town. The water sources here were communal taps or private drilled wells with either a yard tap or in-house connection. The third community was located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while some households had yard-taps or in-house taps.

2.2.2. Data collection tools

Two hundred households were recruited to participate in the study in each country. Stratified random sampling was used to recruit a mix of household with at-house and shared water supplies. In each community three data collection tools were used; the household questionnaire, natural group discussions[1] and a community contextual checklist. The latter was used to capture non-water supply characteristics of the community such as environmental conditions, availability of sanitation and prevalence of open defecation.

The household questionnaire was divided into three parts. Part 1 was administered to all households and investigated sources of water used, water usage patterns and health outcomes. Part 2a was administered to one member of each household who was a water carrier to understand water carrying practices and health outcomes. Part 2b was administered to sub-set of water carriers and involved following the water carrier using a GPS tracker to ascertain exact distances and times involved in water collection activities. In Ghana and South Africa Part 2b was administered to all households, in Vietnam a

[1] Natural group discussions, as compared to focus group discussion with which readers may be more familiar, are carried out with a group of participants who naturally gather together rather than with a group that is purposively selected. They are not representative of the population as a whole, but rather allow people to come together in groups where they feel comfortable to express their views freely.

sample of 10% of water carriers were recruited to participate in Part 2b of the questionnaire.

2.2.3. Fieldwork protocol and ethical approval

The fieldwork was driven by a protocol prepared by the field teams prior to travelling to the field. The protocol was prepared and tested at a project workshop in June 2012 prior to the fieldwork activities which were carried out between June and October 2012. Fieldwork tools were also separately piloted in all three project locations. In each case data collection tools were first translated into the appropriate local language and then back-translated prior to piloting. Fieldwork was staggered so that the first field-based pilot in Ghana could used to make overall modifications to the protocol where required. Subsequent piloting in Vietnam and South Africa was then used to make local adjustments as required.

Ethical approval for fieldwork, including data management strategies, was obtained by the University of Leeds covering work undertaken in Vietnam by Leeds researchers and in South Africa by researchers from UEA. Separate ethical approval was obtained from the University of North Carolina for fieldwork carried out by their researchers in Ghana.

3. Results

3.1. Definitions of access and the experience of households in our field studies

3.1.1. Global definitions of "access"

Conceptually, water services can be described in terms of the source and means of abstraction of the raw water; the nature of the reticulation / distribution system to consumers; and the patterns of use of the supplied water (Merrett, 2002). Water supply system performance can be categorised according to a number of different criteria. The choice of criteria depends on the local policy and service provision norms, which in turn may be based on the sociological, cultural, economic, natural and environmental background. Except in systems where universal access is provided by means of at-house piped supplies, water supply services are commonly described by sector professionals according to the type of technology used, distance to water source for users, quantity of water available and the quality of the water provided.

One of the targets of the Millennium Development Goals is "to halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation." The Joint Monitoring Program (JMP) is the official interagency UN mechanism tasked with measuring progress towards achieving the MDGs and is a collaboration between the World Health Organization (WHO) and UNICEF. Table 1 below sets out the technologies considered 'improved' and those considered 'unimproved' by the JMP. In March 2012, WHO and UNICEF announced that the MDG water target had been met, with over 88% of the world's population having access to an improved drinking water source. For the purposes of estimated progress towards achieving the target, JMP "has established a standard set of categories that are used to analyse national data on which the MDG trends and estimates are based"JMP (2012).

Howard and Bartram, in their 2003 review of the evidence on water quantity noted that a 'basic' level of water consumption of up to 20 litres per capita per day (lpcd) is likely to be sufficient for basic health protection but would still leave inadequate quantities of water for "effective use in hygiene practices". They estimated that around 7.5 litres of this water would typically be required for direct consumption (although the amount would vary with ambient temperatures, typical work patterns and a range of other factors) (Howard and Bartram, 2003). Twenty litres per capita per day has now been internationally recognised as a benchmark consumption figure; it is directly referenced in General comment 15 on the Human Right to Water. As it is currently infeasible to measure water consumption reliably at the household level distance (or time) to water source is often proposed as a proxy indicator for consumption quantities.

Table 1: Definitions of improved and unimproved drinking water sources

Improved drinking water	**Unimproved drinking water**
Use of: • Piped water into dwelling, yard of plot • Public tap or standpipe • Tubewell or borehole • Protected spring • Protected dug well • Rainwater collection	Use of: • Unprotected dug well • Unprotected spring • Cart with small tank or drum • Tanker truck • Surface water (river, dam, lake, pond, stream, canal, irrigation channel) • Bottled water (considered to be improved only when the household uses drinking water from an improved source for cooking and personal hygiene)

Since 2000 'reasonable access' to water supply has been interpreted by JMP as "the availability of at least 20 litres per person per day from a source within one kilomet[re] of the user's dwelling" JMP (2000). According to the most up to date WHO information "Access to drinking water means [for the JMP] that the source is less than 1 kilomet[re] away from its place of use and that it is possible to reliably obtain at least 20 litres per member of a household per day" (WHO, 2013).

The origin of the 1 kilometre (km) break point distance comes from studies conducted during the 1970s and 1980s in sub-saharan Africa by White et al. (1972), Feacham (1978) and Cairncross and Cliff (1987). According to these studies, there is a plateau effect of per capita water usage at the household when the water collection time from house to source is between 5 to 30 minutes and then a substantial decline occurs for households whose collection time to a water source exceeds 30 minutes (See Figure 1). The curve shown in Figure 1 is often referred to as the 'Bradley curve' as it draws heavily on work carried out by Bradley and collaborators looking at water usage in Africa in the early 1970s (White et al. (1972). A round trip time of 30 minutes is approximately equal to a distance of 1 km home to source assuming no waiting time at the tap (Cairncross (1987)).

Evidence for a relationship between 1 km distance and 20 lpcd consumption is extremely difficult to find. Furthermore, since JMP estimates rely on data collected from a range of household surveys, it is not clear that the distance parameter is reliably applied across all the estimates. Recent updates of the JMP estimates do not for example refer to distance when describing access to water supply.

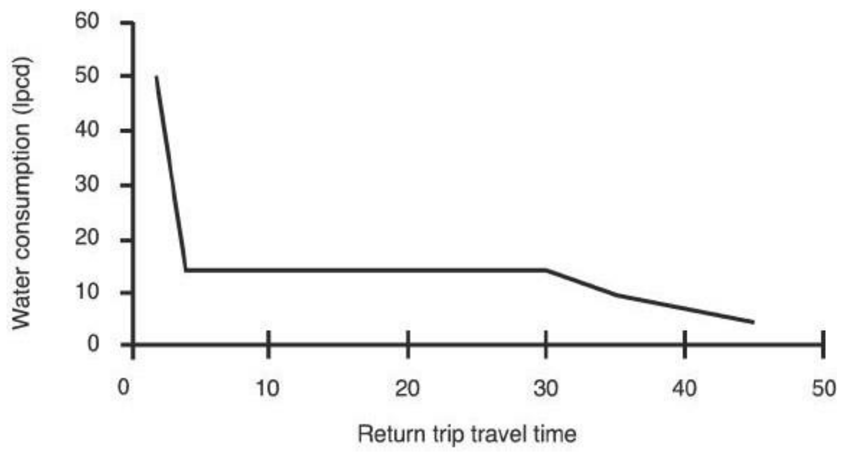

Figure 1: Graph of relationship between travel time (minutes) and water consumption (lpcd)

Source: (Cairncross, 1987)

3.1.2. National definitions of "access"

From a policy perspective both international and national definitions and their use in monitoring are important. In general things that are measured tend to be prioritised over things which are not measured; the degree to which distance is used by national monitoring systems provides a useful insight into the potential policy implications of the research findings of this study.

To establish the extent to which countries use distance as a way to define access to water supply and also to understand how widespread is the use of JMP definitions we carried out a brief review of how countries define access to water supply. To do this we reviewed the country responses to the 2011 UN-Water Global Analysis and Assessment of Sanitation and Drinking Water (GLAAS) country survey (GLAAS (2011). The questionnaire calls on countries to describe how they define 'adequate' water supplies and how this information is collected.

A total of 75 countries submitted returns to the 2011 survey. Of these six did not answer the question relating to definition of 'adequate' water supply (Table 2).

Of the the 69 countries who did return a definition, 61 use technology as one dimension of their definition (Figure 2). Of these, 48 (79% of those using technology definitions) include protected wells, 47 (77%) boreholes/ tubewells, usually with a motor or manual pump, and 33 (54%) include springs (usually defined as 'protected' springs). Eight countries (13% of those using technology in the definition) include all the technologies which are described as 'improved' in the JMP method. These countries are; Bangladesh, Bhutan, the Democratic Republic of the Congo (DRC), Indonesia, Myanmar, Nepal, Pakistan and Sri Lanka. DRC explicitly states that JMP categories of improved water supply will be used. Four countries (7% of those using technology in the definition) only include at-house taps in the measure of access to water supply and these countries are Dominican Republic, Egypt, Iran and Jordan.

The countries which do *not* use technology in their definition are: Ethiopia, Fiji, Maldives, Samoa, South Africa, Tajikistan, Uzbekistan and Vietnam. Vietnam is alone in describing allowable management arrangements for water supply rather than technology or levels of access.

The country with the most comprehensive description of access is the Philippines which describes three levels of service in terms of distance, number of users and type of technologies.

Table 2: Countries responding to the 2011 UN-Water GLAAS country survey

Region	Countries returning access definitions	Countries not returning access definitions
Caucasus and Central Asia	Azerbaijan, Kyrgyztan, Tajikistan, Uzbekistan	
Eastern Asia	Mongolia	
Latin America and the Caribbean	Bolivia, Brazil, Dominican Republic, El Salvador, Honduras, Panama, Paraguay	Colombia, Haiti
Southeastern Asia	Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Thailand, Vietnam	Timor L'Este
South Asia	Afghanistan, Bangladesh, Bhutan, India, Iran (Islamic Republic of), Maldives, Nepal, Pakistan, Sri Lanka	Afghanistan
Sub Saharan Africa	Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, DRC, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Samoa, Senegal, Sierra Leone, South Africa, Sudan, Togo, Uganda, Zimbabwe	South Sudan
Western Asia	Jordan, Lebanon, Yemen	Oman

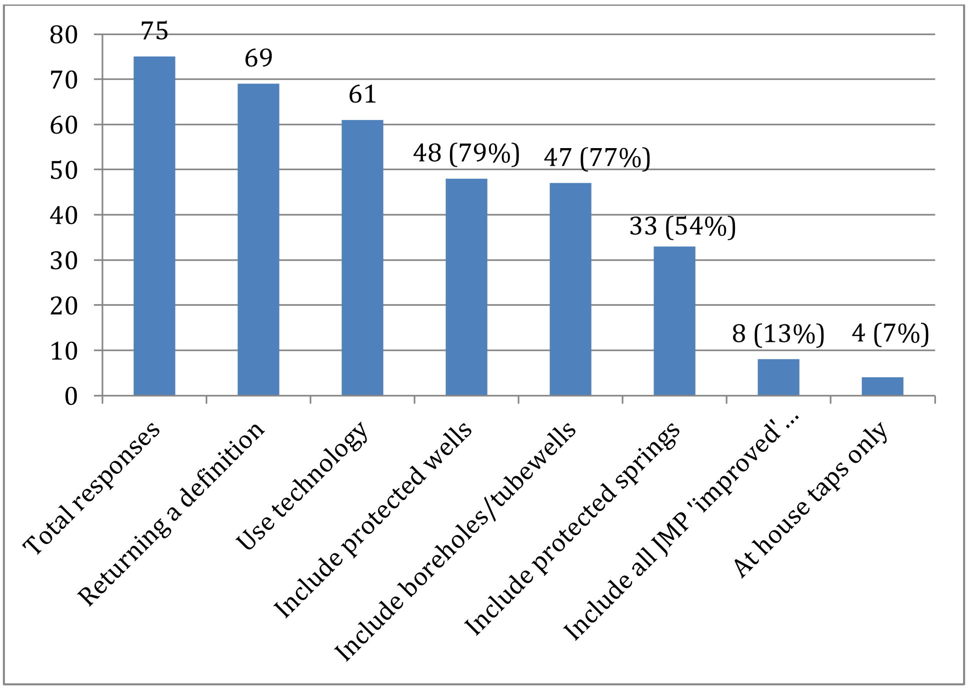

Figure 2: Countries using technology in national definitions for water supply

Nine countries include distance to source as part of their definition; in most cases the distance is considerably less than the 1 km suggested by Cairncross, while Ethiopia counts sources 1.5 km from home in rural areas. The full list of these countries is shown on Table 2. Only one country, Liberia, includes a measure of time to source (within 10 minutes). Six countries use number of users as one measure of access to services for some technologies (Table 4). Eighteen countries have water quality as part of the definition of access (Table 5).

Table 3: Countries using distance to source in their definition

	Technology	Distance to source (m)
Rural and Urban		
Dominican Republic	Private tap	500
Philippines	Point sources (Level 1)	25
Philippines	Shared taps (Level 2)	250
Sri Lanka	Multiple	200
Malawi	Multiple	500
Nigeria	Multiple	250
South Africa	Not specified	200
Rural alone		
Morocco	Public tap	500
Ethiopia	Not specified	1500
Rwanda	Multiple	500
Urban alone		
Morocco	Public tap	200
Ethiopia	Not specified	500
Rwanda	Multiple	200

Table 4: Countries using number of users in their definition

	Type of technology	Nr of Users/ Unit
Rural and Urban		
Egypt	Private tap	Apartment
Bangladesh	Private tap	5
Bangladesh	Public tap	100
Mozambique	Private tap	5
Mozambique	Well/ borehole	500
Rwanda	Public tap or borehole with motor	300
Rwanda	Borehole with handpump	350
Rural only		
Benin	Public tap	250
Guinea-Bissau	Well/ borehole	150
Urban only		
Benin	Public tap	12

Table 5: Countries including water quality in the definition

Country	Water quality standards/ commentary
Ethiopia, Fiji, Rwanda	World Health Organisation standards
Indonesia	Source should be more than 10m from sewage disposal point
El Salvador	Treatment
Dominican republic	Treated and chlorinated
South Africa, Mongolia, Tajikistan, Lesotho, Jordan, India	National standards
Samoa	National standards (in line with EU standards)
Honduras	Protected from fecal contamination
Congo, Morocco	Potable
Maldives	Boiled, treated or chlorinated or desalinated water
Panama	Filtered and disinfected

The specific definitions used in our three study countries are summarised below in Table 6.

Table 6: Minimum criteria for 'basic' water services in Ghana, South Africa and Vietnam

	Ghana	South Africa	Vietnam*
Level	'basic'	'basic'	-
Source	'improved'	tap	-
Density (people per water source)	300 (hand-pump)	-	-
Distance (m)	500	200	-
Quantity (ℓ)	20	25	-
Quality	National standards	National standards	-
Flow rate (ℓ/min)	-	10	-
Reliability	95%	98%	-

*Vietnam defines access to water supplies as those provided through approved institutional arrangements

We can see therefore that definitions of level of service in most countries focus on technology (see also (O'Hara et al., 2008)); issues of reliability and flow rate/pressure are rarely considered and some commentators have observed that they are considered to be of secondary importance (Hope and Garrod, 2004). For water users however the functionality or performance of the supply may be very important (Gulyani et al., 2005). Thus, while a tap in the house may, in theory, provide a higher level of service than a yard tap or communal standpipe, low pressure or intermittent supply may affect quality or quantity water supplied, and effectively render the quality of the service low.

3.2. Sources of water in the study sites

3.2.1. Multiple water sources

Households typically made use of an array primary, secondary and sometimes tertiary water sources. Four hundred and twenty households (64 %) reported using a secondary water source. Forty-six percent of those reporting using a secondary source were households *with* on-site supply. Only 36 % of households relied exclusively on one water source. This is consistent with findings from previous research, for example (Howard et al., 2002).

3.2.2. Main water source

Households in the three survey sites used an array of water sources. The main water sources are shown in Table 7. At-house water sources included house connections to piped systems, wells in the yard and private rainwater collection in Vietnam.

Communal taps were the most common shared water source in both Ghana and South Africa, while surface water was more common in Vietnam. The highest proportion of households using at-house water sources was in Vietnam, with just over three quarters of the sample having access to a supply at the house or yard.

It is perhaps worth noting that although communal taps were available in all the study communities in South Africa, some households reported their main supply as neighbours' private drilled wells, surface water (protecting springs) or municipal water tankers.

Table 7: Main water sources in Ghana, South Africa and Vietnam

		Ghana N (%)	South Africa N (%)	Vietnam N (%)
At-house water sources	Piped supply with HH tap	8 (3.1%)	43 (20.9%)	10 (5.1%)
	Piped supply with yard tap	57 (22.4%)	6 (2.9%)	87 (43.9%)
	Private well (mechanical pump)	4 (1.6%)	54 (26.2%)	40 (20.2%)
	Private well (manual lifting pump)	36 (14.1%)		11 (5.6%)
	Private rainwater collection	-		4 (2.0%)
	Total private sources	105 (41.2 %)	103 (50 %)	152 (76.8 %)
Shared water sources	Shared piped supply with tap	112 (43.9%)	79 (38.3%)	5 (2.5%)
	Shared well with manual pump	20 (7.8%)	-	-
	Shared well with manual lifting	18 (7.1%)	-	2 (1.0%)
	Shared supply surface water		4 (1.9)	38 (19.2%)
	Buying water from neighbours		11 (5.3%)	-
	Other – outside of home (municipal water tanker)		9 (4.4%)	-
	Total shared sources	150 (58.8 %)	103 (50 %)	45 (22.7 %)
	Total households	255 (100 %)	206 (100 %)	197 (99.5 %)

3.2.3. Reliability

Although the majority of main water sources used in the survey were those conventionally classified as ‘improved’, the reliability of the water supplies was low in Ghana and South Africa in particular. On average, water was unavailable for three days of the week in Ghana and South Africa, while in Vietnam it was typically unavailable for one day per week (Table 8). Reliability was reported by household members to be a particular issue for piped supplies.

On the days when it was available, water was supplied for most of the day in all three survey sites. However, breakdowns in the supply system reportedly took an average of a month to repair in South Africa, while in Vietnam repairs were within a day. In Ghana the average time for repairs was just over one week. Just over a quarter of households reported that their domestic water needs were not met all the time (Table 9).

Table 8: Summary statistics on water supply reliability

Variable	Country	N (%valid)	Mean (SD)	Median	Mode	Min	Max	Range
Number of days without water supply per week	South Africa	201 (97.6%)	2.5 (4.2)	1	0	0	30	30
	Ghana	222 (87.1%)	3.0 (3.8)	2	0	0	16	16
	Vietnam	197 (99.5%)	0.8 (2.1)	0	0	0	14	14
Hours of supply per day	South Africa	198 (96.1%)	18.7 (8.2)	24	24	0	24	24
	Ghana	199 (78.0%)	18.7 (8.3)	24	24	0	24	24
	Vietnam	142 (71.7%)	22.1 (5.2)	24	24	1	24	23
Time taken to repair breakdowns (days)	South Africa	110 (53.4%)	34.8 (47.2)	30	30	0	365	365
	Ghana	105 (41.2%)	8.5 (26.5)	3	0	0	210	210
	Vietnam	101 (51.0%)	1.2 (2.8)	0	0	0	24	24

South Africa n = 206; Ghana n = 255; Vietnam n = 198

Table 9: Adequacy of water for domestic needs

	Shared	Private	Total
No	64 (21.5%)	26 (7.2%)	90 (13.7%)
Less than half of the time	17 (5.7%)	10(2.8%)	27 (4.1%)
About half of the time	9 (3.0%)	10 (2.8%)	19 (2.9%)
More than half of the time	11 (3.7%)	27 (7.5%)	38 (5.8%)
Yes	196 (66.0%)	286 (79.7%)	482 (73.5%)

For those households where supply was inadequate a major reported reason was temporal variation in supply (Table 10). Households that had at-house water supplies cited seasonal availability of water, water pressure as well as temporal availability of water at the source amongst the reasons for having inadequate water quantities.

Table 10: Reasons why water supply is inadequate

	Shared	Private	Total
Storage problems	3 (3.2%)	2 (3.2%)	5 (3.2%)
Number of water collectors	6 (6.5%)	1 (1.6%)	7 (4.5%)
Number of water collection containers that can be used	3 (3.2%)	0 (0%)	3 (1.9%)
Temporal availability of water at source	23 (24.7%)*	16 (25.4%)*	39 (25.0%)*
Seasonal availability of water at source	8 (8.6%)	19 (30.2%)*	27 (17.3%)*
Power to extract water from source of water	2 (2.2%)	1 (1.6%)	3 (1.9%)
Reliability or predictability of source of water	2 (2.2%)	0 (0%)	2 (1.3%)
Price	16 (17.2%)	4 (6.3%)	20 (12.8%)
Water pressure	11 (11.8%)	16 (25.4%)*	27 (17.3%)*
Accessibility (location) to supply	19 (20.4%)*	4 (6.3%)	23 (14.7%)

3.3. Distance to source and water consumption

3.3.1. Summary findings from the systematic review of literature

The full text of the systematic review of literature will be made available in an open access journal article.

The Cairncross curve of travel time and water consumption (Figure 1) suggests that water consumption drops substantively when water sources are located at distances greater than 30 minutes (1 km) away. At distances between 5 and 30 minutes, per capita water consumption remains relatively constant, but dramatically rises as water becomes available within five minutes of the household.

A systematic review of studies was conducted in order to assess the evidence for this phenomenon and its implications for new recommended standards on distance to water sources. A search of peer reviewed journal articles was conducted in three academic databases, PubMed, Embase, and Global Health. The search was conducted in January 2013 and included articles published between January 1970 and January 2013[2]. No language restrictions were imposed however only articles published in English were examined for review. Location was restricted to developing countries through search terms.

Studies were excluded if they did not report data on water consumption and time or distance from the household to the main water source. Papers collecting both quantity and distance or time but not reporting them together were also excluded. Authors were contacted in cases where both water quantity per capita and distance (or time) to water source data were collected but not published in the results.

[2] Global Health contained articles from January 1972 and Embase contained articles from January 1973.

Data extraction from the studies included details regarding the time and setting of the study, the study design, statistical analysis used, and methods related to data collection. Particular attention was paid to the method used for measuring distance (or time) and the quantity of water used per day. Although some articles were unclear in their methods and analysis, there was no restriction based on study quality.

The search identified 5,961 potentially relevant articles from three databases of peer reviewed journal articles with 17 articles being included in the final review. An additional eight articles and books were identified based on a search of bibliographies of included papers. Further details will be published in a forthcoming paper reporting the findings of this review.

A review of the included studies resulted in the following key findings:

- There are very few studies investigating factors affecting water use in developing countries. Since 1968, only 25 studies have reported data on both water quantity and distance to the water source (or collection time). Of the 25, only 15 studies were specifically examining water consumption.
- Reported studies represent a mix of study designs, sampling schemes, data collection methods and approaches to statistical analysis. This complicates comparison of study results and derivation of overall conclusions regarding the relationship between the distance to water sources and household water use.
- Self-reported data on water use were used in seven studies and only five studies used direct measurement to obtain quantity data. Data on distance to the water source was directly measured in nine studies and in five studies the method was unclear.
- Results from included studies were mixed; eight studies reported no relationship between distance to the water source and water use and 12 presented data suggesting a decrease in water consumption with increasing distance. The differences in results could be due to differences in study design, data collection methods, assumptions, or geographical and cultural practices.
- The five studies comparing households having at-home supplies with those using off-plot sources show a substantially greater quantity of water used when water is available on-home.
- The identified papers show a pronounced geographical bias towards Sub-Saharan Africa (SSA). This may be due in part to the search being restricted to articles published in English. Three-quarters of the included studies were conducted in SSA, with the remainder conducted in Latin America and the Caribbean, North Africa, Southern Asia and South-eastern Asia. The Millennium Development Goal regions of Western Asia, Oceania, Caucasus and Central Asia, and Eastern Asia, were not represented in the literature.
- The majority of studies were performed in rural settings. Two papers contained study sites in both rural and urban communities and only one paper looked at water use patterns in peri-urban communities.

Current policy appears to be based on a handful of studies White et al. (1972), Feacham (1978) and Cairncross and Cliff (1987), performed over 30 years ago and summarised by Cairncross in 1987. The existing literature presents a mixed picture of water use patterns reflecting the complex dynamics governing water behaviour for those relying on off-plot water sources. In contrast, the included studies comparing households with at-home supplies and households using off-plot sources show a consistently greater water use.

At the moment, at-home water supplies are not available for all households with rural households less likely than urban households to enjoy this type of supply. More rigorous studies would aid in determining what indicators are the most indicative of water use by households across all regions, in both rural and urban settings.

3.3.2. Summary findings from the fieldwork

Water quantity by source type

To examine the relationship between median water use and water source type, a quantile regression model was used. Quantile regression was used due to the presence of some extreme water use data points (indicated in **Appendix D**, Figure D.1). The method of least squares is used in some regression techniques to model the relationship between a covariate and the conditional mean of the outcome variable. Whereas the mean can be obscured due to outliers, the median is less influenced by extreme values. Quantile regression describes the relationship between a covariate and the conditional quantiles (median or other quantiles) of the outcome variable (Chen, 2005).

The quantile regression model was adjusted for country of study, crowding, highest level of education within the household, the number of types of assets owned, and water source type. Crowding was defined as the number of people in the household divided by the number of reported rooms within the home. Assets were defined as radios, televisions, mobile telephones, refrigerators, washing machines, cars, bicycles, motorbikes, and stoves. Crowding and number of assets were used to minimize confounding due to wealth and socio-economic status. Level of education has been shown to be correlated with water use and was therefore controlled for in the model (Sandiford et al. (1990)).

Figure 3 shows the median water use (lpcd) for households using different sources with bars indicating the 95% confidence intervals. Table 11 shows the results from the quantile regression model assessing the relationship between water quantity and water source type using communal standpipes as the basis for comparison between sources. Both Figure 2 and Table 11 show that there are significant differences in water use by source type ($p<0.0001$). The results from the quantile regression show the change in water use between sources, while Figure 2 shows the actual median water use for each source. The aggregated data was used for this analysis since disaggregating by country would lead to small samples sizes for some source types.

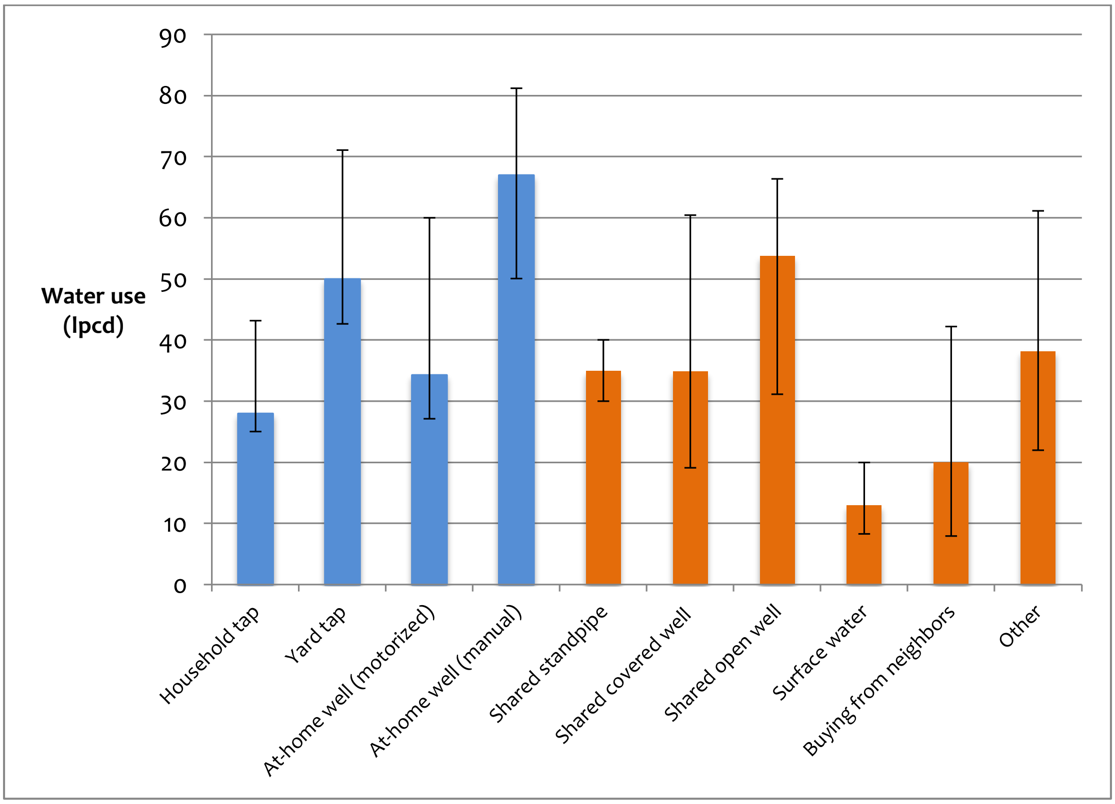

Figure 3: Median water use (lpcd) by source type (bars indicate 95% CI)

Note: At home sources are shown in blue and off-plot sources in orange. Rainwater collection is not shown due to the small sample size and wide confidence intervals

Table 11: Results from quantile regression of water use (lpcd) and location of water source (data from all three countries)

Water source	n	Extra water use	L95%CI	U95%CI
Shared standpipe	191	0		
Shared covered well with manual pump[1]	19	-0.6	-17.5	16.3
Shared open well with manual lifting	19	15.7	-1.6	33.0
Surface water	40	-19.3	-35.5	-3.1
Buy from neighbours	11	-11.1	-23.3	1.2
Other[2]	8	10.9	-14.1	35.9
Tap in house	37	-7.5	-20.9	5.8
Tap in yard	99	8.8	-1.8	19.3
At-house mechanical lift	52	-5.0	-18.0	8.0
At-house manual lift well	30	29.8	15.4	44.2
Rainwater collection	3	64.4	28.5	100.3

1- *Most often boreholes with handpumps*
2- *'other' most often tanker trucks*

Extra water use' refers to an increase or decrease in the median water quantity (lcpd) rather than the mean water quantity. ($F(10, 493) = 9.91$, $p<0.0001$).

The median per capita daily water consumption for households using shared standpipes was 35 lpcd. Households that identified shared manual wells as their primary source used 15.7 ± 17.3 lcpd more than households using public standpipes. Surface water users use considerably less water (19.3 ± 16.2 lpcd) than households using public standpipes. Households relying on surface water as their primary source had the lowest median water use of 13.0 ± 5.9 lcpd. Within the set of households using on-plot supplies, those with a piped supply used least water.

The results from Table 11 should be viewed in light of the sample sizes for each water source. While there were a substantial number of observations for public taps (n=191) and yard taps (n=99), some sources (shared pump well, shared manual well, rainwater collection, buying from neighbours, and other) had sample sizes less than 20 households, therefore conclusions regarding these sources cannot be made with statistical confidence.

At-home and off-plot supplies

We used a similar approach and quantile regression to examine the relationship between quantity of water used (lpcd) and the location of water sources.

The regression was done on the aggregated data from all three countries, and separately to examine possible different relationships occurring at the country level. Table 12 shows the results from the regression model comparing the difference in median water use using off-plot sources as the comparison.

In Ghana households with at-home supplies use 30.4 (16.1-44.8 95% CI) more water than households using off-plot sources, which was statistically significant (p<0.0001). The model for Vietnam showed the same relationship with at-house supplied households using 29.0 (-8.7-66.6) more water than off-plot households, however this was not statistically significant (p=0.130). Even after adjusting for other variables, South Africa still shows a different trend from Ghana and Vietnam with off-plot supplied households using more water than households with at-home supplies.

Table 12: Results from quantile regression of water use (lpcd) and location of water source as at-home or off-plot..

Country	Location of water source	Extra water use[1] (lpcd)	L95%CI	U95%CI	p
	Off-plot	0	---	---	---
All	At-home	10.9	2.9	18.8	0.007
South Africa	At-home	-13.4	-23.6	-3.2	0.01
Ghana	At-home	30.4	16.1	44.8	<0.0001
Vietnam	At-home	29.0	-8.7	66.6	0.130

[1]- *'extra water use' refers to an increase or decrease in the median water use (lpcd) rather than the mean water use*

Households fetching water off-plot

According to Cairncross (1987), the expected relationship between water quantity used and round-trip collection time is a steep decrease when the trip takes over five minutes; water quantity used remains constant between five and 30 minutes and declines again when the trip exceeds 30 minutes (See Figure 1). Round -trip collection times reportedly correspond to a distance of 1 kilometre from the home to the source (ibid.) although in reality walking speeds vary greatly by individual and terrain and queue times may also vary, all of which may affect travel time (White et al. (1972)).

Figure 4 shows the scatterplot of water quantity and measured round-trip time (min) to the primary water source for households using off-plot water sources in South Africa, Ghana, and Vietnam. The inverse relationship between water quantity used and round-trip travel time varies between countries. In comparison to Ghana and Vietnam, South Africa has a more uniform distribution of water quantity used for households between zero and 35 minutes from the source. In Ghana all households had a round-trip collection time less than 25 minutes, while in Vietnam households travelled less than 20 minutes round -trip.

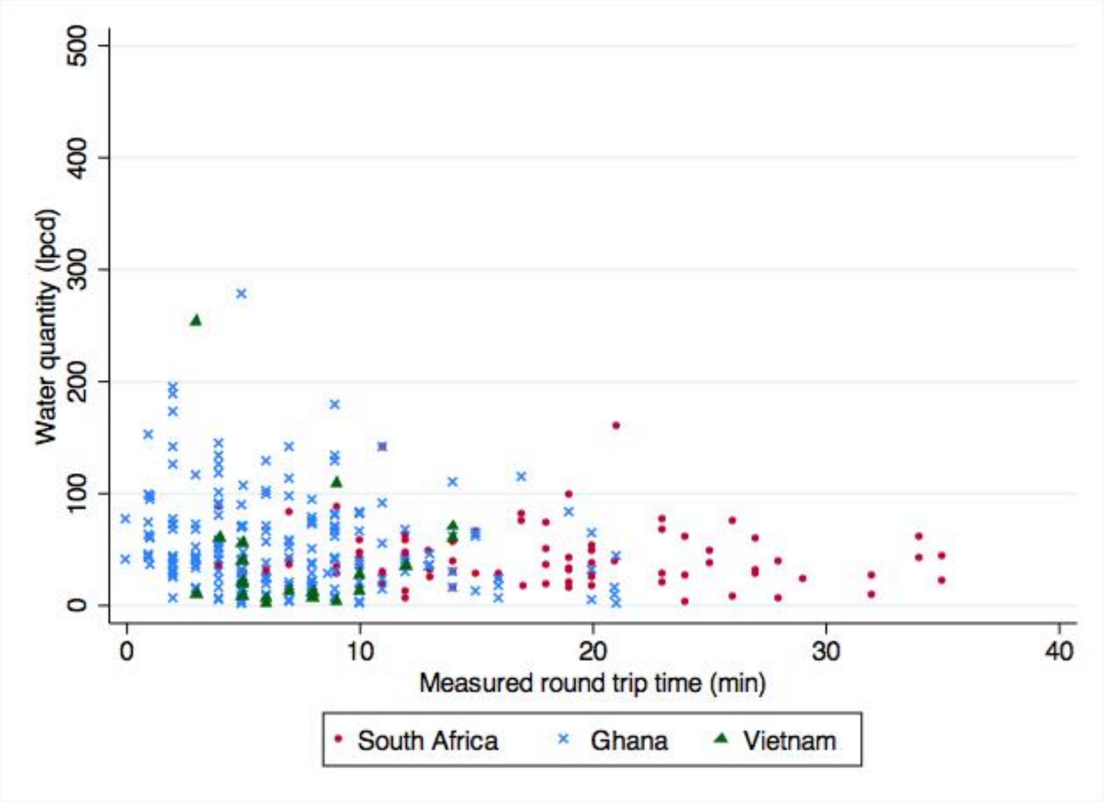

Figure 4: Scatterplot of water quantity (lpcd) and measured round-trip travel time to the primary water source for households using off-plot sources in all three countries with extreme values excluded.

Note : Refer to Appendix D for scatterplot with all values).

A quantile regression model was used to assess if time or distance had a significant relationship with water quantity for households using off-plot water sources. Self-reported round-trip travel time, measured round-trip travel time, and measured round-trip distance were used in regression analyses to see if one provided a more significant relationship with water quantity.

The results from the regression model for self-reported round-trip time for each country are shown in Table 13. Table 14 shows the results from the quantile regression model for measured round-trip time for each country, and Table 15 shows the results from the measured round-trip distance and water quantity.

Table 13: Results from quantile regression of water use (lpcd) and self-reported round-trip time.

Country	n	Extra water use[1]	L95%CI	U95%CI	p
South Africa	79	0.1	-0.1	0.4	0.368
Ghana	114	0.1	-0.5	0.8	0.710
Vietnam	40	-0.1	-0.6	0.3	0.637

[1] - *'extra water use' meaning for every increase in 10 minutes of self-reported round-trip time there was an increase or decrease in median water use by X lpcd.*

Table 14: Results from quantile regression of water use (lpcd) and measured round-trip time to source.

Country	N	Extra water use[1]	L95%CI	U95%CI	p
South Africa	86	0.6	-6.1	7.3	0.865
Ghana	132	-14.4	-32.8	4.1	0.126
Vietnam	17	-2.1	-36.5	32.4	0.897

[1] - *'extra water use' meaning for every increase in 10 minutes of measured round-trip time there was an increase or decrease in median water use by X lpcd.*

Table 15: Results from quantile regression of water use (lpcd) and measured round-trip distance to source.

Country[1]	n	Extra water use[2]	L95%CI	U95%CI	p
South Africa	86	0.2	-1.2	1.6	0.765
Ghana	139	-0.1	-5.2	4.9	0.955

[1] –No measured distance data was available for Vietnam

[2]- 'extra water use' meaning for every increase in 100 meters of measured round-trip distance there was an increase or decrease in median water use by X lpcd.

The results from the regression model for each country show no statistically significant relationship between self-reported round-trip time or measured round-trip time and water quantity. There was no statistically significant relationship for measured round-trip distance and water quantity for data from South Africa and Ghana. The results from the three sites were consistent in regards to no statistical relationship for self-reported and measured round-trip time. While there was no measured distance data from Vietnam, the results for South Africa and Ghana both showed no relationship for round-trip distance and water quantity.

Location of water using activities

Drinking water accounts for only a fraction of water used by households. Other uses can have large impacts on the quantities of water used, both for domestic and productive purposes. Domestic uses such as laundry or bathing require more water than is used for drinking and food preparation. Many water quantity papers only record the amount of water carried home by households in their calculations of water quantity. The location where households perform certain tasks can impact the calculated water use per person. As part of the household survey, respondents were asked to identify where they performed various domestic and productive activities requiring water (at home, at the source, elsewhere, or in multiple locations). The disaggregated results for households using off-plot water supplies in South Africa, Ghana, and Vietnam are shown in Table 16. Less than 10% of households using off-plot water supplies in any of the countries performed domestic water-using activities (bathing, laundry and cleaning dishes) on plot.

Table 16: Locations of domestic water-using activities by households using off-plot supplies (South Africa, SA n = 206; Ghana, GH = 255; Vietnam, V = 198).

Activity	Country	n (% HH)	Location of water-using activity			
			At Home	At Source	Else where	Multiple locations
Bathing	SA	103 (50.0%)	103 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	148 (58.0%)	147 (99.3%)	1 (0.7%)	0 (0.0%)	0 (0.0%)
	V	45 (22.7%)	6 (13.3%)	39 (86.7%)	0 (0.0%)	0 (0.0%)
Laundry	SA	103 (50.0%)	72 (69.9%)	15 (14.6%)	10 (9.7%)	6 (5.8%)
	GH	148 (58.0%)	145 (98.0%)	3 (2.0%)	0 (0.0%)	0 (0.0%)
	V	45 (22.7%)	2 (4.4%)	43 (95.6%)	0 (0.0%)	0 (0.0%)
Cleaning dishes	SA	103 (50.0%)	103 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	148 (58.0%)	147 (99.3%)	1 (0.7%)	0 (0.0%)	0 (0.0%)
	V	45 (22.7%)	34 (73.9%)	12 (26.7%)	0 (0.0%)	0 (0.0%)

Households in Ghana and South Africa often bathed and washed clothes at home rather than at the source. In contrast, a larger percentage of households (85% bathing, 94% laundry) using off-plot supplies in Vietnam reported performing these tasks at the source.

Very few households reported using water for productive uses such as farming and commercial services. More households in Vietnam (n=16) specified using water for agricultural purposes than households in Ghana (n=6) or South Africa (n=2). Ghana had the largest number of households reporting commercial activities utilizing water (n=18), which include but are not limited to food preparation, laundry for others, and washing vehicles.

In terms of productive uses, more households in Vietnam reported using water for farming (n=73) than households in South Africa (n=10) and Ghana (n=13). Table 17 shows the reported number of households from each country using water productively and the location of water use. Ghana had the largest number of households reporting commercial activities utilizing water (n=36), which include but are not limited to food preparation, laundry for others, and washing vehicles.

Table 17: Locations of productive water-using activities by households using off-plot supplies (South Africa, SA n = 206; Ghana, GH = 255; Vietnam, V = 198).

Activity	Country	n (% HH)	Location of water-using activity			
			At Home	At Source	Else where	Multiple locations
Farming[1]	SA	10 (4.9%)	10 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	13 (5.1%)	6 (50.0%)	2 (16.7%)	4 (33.3%)	0 (0.0%)
	V	73 (36.9%)	0 (0.0%)	62 (84.9%)	11 (15.03%)	0 (0.0%)
Commercial services[2]	SA	2 (1.0%)	2 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	36 (14.1%)	20 (66.7%)	6 (16.7%)	7 (19.4%)	3 (8.3%)
	V	6 (3.1%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

1- *Includes agriculture, aquaculture, raising livestock*
2- *Includes preparing food, laundry for others, washing vehicles*

Selection of additional sources

Issues of seasonality, source reliability, cost, and convenience can lead to households choosing to use alternative sources in addition to or in place of their primary sources. Households may also chose to use different sources based on the purpose for which they are using water. For example, some households may use an improved source farther away for drinking water, but use an unimproved source next to their house for bathing. In order to better assess the extent and variation of multiple source use, households were asked to specify whether they used their primary water source or an additional water source for different activities. The results from the three countries are presented in Table 18.

Table 18: Reported use of main and additional sources for various water-using activities (South Africa, SA n = 206; Ghana, GH = 255; Vietnam, V = 198).

Activity	Country	n (% HH)	Main source	Alternative source	Main and alternative
Drinking	SA	206 (100%)	58 (28.2%)	2 (1.0%)	146 (70.9%)
	GH	252 (98.8%)	81 (32.1%)	30 (11.9%)	141 (56.0%)
	V	197 (99.5%)	162 (82.2%)	16 (8.1%)	19 (10.6%)
Preparing food	SA	205 (99.5%)	59 (28.8%)	0 (0.0%)	146 (71.2%)
	GH	252 (98.8%)	219 (86.9%)	3 (1.2%)	30 (11.9%)
	V	197 (99.5%)	168 (85.3%)	12 (6.1%)	17 (8.6%)
Bathing	SA	206 (100%)	59 (28.6%)	0 (0.0%)	147 (71.4%)
	GH	252 (98.8%)	221 (87.7%)	0 (0.0%)	31 (12.3%)
	V	197 (99.2%)	163 (82.7%)	17 (8.6%)	17 (8.6%)
Laundry	SA	205 (99.5%)	57 (27.8%)	3 (1.5%)	145 (70.7%)
	GH	252 (98.8 %)	225 (89.3%)	2 (0.8%)	25 (9.9%)
	V	196 (99.0%)	150 (76.5%)	21 (10.7%)	25 (12.8%)
Cleaning house	SA	206 (100%)	59 (28.6%)	0 (0.0%)	147 (71.4%)
	GH	251 (98.4%)	225 (89.6%)	1 (0.4%)	25 (10.0%)
	V	102 (51.5%)	94 (92.2%)	2 (2.0%)	6 (5.9%)
Gardening	SA	44 (21.4%)	29 (65.9%)	0 (0.0%)	15 (34.1%)
	GH	46 (18.0%)	24 (52.2%)	12 (26.1%)	10 (21.7%)
	V	135 (68.2%)	96(71.1%)	22 (16.3%)	17 (12.6%)

A high percentage of households in South Africa (70.9%) and Ghana (56.0%) reported using main and an additional source (multiple sources) for drinking. In Ghana, the field researchers observed the frequent use of sachet water, 250 mL of drinking water sealed in plastic. A large portion of study households in Ghana (61.2%) reported using bottled or sachet water as an additional source, which contrasts sharply with the other peri-urban communities from South Africa which did not report any use of bottled or sachet water (Table 19).

Table 19: Number of households reporting use of bottled water or sachet water.

	South Africa	Ghana	Vietnam
Bottled/sachet water	0 (0.0%)	156 (61.2%)	4 (2.0%)
Total	206	255	198

For activities other than drinking, households in South Africa reported using their main and additional sources. Interestingly, the reverse is seen for households in Ghana, where most households used their main water source exclusively for all activities other than drinking. Households in Vietnam predominately used only their main source for all domestic activities.

Table 20 shows the reported number of additional sources used by sampled households. Bottled water and sachet water were separated (Table 19) since these alternative water sources are a unique category. More households in South Africa (72.8%) and Vietnam (59.0%) use additional sources compared to Ghanaian households (26.2%). Table 21 breaks down the reported additional sources by type. The results shown in Table 22 account for all reported additional sources used by households except for sachet water and bottled water. Public standpipes were the most reported additional source used in Ghana (30.4%). In contrast, surface water accounts for 56% and 48% in South Africa and Vietnam, respectively.

Table 20: Number of additional sources used by households in each country.

Number of alternative sources used	South Africa HH (%)	Ghana HH (%)	Vietnam HH (%)
0	56 (27.2%)	76 (73.8%)	107 (54.9%)
1	149 (72.3%)	2 (2.0%)	75 (38.5%)
2	1 (0.5%)	21 (20.4%)	10 (5.1%)
3	0 (0.0%)	4 (3.9%)	3 (1.5%)
Total HH	206	103	195

Table 21: Types of additional sources reportedly used by households reporting at least one alternative source.

Alternative water source type	South Africa	Ghana	Vietnam
Household tap	0 (0.0%)	0 (0.0%)	1 (0.9%)
Yard tap	0 (0.0%)	4 (7.1%)	5 (4.8%)
Private well (motorized pump)	0 (0.0%)	0 (0.0%)	3 (2.8%)
Private well (manual lift)	0 (0.0%)	4 (7.1%)	1 (1.0%)
Rainwater collection	2 (1.3%)	- [1]	29 (26.9%)
Public standpipe	14 (9.3%)	17 (30.4%)	9 (8.3%)
Shared covered well (manual lift)	0 (0.0%)	6 (10.7%)	3 (2.8%)
Shared open well (manual lift)	0 (0.0%)	16 (28.6%)	1 (0.0%)
Surface water	85 (56.3%)	9 (16.1%)	52 (48.2%)
Buying from neighbors	36 (23.8%)	0 (0.0%)	0 (0.0%)
Other	14 (9.3%)	0 (0.0%)	0 (0.0%)
Total alternative sources reported	151	56	104

1- *“rainwater collection” was translated as “rain”therefore rainwater collection data was excluded for Ghana.*

Discussion

The field data from all three countries reveal an important relationship between whether water supplies are located on- or off-plot and water quantity. The aggregated data from all three countries showed households with at-home water sources used a significant ($p=0.007$) more amount of water (10.9 ± 8.0 lpcd) compared to those needing to fetch water outside their house.

Looking at the sample of selected communities and households in individual countries, Ghana and Vietnam showed a higher water use in households with at-home water supplies. There appears to be a different trend in South Africa, where households using off-plot supplies use more water than households with on-plot supplies. This is most likely due to an underreporting by households using at-home water supplies. The predominate at-home water supplies in South Africa were household taps and private wells with a motorized pump. Municipal water bills were not available for households, which meant the respondents estimated total daily water use. All of the on-plot wells used motorized pumps that pumped water into a 2,500 litre or larger storage tank from which households withdrew water from a tap connected to the tank. One field researcher observed respondents storing a 2-litre container of water in a refrigerator for drinking purposes and for other uses water was directly drawn from the tank tap. This could have resulted in an under estimation since households with in-house taps and motorized wells are not necessarily filling buckets and making specific water fetching trips, which would be easier to recall.

Counter-intuitively, respondents using household taps had a lower median water use (28.0 ± 9.1 lpcd) compared to households with yard taps (50.0 ± 14.3 lpcd). This result could be due to the effect of the data from all three countries being pooled together in the analysis. A systematic under-reporting by households having a tap within the home compared to those having to go out to the yard to collect water could also be the reason for this result. Another possibility for the lower water use by household taps could be the sharing of water supplies with neighbours. Households would be more prone to collect water from their neighbour's yard tap than an interior household tap. The location of where households were performing tasks such as washing clothes or cleaning dishes, or gardening could be another reason for the discrepancy between household and yard taps. Households could use yard taps more for these activities, which use more water than activities such as drinking and cooking.

For households using off-plot supplies, shared open wells reported the highest median quantity (53.8 ± 17.6 lpcd), compared to other off-plot sources. This could be due to tariff structures or varying queue times at the different public sources. If queue times are longer at certain public sources, water carriers could chose to use other sources and make more frequent trips. It could also be due to the fact that the availability of water in wells is more consistent and reliable than the availability of water in other supplies, particularly in taps. Households reported 'temporal availability of water' as one of the main reasons for dissatisfaction with their main water supplies, suggesting that an sporadic or unpredictable supply created problems in terms of water collection. The higher rate of consumption in wells when compared to taps could also be seen amongst households with at-home supplies, suggesting that this aspect of reliability may hold irrespective of the location of the source.

The results from the quantile regression models for self-reported and measured round-trip travel time and measured round-trip distance demonstrate no statistical significant relationship with water quantity, but there also appears to be no evidence to substantiate a general plateau effect where water use remains constant between five and 30 minute round-trip collection times. There was no indication that any of the three independent variables (self-reported travel time, measured travel time, and measured distance) provided a better indicator for water quantity used. Neither round-trip time or round-trip distance provided an accurate predictor for the amount of water households accessed when it was located off-plot. Comparing the results from self-reported travel time and measured travel time did not reveal whether either method provided a better estimate of water quantity used by households.

The data on households collecting water off-plot from all three countries reveal no significant relationship between distance and water quantity. The thresholds at five and 30 min noted by Cairncross (1987) are not clearly observed in the sample as shown in Figure 4. Few households within the sample travelled further than 1 km to their water source; of those who did, the vast majority were in South Africa. This would explain why a decrease in water use was not seen in the data since households were not walking far enough to see the effect. The lack of a relationship between distance and water quantity is consistent with other studies (Verweij (1991) and West (1989)). The part of the curve depicting a substantially higher quantity of water used when water is located on premise, however, is supported by the pooled field data from all three countries.

Water use patterns were different between the study sites with the majority of bathing and laundry being done at home in Ghana and South Africa while these activities more frequently occurred at the source for Vietnamese households. All communities in South Africa and Ghana were peri-urban, while all the study sites in Vietnam were rural. The difference in location could be due to the variation in settings or even due to the source type available. In South Africa and Ghana, the principal off-plot water source was public standpipes (77% and 75% respectively), while in Vietnam the principal off-plot source was surface water (84%). Respondents might have felt more comfortable bathing at a river compared to bathing at a public standpipe. Cultural differences could also account for the different behaviour between the three sites with two being in Africa and the other being in South-Eastern Asia.

The variation in water behaviour between the three countries has been noted in other studies. Noda (1997) conducted a schistosomiasis intervention study in rural Kenya and reported people bathing and cleaning their clothes at the river. Similarly, Gazzinelli (1998) observed households washing their clothes and utensils in the river during a water use study in rural Brazil. Similar to the results from Vietnam, Polack (2006) noted that bathing and laundry occurred at the home rather than at the source in their study in rural Tanzania. In their introduction, Mertens (1990) reported that throughout rural Sri Lanka, all water used for domestic purposes was carried back to the home. Although the communities within our study were not nationally representative, the results demonstrate that the location of water-using activities can vary between geographic contexts. This highlights the importance of validating the implicit assumptions regarding where water is used in data collection methods when studying water use.

Although more households in Vietnam reported using water for farming purposes, this could be due to the different settings of the study communities. The study sites in South Africa and Ghana were peri-urban, whereas the study sites in Vietnam were all rural communities. This could also account for the higher portion of households in Vietnam who reported using water for gardening. More households with on-plot water supplies (57.1%) reported using water for gardening than households using off-plot supplies (11.6%). This could mean there are important nutritional benefits for households with on-plot water supplies in rural areas.

It is not clear if the estimated household water quantity included water used for productive uses or not. Water quantity data from households with a water meter would have captured water used for commercial purposes, however if households chose to use a different source other than their house tap or yard tap, the quantity might not have been reflected in the per capita water use. Households were not specifically prompted to consider water used for commercial purposes when asked about water collection patterns. The section in the survey inquiring about water source type used and the location of activities occurred after respondents were asked about their water collection habits.

An interesting finding was the high percentage of households in Ghana using sachet water. In comparison, the peri-urban study communities in South Africa did not report using bottled or sachet water, which could be due to cost, user preference or unavailability of these sources. While sachet water was not indicated as the primary drinking source, it could account for a substantial amount of drinking water ingested outside the home. Since sachet water is readily available in certain settings, it could be a significant way to provide quality drinking water and therefore reduce the risk of water-borne diseases.

There were also differences in the use of multiple sources between the three countries. More households in South Africa and Vietnam used at least one additional source compared to Ghanaian households who primarily used one water source (after separating out sachet water). The specific reasons for why households chose to use an additional source were not addressed in this study, but the findings show that in order to accurately determine total water quantity, multiple sources should be considered in the data collection methods. Since the questionnaire was administered in the wet season, it is unlikely due to seasonal effects where the main source has run dry. In a multi-country study in East Africa, Thompson (2011) reported issues in water system service to be a reason for households using other sources. Other explanations for using multiple water sources could be due to cultural habits (location of bathing and laundry) or simply due to user preference. Mertens (1990) reported taste being an important element in water source selection for drinking water

Conclusions

The results from the field studies in Ghana, and Vietnam show a statistically significantly higher water use by households with at-home supplies compared to those who use off-plot supplies. Although this trend was not demonstrated in South Africa it was most likely due to recall bias from under-reporting water use for at-home water supplies.

Quantile regression revealed no relationship between distance to the water source (or collection time) and water quantity used for households relying on off-plot water supplies. Factors affecting water quantity for households fetching water are nuanced and can range from weather patterns to issues of supply or personal preference. In this study, the volume of water collected per trip was verified through the measured mass of the filled water container, however the calculation of litres per capita per day (for households relying on off-plot sources) relied on self-reported data such as number of trips per day and the number of days per week that households collected water. The observation period was also limited to one water carrier on one water collection trip. Thus, some uncertainty is introduced by the unknown accuracy of these user self-reports.

While the impact of distance on water quantity appears complex, the higher water use for those households having at-home water supplies has been demonstrated in this study and others. If international policies aim to substantially increase the amount of water used by households, then simply bringing off-plot water supplies closer to users' homes may not provide sufficient improvement for households to raise their water quantities. Rather than aiming for improved water supplies to be within 30 minutes of the household, there should be a focus on at-home water sources, which has been shown to increase water quantity.

Our results also shows higher water use by households using wells when compared to those using taps both for households whose water source is at the house or yard and those whose water source is outside the home. These results are less robust due to the relatively small sample size for households reliant on wells in some of the study sites but they merit consideration. When considered in tandem with the reported high levels of dissatisfaction with temporal variations in supply this finding suggests that reliability of all sources, but piped supplies in particular, may be at least as important as their distance from the household.

While the communities within this study are not nationally representative, there were interesting differences in water use patterns between the three countries. Most water behaviour studies only collect data about water carried back to the household, without considering water used at the source. In Ghana and South Africa, most activities involving water use occur at the home, but this is not the case in the households studied in Vietnam. Data collection methods for household water use should take into account cultural behaviours and seek to account for all water used by the household, whether at home or at the source. Further research on water quantity and water use patterns employing more detailed observation methods could aid in developing more effective international policies to increase water access for households.

3.4. Health benefits of at-house water supplies (water-related diseases)

3.4.1. Summary findings from a systematic review of the literature

We carried out three reviews of the literature relating health outcomes to water sources. The first was a systematically organised review of the literature on the health benefits of at-house water supplies. A write up of this review will be published separately The paragraph below summarises the findings from the review.

Research evidence indicates that decreased household distance to water source reduces risk and prevalence of diarrhoea, trachoma, and other water-washed diseases.

However, these findings have not been compiled to investigate whether households with at-house water supplies experience better health than households without water supplies on the premises.

A systematic literature review was conducted on at-house water sources and their impacts on diarrhoea, trachoma, child growth, and other water-washed infections to further examine the relationship between distance to water source and health and assess whether there is evidence within literature that use of at-house water supplies generates health gains for households.

The literature search was conducted in three computerized databases of peer-reviewed journals: Embase, Global Health, and PubMed. The search included terms to describe water sources within household premises and targeted common water-washed agents and diseases. Studies conducting secondary research were excluded from the literature review; therefore, child mortality was not included in the search terms due to mortality study reliance on census data or hospital records. Peer-reviewed studies written in English from 1970 to 2013 were included in the screening.

The titles of all search results were screened, and potentially relevant studies were marked for abstract review. Abstracts were reviewed for relevance and were included in the full-text review, where studies were stringently screened by exclusion and rigor criteria. The bibliographies of accepted studies were also screened for relevant studies.

The initial electronic search retrieved 2,298 citations, and 44 studies were selected for the final analysis. Studies demonstrated varied results on the impact of at-house water sources on household diarrhoea and growth outcomes, while within a smaller number of studies, reductions in trachoma, helminth infections, and Hepatitis A were significantly correlated with the use of at-house water sources. The heterogeneous findings regarding the effects of at-house water supplies on diarrhoea and growth outcomes may be explained by variability in study designs and multiple aetiologies, in particular the fact that the incidence of a range of pathogens varies in different contexts and that different pathogens are influenced by hygiene and water quality to a different extent.

Few studies examining the health impacts of at-house water sources investigated distance to water source, and the lack of evidence for this link reveals an important gap in current literature. More studies that jointly examine the impacts of at-house water supplies and distance to water source on water-washed diseases are needed to better understand the synergy between these two factors and their contributions to household health.

3.4.2. Hygiene behaviours and at-house water supplies

The second review took a rapid look at the literature which links at-house water supply to hygiene behaviours. Improved hygiene is an integral element of the hypothesis which links improved water supply with improved health so we deemed it useful to examine the literature on this topic.

Hygiene and health

Personal and domestic hygiene activities are critical determinants of household health. In the classic F-diagram developed by Wagner and Lanoix, faecal-oral diseases stem from the transmission of human excreta to food via fingers, flies, fluids, and fields (Wagner and Lanoix (1958)). Safe hygiene practices can block all of these transmission pathways. Safe stool disposal reduces excreta in the environment and can reduce fly transmission of faecal matter to food and utensils. Latrine use limits human exposure to excreta and has been shown to reduce household diarrhoea (Baltazar et al. (1988), Daniels et al. (1990)). Washing hands after defecation prevents cross-contamination of domestic water supplies, dishes, and food, lowering exposure for other household members (Pinfold (1990)). Handwashing blocks several transmission routes of diarrhoeal pathogens and has been shown to significantly reduce diarrhoeal morbidity (Esrey et al. (1991), Cairncross et al. (2010)).

Hygiene affects not only household diarrhoea outcomes, but also has been shown to positively impact outcomes of water-washed diseases. Studies have demonstrated that clean faces are significantly associated with reduced trachoma prevalence ((Taylor et al., 1989), West et al. (1991), Hsieh et al. (2000), Golovaty et al. (2009)) and that frequent washing is associated with lower prevalence of trachoma (Cumberland et al. (2005)) and skin infections (Verweij et al. (1991)). Handwashing has been shown to significantly reduce prevalence of respiratory infections (Ryan et al. (2001), Rabie and Curtis (2006), Aiello et al. (2008)). Evidence suggests that hand and face washing can generate significant reductions of faecal-oral and water-washed diseases, exemplifying the Mills-Reicke phenomenon of producing not additive, but multiplicative health gains.

Hygiene and water access

Many household hygiene activities, such as washing, bathing, and cleaning, are dependent on water availability in the household. Several studies have demonstrated that households in close proximity to their water sources have greater domestic water supplies than households using distant water sources (Frankel and Shouvanavirakul (1973), Tonglet et al. (1992), Gazzinelli (1998), Aiga and Umenai (2002)). White et al (1972) suggested in the seminal Drawers of Water study that households with improved water access can allocate greater quantities of water for hygiene activities. This notion has been supported by more recent studies demonstrating that households with at-house water supplies use greater quantities of water for hygiene activities such as bathing and handwashing (Thomson (2001), Schémann et al. (2002)). .

Researchers have investigated how water allocation for hygiene affects household hygiene behaviour. Availability of soap and handwashing water near latrines has been shown to significantly increase frequency of handwashing (Lopez-Quintero et al. (2009), Mariwah et al. (2012)), and one study reported that mothers' dissatisfaction with the quantity of water available for hygiene was significantly associated with faecal contamination of both mothers' and children's hands (Pickering et al., 2010).

The hygiene impacts of water access and domestic water supply are corroborated by studies examining the relationship between household distance to water source and hygiene. In a study conducted in Mozambique, households living less than one kilometre from their water source used 70% of their domestic water supply to bathe, wash clothes, and bathe children on a daily basis, whereas households four kilometres from their water source used less than half of their water supply for hygiene-related activities and only rarely bathed their children (Cairncross and Cliff, 1987). Households in rural Swaziland used greater quantities of water for hygiene and bathed and washed hands more frequently after the implementation of water projects that decreased distances to water sources (Peter (2010)).

Additional evidence suggests that households with at-house water supplies experience hygiene gains. A study in Burkina Faso reported that households with domestic water connections were more likely to dispose excreta safely than households using water sources off the premises or outside of the compound (Curtis et al. (1995). Good handwashing practices have been shown to be more prevalent among Indian adolescents with at-house water supplies than among their peers using other water sources (Dobe et al., 2013). Ownership of a private well was a significant predictor of handwashing after defecation among mothers in a study conducted in the Philippines (Sakisaka et al. (2002)). Households in Kenya with at-house water supplies were shown to be significantly more likely to wash hands with soap and wash hands after contact with faecal matter than households using wells in the compound, boreholes and tubewells, water from vendors, or surface waters (Schmidt and Cairncross (2009)).

While these findings indicate a significant link between household water access and hygiene behaviour, they are solely associations and do not provide evidence for a causal relationship. Factors such as socio-economic status and maternal education may have confounding effects in study results. However, the consistency within literature of reported positive hygiene outcomes for households with improved water access and the lack of evidence demonstrating equivocal or negative hygiene outcomes suggest that increased proximity to water source not only can affect household allocation of domestic water supply for hygiene, but may also encourage safe hygiene behaviour.

Summary

Hygiene is a nexus for water and sanitation in the transmission of faecal-oral diseases and also has a critical role in water-washed diseases. Safe hygiene behaviour can unlock a multitude of health gains, and improved water access may facilitate hygiene improvements through greater domestic water supply and water allocation for hygiene activities. Evidence from research literature indicates that safe hygiene practices increase with household proximity to water source, presenting significant benefits and opportunities for the health and well-being of households in developing countries.

3.4.3. Impact of at-house supplies on skin and eye disease and diarrhoea

Detailed data sets on health outcomes were assembled from our field studies. These merit further detailed analysis but the preliminary findings are shown below. Analyses for health outcomes were done using a Generalised Estimating Equation (GEE) adjusted for age and sex and accounting for clustering at the household and country level. GEE is useful for predicting generalised effects across the population and is particularly useful for cohort studies with multiple sites. Where the outcome variable was binary we used negative binomial regression with a log link. Where the outcome variable was scalar we used linear regression models (Table 22).

Table 22: Water predictors for skin disease, eye disease and diarrhoea in previous two weeks adjusted for age and sex

Health outcomes	Predictors	N	RR	L95%CI	U95%CI	P
Skin disease	At home water source	2880	1.129	0.770	1.656	0.534
	Any water fetched from out of home	2882	1.027	0.696	1.515	0.895
	Estimated time to source/min	2215	0.977	0.941	1.015	0.231
	Estimated water used/p/d	2431	0.999	0.995	1.003	0.602
	Measured round trip distance/m	1476	0.998	0.997	0.999	0.003
	Measured round trip time/min	1532	0.949	0.904	0.996	0.032
Eye disease	At home water source	2879	1.076	0.820	1.411	0.597
	Any water fetched from out of home	2881	1.073	1.361	2.250	0.647
	Estimated time to source/min	2215	0.983	0.960	1.007	0.168
	Estimated water used/p/d	2430	0.999	0.996	1.002	0.453
	Measured round trip distance/m	1476	1.000	0.999	1.000	0.251
	Measured round trip time/min	1532	0.997	0.969	1.026	0.845
Diarrhoea	At home water source	2858	0.732	0.487	1.102	0.135
	Any water fetched from out of home	2860	1.479	0.854	2.561	0.162
	Estimated time to source/min	2197	0.998	0.971	1.026	0.909
	Estimated water used/p/d	2411	0.999	0.994	1.004	0.578
	Measured round trip distance/m	1464	1.000	0.999	1.001	0.559
	Measured round trip time/min	1518	1.006	0.972	1.040	0.748

There was no strong evidence of a significant impact on eye disease or diarrhoea of any of the predictors we tested. Measured round trip to source showed a weak impact on skin disease but the effect was small.

3.5. Musculo-skeletal and general health impacts of carrying water

3.5.1. Literature review

A review of literature was conducted in 2012, to identify and evaluate published literature reporting health impacts of carrying water over distance from an out of home or publically share water supply. The full review will be published separately. The findings of this review are summarised below.

Six studies met the inclusion criteria and were deemed relevant to the review topic. Several studies focussed on descriptive statistics related to water carrying and access (Hemson, 2007, Geere et al., 2010a, Thompson et al., 2000); two were qualitative research reports, one on children's health perceptions (Geere et al., 2010b) and the other on gender issues (Sultana, 2009); and a final paper reported pain and rating of perceived exertion on head loading in a laboratory setting (Lloyd et al., 2010). A common conclusion of all studies was that water carrying can impact on general health and pain, but that further research is required. No large scale epidemiological studies were found which had used an appropriate study design to scientifically analyse the association between water carrying or related risk factors and physical health outcomes such as self-report of pain, physical functioning or disability.

3.5.2. Findings from the field study

Descriptive statistics on key health outcomes were generated for adults and children in each country, comparing people with at house water supply to those using shared water supplies. Summary data tables are included in **Appendix E**.

The reporting of pain in hands and upper back was statistically significant for individuals who had previously or who currently carry water. There was also a close-to-statistically significant relationship between water carrying and reported pain in the shoulders/arms, head, chest/ribs and abdominal area.

Interestingly those who previously or currently carry water scored higher on overall ratings of general health than those who had not and this finding was also statistically significant. This may indicate some general health benefits linked to water carrying, which for example, could be derived from better cardiovascular fitness linked to being more physically active, or a greater sense of wellbeing linked to the positive social contribution or interactions associated with water carrying. Such positive health benefits were reported in previous qualitative research conducted with people who carry water (Geere et al. (2010a)).

A factor analysis of different pain location variables aligned well with this general finding; there was a marginally significant negative association between currently or previously carrying water and a set of pain outcomes (in the neck, shoulders/arms, lower back and hips/ pelvis) which are typical of muscle or joint strain. These are likely to be improved through remaining generally fit and active and having regular physical activity such as would be associated with water carrying.

By contrast the factor analysis also resulted in the identification of a specific set of pain outcomes (in the chest/ribs, hands, feet, abdomen/ stomach, head and upper back) which were highly associated with currently or previously carrying water. There is a plausible biological explanation connecting such outcomes with the carrying of water-filled buckets on the head via sustained compressive loading on the spine and upper back. These findings are sufficiently significant to suggest a relationship between water carrying and an increased risk of specific musculo-skeletal related diseases such as cervical spondylosis which merit further investigation.

In summary the data suggest both a mild positive impact on general health for some water carriers as well as a potentially serious negative impact on spinal health via a specific musculoskeletal mechanism for others.

3.6. Water quality

3.6.1. General

Water quality and its relationship to source types, distance to source and storage practices was not part of the terms of reference for this study. However, the team was able to make use of additional funding from another source to take advantage of the fieldwork being undertaken in three countries and to add additional texture to our study. We are also able to report on the findings of a review of literature undertaken by UNC with support from WaterAid.

3.6.2. Literature review

A forthcoming review concluded that improved sources had significantly lower *E.coli* concentrations than unimproved sources Bain et al. (2013). The literature also suggest a view that, despite being less contaminated than unimproved sources, a significant percentage of improved sources have water quality associated with higher health risks. The heterogeneity of source water quality for sources of all types supports the argument that a hierarchical "water ladder" may tend to oversimplify a complicated water safety landscape (ibid.).

A few studies directly comparing water quality from water supplies on premises with those off premises were identified. These found that contamination can be more common among community sources. For example, in urban Nigeria, Ejechi and Ejechi (2008) found 18% of public water sources to be contaminated whereas 6% of private boreholes contained thermotolerant coliform (n=100 for both source types). Similarly, Genthe and Seager (1996) found contamination in community standpipes whereas in house taps were free of thermotolerant coliform in a South African township (n= 153 and 24 respectively). Zuin et al. (2011) did not find significantly more frequent E. coli contamination in community taps than in-house taps in peri-urban area of Maputo, potentially due to the small sample sizes (62 and 27).

3.6.3. Results from the field

Details of the water quality study will be published separately.

Samples were analyzed using the Aquatest method, described in detail on the Aquatest Programme website (Bristol, 2013).

Stored water and source water

When the pooled multi-country data were analysed, it was found that stored water contained significantly ($p<0.05$) higher E. coli concentrations than source water (Table 23, Figure 5). Mean stored water concentrations were 25.2 (95% CI 18-32) CFU/100 mL; while mean stored water concentrations were 62.8 (95% CI 53 - 73) CFU/100. A higher percentage of stored water samples contained concentrations of E. coli in excess of 100 CFU/100 mL. Interestingly, both source and stored water samples with turbidities > 1 NTU tended to have higher E. coli concentrations (turbidity data were available for Ghana only). These effects were significant at the 90% and 95% confidence levels for source and stored water samples, respectively.

Table 23: *E. coli* concentrations in source and stored water from on-plot and off-plot sources

Source Access	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
On-plot	24.32 (61.57) [14.33 - 34.33]	62.52 (88.87) [44.42 - 80.63]
Off-plot	25.99 (65.65) [15.47 - 36.51]	62.94 (89.27) [50.97 - 74.92]
Total	25.17 (63.57) [17.95 - 32.39]	62.82 (89.01) [52.88 - 72.75]
P	0.8213	0.9698

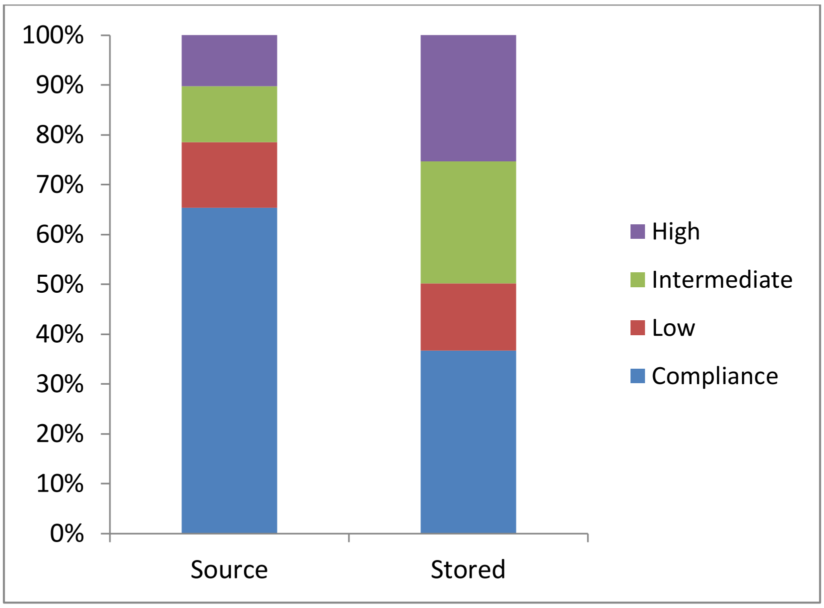

Figure 5: Health-based risk categories of source and stored water samples

Source categories

E.coli concentrations in source water from on-plot sources were not found to be significantly different from those in water from off-plot sources (Table 23). However, source water from improved sources was found to have significantly lower *E.coli* concentrations ($p<0.05$) than water from unimproved sources; interestingly, stored water from improved sources also had significantly less *E.coli* ($p<0.05$) than stored water from unimproved sources (Table 24). Similarly, it was found that source and stored water from on-plot improved sources had significantly lower *E.coli* concentrations ($p<0.05$) than source and stored water, respectively, for other sources (Table 25). Finally, source water samples from household taps was found to contain lower *E.coli* concentrations ($p<0.05$) than water from other sources (Table 26, Figure 6); differences for stored water were not significant.

Table 24: *E. coli* concentrations in source and stored water from improved and unimproved sources

Source Type	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
Improved	12.27 (45.61) [6.53 - 18.01]	55.44 (85.81) [44.80 - 66.09]
Unimproved	82.61 (94.12) [57.17 - 108.06]	94.31 (96.08) [69.27 - 119.35]
P	0.0000	0.0024

Table 25: *E. coli* concentrations in source and stored water from on-plot improved sources and all other sources.

Source Access	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
On-plot Improved	8.62 (39.06) [1.53 - 15.71]	37.31 (71.52) [19.86 - 54.75]
Other	36.05 (73.56) [25.26 - 46.84]	69.82 (92.14) [58.20 - 81.44]
P	0.0002	0.0079

Table 26: *E. coli* concentrations in source and stored water from on-plot piped sources and all other sources.

Source Type	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
At-home piped water	0.31 (0.82) [0.01 - 0.61]	31.44 (89.51) [53.89 - 74.26]
All other sources	28.04 (66.55) [20.05 - 36.02]	61.07 (71.45) [-13.96 - 76.84]
P	0.0212	0.2136

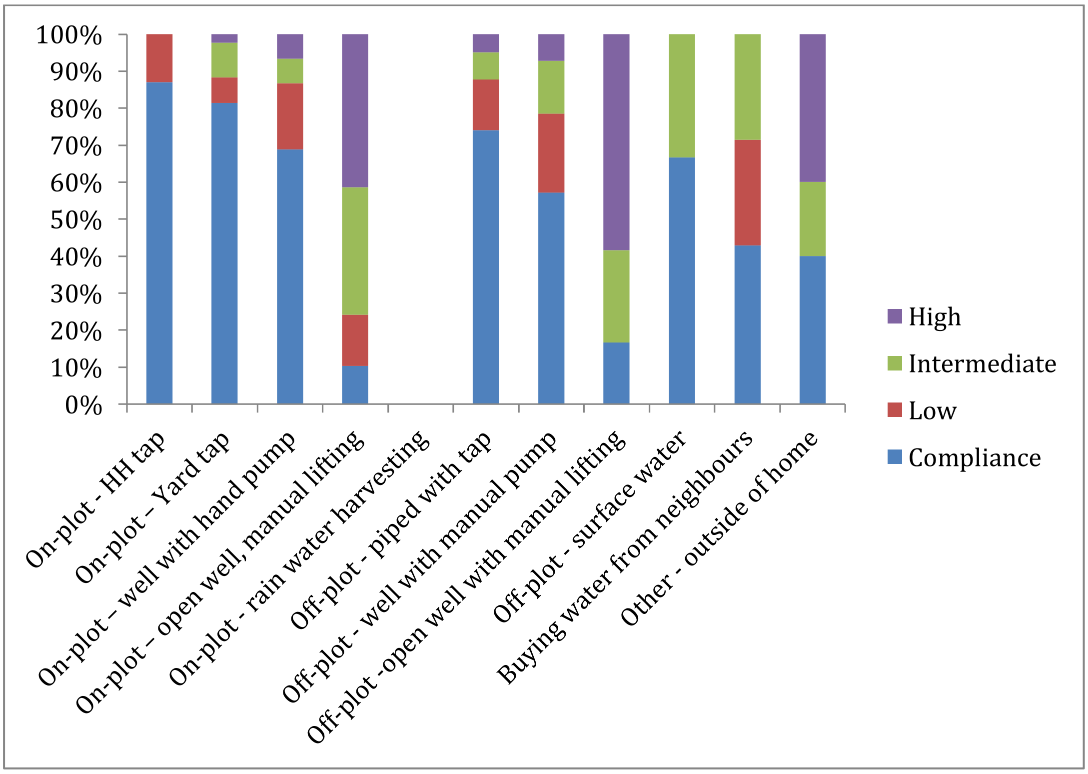

Figure 6: Health-based risk categories of *E. coli* concentrations for source and stored water from various sources.

Individual source types

A pairwise comparison of all source types showed significant differences between several different types of sources. Most notably, source water from open wells, both on-plot and off-plot, was significantly ($p<0.05$) more contaminated than water from all on-plot improved sources, as well as off-plot piped water and water purchased from neighbours (generally also piped) (Table 27**,** Figure 6). No significant differences in water quality were observed between samples of stored water from different sources.

Distance and time to source

There were no significant effects of distance or time to source on *E.coli* concentrations in source or stored water. Specifically, across log distance quintiles and log time quintiles, *E. oli* concentrations were not significantly different at the 95% confidence interval (Table 28**,** Table 29).

Table 27: *E. coli* concentrations in source and stored water from various sources

Source Type	Source Group CFU/100 mL (S.D.)	Stored Group CFU/100 mL (S.D.)
On-plot - HH tap	A 0.31 (0.82)	A 31.44 (71.45)
On-plot – Yard tap	AB 6.81 (35.19)	A 39.00 (74.77)
On-plot – well with hand pump	AB 16.08 (52.92)	A 2.23 (4.40)
On-plot – open well, manual lifting	CD 88.78 (90.10)	A 122.87 (98.16)
On-plot - rain water harvesting	. .	A 114.5 (64.35)
Off-plot - piped with tap	AB 15.69 (51.43)	A 54.92 (85.80)
Off-plot - well with manual pump	ABC 23.19 (61.72)	A 44.81 (74.51)
Off-plot -open well with manual lifting	D 137.04 (102.44)	A 93.79 (96.35)
Off-plot - surface water	ABC 17 (29.44)	A 127.82 (100.65)
Buying water from neighbors	AB 5.4 (8.29)	A 29.49 (75.57)
Other - outside of home	BCD 88.2 (102.72)	A 25.46 (59.44)

Note: Vertical groups sharing a letter are not significantly different at the 95% confidence level

Table 28: Log travel time to source and water quality

log time quintile	Stored Group CFU/100 mL (S.D.)
1	A 68.04 (95.46)
2	A 67.25 (89.00)
3	A 67.85 (88.23)
4	A 51.98 (87.32)
5	A 49.74 (79.60)
Kruskal-Wallis p	0.662

Table 29: Log distance and water quality

log dist quintile	Stored Group CFU/100 mL (S.D.)
1	A 74.57843 (96.11415)
2	A 68.52069 (96.44541)
3	A 56.8 (87.10228)
4	A 47.32131 (73.64256)
5	A 36.45185 (73.61668)
Kruskal-Wallis p	0.3605

Health impacts

When the cross-sectional prevalence of skin infections, eye infections, and diarrhoea, as well as missed days of school or work were compared across water quality categories (by presence/absence of *E.coli*), only one significant effect was observed; detectable *E.coli* in source water samples was found to be associated with someone in the household missing school or work due to illness.

Country-specific Results

In both Ghana and South Africa, as in the multi-country analysis, stored water was significantly more contaminated than source water, while differences in *E.coli* concentrations between on-plot and off-plot sources were not significant. Source water samples from household piped sources were significantly less contaminated than samples from all other sources, while there was no significant difference among stored water samples. In Ghana, both stored and source water from improved sources was significantly less contaminated than stored and source water, respectively, from unimproved sources. Comparisons between improved and unimproved sources were not possible for South Africa, as only 5% of samples were collected from unimproved sources. Finally, in Ghana, source water from all sources except on-plot open wells with manual lifting was found to be significantly less contaminated ($p<0.05$) than source water from off-plot open wells with manual lifting. In South Africa, the only significant difference observed was that source water from at-home taps was significantly less contaminated ($p<0.05$) than samples from sources classified as "Other", primarily tanker trucks. There were no significant differences among stored water samples in either Ghana or South Africa.

Conclusions

The results of this work suggest that on-plot improved water supplies in general, and household piped water connections in particular, result in lower rates of *E.coli* contamination than other sources, particularly unimproved sources such as open wells, both with respect to source water and stored water.

3.7. Social benefits of at-house supplies

The field research generated information about what activities were carried out by household water carriers and former household water carriers over a 24 hour period. The activities described were then clustered as follows:

- Social activities: Drink and Eat, Religious and spiritual activities, Spending time with other people, "Phone calls, letters, emails, internet, video games", Playing, Playing sports, and Visits / meeting
- Personal hygiene: Dressing, getting ready, Bathing and Going to the toilet
- Domestic: Washing (dishes and / or clothes), Preparing to eat, Other domestic activities, Purchases (at the market, etc.), Taking care of other members of the household
- Employed work: Work and activities related to work (going to work, finding a job etc) and Professional training
- Inactivity: Sleep, Resting, Watching television

We carried out a multivariate regression which indicated that inactivity, employed work and personal hygiene were significant within the multivariate regression. However, when we looked at the predictors of these activities the only significant association was between carrying water and 'inactivity'. People who collect water had about 40 minutes less inactivity time than those who did not.

The finding that reduced time carrying water is not significantly correlated with increased economic activity bears out similar recent findings (Devoto et al. (2012)). However there is a plausible case to be made for the benefits of increased 'rest' time which may also be in part defined by time spent with the family and in particular time spent by parents with children in non-work activities. This could be linked to intergenerational effects; children who have the opportunity to spend more time with their parents may have improved opportunities for learning and this may have knock-on effects in their own adult lives. This intergenerational impact of reduced time for children or parents spent collecting water merits further investigation.

4. Discussion

We carried out a mix of secondary and primary research to examine the hypothesis that access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply.

The relationship between water source, water usage and health and social outcomes is complex and mitigated by range of contextual and intermediate factors. A recent review of global data sets for example suggests that time spent walking to the household's main water source was a strong determinant of under-five child health (Pickering and Davis, 2012). However a review of this analysis suggests that alternative interpretations would be possible if the data were to be adjusted for other water- and sanitation-related variables or for a broader set of determinants of these multiple child health outcomes. In general it is likely that households experience a clustering of risk factors so that simply looking at water fetching time in the analysis without adjusting for type of water source, type of sanitation facility, type of cooking fuel masks specific effects and the outcome is more likely to be a measure of general "environmental deprivation" rather than the specific effect of water fetching time.

A fundamental challenge in comparing outcomes of at-house supplies with shared supplies lies with wealth as confounder. In our analysis we were able to account wealth effects to some extent because of the detailed household information we were able to collect. Nonetheless these challenges are significant.

In our research we focused on a two-step approach, looking at the relationship between distance to source and volumes of water consumed followed by an analysis of volumes of water carried/consumed and health and social outcomes, including hygiene practices. In this way we hoped to reduce the effect of wealth and other broader social contextual factors in the analysis. This was supplemented by the analysis of the relationship between source-type and water quality.

From our field data a strong theme was the heterogeneity of water sources used by many households. This dimension of water usage has received only limited attention from researchers although our findings did align well with earlier work carried out in urban Uganda (Howard et al., 2002). The diversity of multiple use strategies is much greater than the literature in general suggests. It is likely that the use of multiple sources of water for different activities is a significant confounder and one of the reasons why research into the relationships between health outcomes and use of specific water sources has been inconclusive.

We found a strong link between volumes of water consumption and the at-home-off-plot break point in services but limited evidence of a distance-volume relationship once households were using off-plot supplies. We also found some evidence to suggest that, where reliability of services is poor, the location of the water source may be less significant than its performance characteristics. In our study locations we found some evidence of households who access water from both private and public wells collecting higher quantities of water than users who access water from taps. Similarly we found strong evidence of a 'break point' in health outcomes between those who carried, or who had previously carried, water from outside the house and those who did not particularly relating to musculo-skeletal effects.

Water quality was significantly better for those with piped water at home that those who carried water from elsewhere and stored it at home. The evidence on social benefits was limited but points to possible advantages to families who do not have to spend time carrying water but can spend time in leisure activities.

Overall the results from our research indicate that evidence for the detailed water quantity versus distance to source curve is tenuous. The conclusion that at-house supplies are associated with higher consumption and health and social benefits is supported but there is no evidence for the secondary drop in consumption at a fixed distance from home. In reality it seems most likely that the relationship between distance to source and volumes of consumption is likely to be highly mediated by social and geographical factors, with the curve likely to be 'displaced' upwards or downwards in different contexts. This research has highlighted a number of important gaps in the literature and indicates that the relationships between dimensions of water provision and health and well-being merit further investigation.

Further work and publications

The study team has planned a series of publications arising from then study. A preliminary publication list is indicated below with indicative target dates for publication and possible journals indicated in brackets:

(i) Review of International and National Targets and Standards (December 2013, JWASHDev)
(ii) Relationship between distance to source and water quantity (November 2013, IJERPH)
(iii) Water quality aspects of source types and distance to source (January 2014, WST)
(iv) Effect of at-home water supplies on hygiene behaviours - A review of literature (November 2013, IJTMH)
(v) Distance to source and health impacts – a review of literature (January 2014, Bull.WHO)
(vi) Relationships between distance to source and MSK effects (February 2014, Journal to be identified)
(vii) Synthesis study report (update of Howard and Bartram, 1993) (December 2013, Bull. WHO)

5. Conclusion

The headline conclusion from our research is that at-home water supply has significant, measurable benefits when compared with shared water supply outside the home provided that the service provided is reliable enough to ensure access to adequate quantities of water when required. Reliable at-home water supply results in higher volumes of water consumption, greater practice of key hygiene behaviours, a reduction in musculo-skeletal impacts associated with carrying water from outside the home, and improved water quality.

This suggests a logical policy shift towards the promotion of reliable household access as the international benchmark for water supply.

For many governments, the implications of this are relatively simple. Where most people have access to reasonable quantities of water close to the home, there is a strong and compelling argument to focus investment in getting reliable water supplies into the home. In such cases, the outstanding challenges relate to improving our understanding of the relative risks associated with dimensions of levels of service. For example, under what circumstances does a tap in the house have significant benefits over a tap in the yard? What is the relative risk associated with intermittent supply or low pressure of at-house piped supplies compared with private wells or shared supplies, if the latter can provide a more reliable service? A pressing gap in the literature relates to the water resources and cost implications of providing 24 hour supply in piped systems.

For some countries however, the challenge of moving to household supply as the benchmark level of service is more significant and will take time. In these locations (typically arid regions with limited water resources and limited access to capital funds) the policy emphasis may change more slowly. The clear policy message is that investments in water supply should be designed to enable a progressive move towards provision of household supplies even if this level of service cannot be achieved immediately. This might mean for example, designing point-source systems in such a way as to facilitate the addition of networks and house connections at a later date.

In the post-2015 era, the available evidence suggests that access to water supply at-home should be the benchmark for water supply.

Appendix A: Field work report: Ghana

Study Area and Communities

Four communities (Table A-1) near Kumasi in the Ashanti region of Ghana were included in the DFID field study. All four communities were centred around a main road, stretching out densely along the road and less densely outward from the road on either side.

Table A-1. Ghana study community characteristics.

Town Name	Density	Population 2012	No. of registered users (GWC)	No. of HHs in Survey
Nkawie (a town)	Urban	9, 054	528	67
Asuofua (a town)	Peri-urban	8, 373	132	61
Barekese (a town)	Peri-urban	10, 544	---	63
Abuakwa (a small city)	Urban	23, 634	---	64
Total				255

Household Characteristics

The definition of "household" in the Ghanaian context is also distinct from the definitions applicable in other countries. Households in the study communities lived almost exclusively in compounds comprised of 3-6 nuclear family units living in adjacent rooms that formed a larger structure with a shared courtyard. These family units were often but not always biologically related to each other. Enumerators were trained to collect data from a single family unit within each compound to avoid confusion. For the purpose of this study, a single water source used exclusively by the households within a single compound was classified as a private source. Since only one household was interviewed in each compound, respondents with private sources were asked to report the total number of individuals sharing the source. If a water bill was available for that source, the previous month's consumption was divided by the total number of users reported to calculate the average per-capita consumption.

In addition, it was observed during training that Ghanaians often use the words for "sister" and "brother" figuratively for close friends and familiar cousins, and often use "husband" and "wife" figuratively to refer to their husband's brothers or their wife's sisters. Thus, enumerators were instructed to clarify the actual biological relationships among household members when administrating questionnaires.

Water Points and Water Collection

Some households in the study area were served by private connections provided and maintained by the Ghana Water Company Limited (GWCL, responsible for water supply in urban areas and some small towns in Ghana), while others used public water sources, largely provided by local government (District Assemblies), with support from the Community Water and Sanitation Agency (CWSA). Other households used private boreholes and piped sources that may have been installed by local government or by the users, and some used hand-dug wells, presumably installed by the users. Households included in the study that were serviced by GWCL were asked to share their previous month's water bill, and the previous month's water usage was recorded. Consumption by non-GWCL users was estimated based on observed container volume and self-reported collection frequency. All four communities contained a mixture of private and public supplies shown in Table A-2.

Table A-2. Primary water sources used by households in study communities.

	Number of Households				
	Nkawie	Asuofua	Barekese	Abuakwa	Total (%)
Household tap	2	2	1	3	8 (3%)
Yard tap	6	15	21	15	57 (22%)
Private well, motorized pump	0	0	0	4	4 (2%)
Private well, manual lift	16	5	7	8	36 (14%)
Total Private Sources	24 (36%)	22 (36%)	29 (46%)	30 (47%)	105 (41%)
Communal tap	22	36	30	24	112 (44%)
Communal covered well, manual lift	8	0	3	9	20 (8%)
Communal open well, manual lift	13	3	1	1	18 (7%)
Total Public Sources	43 (64%)	39 (64%)	34 (54%)	34 (53%)	150 (59%)

No households reported using rainwater for drinking and domestic purposes. A mistranslation in the survey questionnaire resulted in "rainwater collection" bring translated as simply "rain" in the local language, but field observations of the communities did not reveal evidence of any households using rainwater collection methods of any kind.

A substantial number of respondents also reported obtaining drinking water in the form of "sachets," or 500-mL plastic water bags produced by commercial manufacturers and sold in most shops and by ubiquitous street vendors for 0.10 GHS (equivalent to USD $0.05). While these were not the primary source of water for domestic purposes, they provided a convenient and readily accessible drinking water source.

Household interviews also revealed the sharing of some private supplies amongst households, creating an added level of complexity in determining ownership of and access to water supplies. In cases where a respondent used a neighbours' "private" source (usually for a fee comparable to that for public sources), that respondent was considered to be fetching water from a public supply. In cases where a respondent shared their own "private" source with neighbours, however, the respondent was considered to be accessing her own private supply when she fetched water. These decisions were made based on the relative proximity, access, and control users had to their own "private" source vs. their neighbours' source. The notion of "public" and "private" sources was further complicated in a small minority of households, where respondents with water sources on their properties reported that the government had given them "private" supplies to be used by their communities.

Some respondents were also unsure as to the type of primary drinking water source they used, as they hired other women in the community to fetch water for them. These respondents were similarly unable to show enumerators where they fetched the water, preventing measurement of the distance travelled and time spent fetching water. This finding was of interest, as delivery of water from public sources by others had not been considered in the study design. This mode of water collection is unique because the physical and time burden of water collection shifts from the household to an outside water carrier. A properly controlled comparison of domestic and professional water carriers in relation to musculoskeletal outcomes could be of interest with respect to the health impacts of water carriage.

Most respondents reported paying to access water. Users of public and shared private sources typically paid a small fee to fetch water, typically ranging from GHS 0.05 (USD $0.025) to GHS 0.10 (USD $0.05) per trip, with users typically being allowed to fetch 20-60 L of water per trip. Users fetched water in a large variety of containers, but the most commonly used vessels were 20, 30, or 40-L round plastic or metal basins, followed by 20-L jerricans and 15 or 20-L buckets. Most adult water carriers were observed to fetch between 15 and 40 L per trip, while most children fetched 10-30 L. Professional water carriers typically fetched 40-60 L per trip in large basins. Most users transported water by balancing one container on their head, cushioned by a ring of folded cloth. Users fetching water from a well with a manual pump or manual lifting would fill a container, then lift it onto their head, usually with the help of another user waiting to collect water. Where piped water was available from public standpipes, community members often modified these standpipes with an additional length of pipe, so that water could be dispensed from the original faucet to fill a narrow-mouthed jerrican on the ground, or from the extension pipe, at a height of approximately 2 m, allowing the user to fill a basin or bucket while it was balanced on the head.

Wealth Data

In Ghana, it was observed that many households reported extremely low or non-existent incomes when asked directly about their earnings, in contrast with significant water costs and the ownership of mobile phones, etc. Anecdotally, one Ghanaian colleague mentioned that rural Ghanaians are often very circumspect about their finances, and will frequently under-report income and possessions to avoid provoking envy or discomfort among their neighbours. Thus, it is possible that the apparent disparity between reported incomes and consumption patterns may be related to this cultural bias.

Appendix B: Fieldwork report – Vietnam

Study area and communities

Four villages in the province of Lao Cai were included in the field study. The villages are in a remote rural area close to the border with China in the north of Vietnam. The area is mountainous and experiences a cold dry season from October to April and a tropical monsoon season from April to September. The province is one of the poorest in the country, with an estimated expenditure and income poverty incidence of 54% (REF).

Four communities were included in the study (**Table B-1**)

Table B-1: Vietnam study community characteristics

	Number of households	Number of HHs in the survey
Trạm Thải	72	50
Lắp máy	67	43
Phân Lân	68	55
Láo Lý	57	51

Sampling of households was hampered by the fact that available local records, provided by the district health posts, were unreliable. Local village leaders felt that more than half the data provided by the district was out of date or otherwise inaccurate. Sampling in any community therefore had to be based on a revised household list prepared in consultation with local leaders.

Láo Lý was reportedly a much poorer environment than the other three communities, with evidence of widespread open defecation and indiscriminate solid waste dumping. The quality of housing was reportedly poorer, with more common use of low cost materials such as masonry breeze blocks or thatch rather than bricks and tiles. The other three communities were reportedly clean with only minor evidence of littering.

Household characteristics

The average household size was 4.1 and the maximum number of people in any study household was 11. The area is highly ethnically diverse, with at least five ethnic groups represented in the survey. These were Day, Tay, Dao, Mong and Kinh. The Kinh group are reportedly the ‘senior’ community and generally live lower down the mountainside with other groups higher up.

Water use

Most of the study area has been provided with gravity piped water supply systems through the Government of Vietnam’s ‘Programme 135’. These systems generally draw water from springs or streams higher up the mountain and deliver it to individual households. The water is often stored in a concrete tank in the house or yard. Households widely reported that this water is ‘not clean’ or ‘not enough’. During the rainy season the water is reportedly ‘dirty’ and this was confirmed by our enumerators who observed high rates of suspended solids in the gravity scheme water. An inspection of the source for some of these schemes confirmed that the protection of springs and surface sources is rudimentary. Many households who had connections to these systems supplemented their supply with shallow wells, 2-3m deep, located within the yard, and this was often reportedly preferred as a source of water for drinking and cooking. Unusually for Vietnam rainwater harvesting systems were not prevalent in the area; households reported that rainwater is scarce.

Most of the gravity piped supplies in the area have been installed relatively recently. In village Phân Lân a system was installed during the period of the research. Households appeared to have good knowledge of the location of the source. The sources were often fairly distant from the households and access was via steep narrow paths.

Overall 43.9% of the respondents reported piped water to the house or yard as their main source of supply, 25.8% reported a well as the main source and 19.2% a shared supply of surface water. The latter may include water piped into the house from a distant source. Overall 76.8% of households reported that their main supply was outside the house but this often referred to water from elsewhere that was piped into the house or yard. Since most households used multiple sources of water for different uses it was difficult for many households to say with confidence which was their 'main' supply.

31.3% of households reported carrying water from outside the home and this was usually carried manually but not on the head.

Piped water supply is supposedly metered although we were not able to confirm the presence of meters during the fieldwork. In focus group discussions the general impression was that there was a willingness to pay for piped water but that the quality and quantity of the water was inadequate. Households reported that in the new scheme in Phân Lân water would be free up to 3,000 l per month per household. It was observed by participants in focus group discussions that this amount was quite low, particularly for rural households with livestock.

In Phân Lân, Lắp máy and Trạm Thải water was reportedly boiled before drinking although not in Láo Lý. This result could not be confirmed during household interviews.

Appendix C: Fieldwork report - South Africa

The study was conducted over a period of 10 weeks (late September to early December, 2012) in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province in South Africa. Three communities were selected from a sample frame of ten, that represented water service levels in the area (**Table C-1**).

Table C-1: Private and shared water supplies in the study communities

Community	Households with shared supply	Households with private supply	Total number of households
1	406	56	462
2	741	84	825
3	467	359	826

Communities 1 and 2 (C1 and C2) are located in the dry, flat area west of Makhado / Louis Trichardt town. .The water sources in Communities 1 and 2 (C1 and C2) are communal taps or private drilled wells with either a yard tap or in-house connection. Community 3 (C3) is located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while private supplies are yard taps or in-house connections.

Although all three communities had problems reliability of water supply, the supplies C1 and C2 seemed to be particularly unreliable. Most of the households using communal taps as their main source reported their alternative source as buying from neighbours with private drilled wells, and a few more relied on a municipal tanker that delivered water to the area once a week.

Although the households in C1 and C2 bought water from neighbours with drilled wells, a common complaint was that the water from these wells was very salty. This is not surprising, as the two communities are located at the base of the Soutpansperg (“salt pan mountain”) mountain range. Because the water was so salty, some households with private supplies reported using communal taps or a municipal tanker that delivered water once a week as alternative sources, mainly for their drinking water.

Thus the ‘private’ supplies in C1 and C2 were private in the sense that they were wholly managed by the households themselves. By drilling their own wells and setting up yard or house connections and in some cases subsequently selling water to their neighbours, these households performed the role ‘service’ roles of abstraction and distribution roles themselves.

The relatively wealthier households in C3 did not drill wells, but paid for a municipal connection to the yard / house, or privately connected pipes from the protected springs in the area to the yard / house. Some households with municipal connections still collected drinking water from springs, as they preferred the taste of the water from there. During water supply failures, households using communal taps collected water from either the nearest springs, or from neighbours with connections from the spring. Unlike in C1 and C2, water collected from neighbours in C3 was obtained for free.

Appendix D: Field work analysis – supplementary data

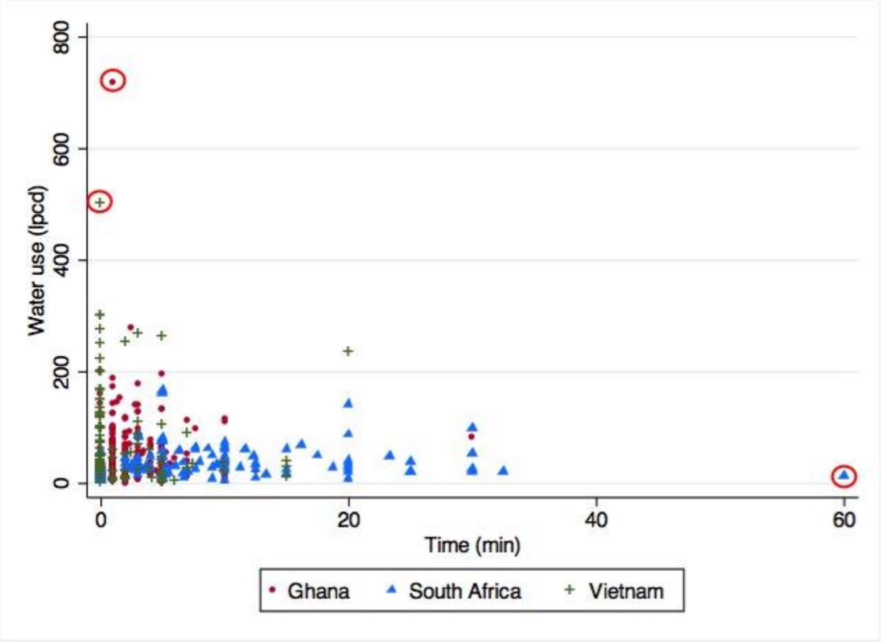

Figure D.1. Scatterplot of water use (lpcd) and self-reported one-way travel time to the primary water source for households in all three countries. Extreme data points are circled in red.

Appendix E: Musculo-skeletal health outcomes

Analyses for physical health outcome of pain reported in the previous 7 days, pain location and self-rating of general health were done using Generalised estimating equations (GEE) adjusted for age and sex and accounting for clustering at the household and country level. Where the outcome variable was binary we used negative binomial regression with a log link. Where the outcome variable was scalar we used linear regression models. Personal history of carrying water (current, previous, or no history) was used as the predictor variable, as the descriptive statistics indicate that categorisation into at-house or shared supply does not distinguish between people with different levels of exposure to water carrying.

Report of pain in the hands and upper back were statistically significant, whilst report of pain in the shoulders/arms, head, chest/ribs and abdominal area were close to statistically significant, with increasing relative risk for pain in these locations in people who previously and currently carry water (**Table E-1**).

Table E-1: Reported presence of pain by whether person current carries water, previously used to carry water or had never carried water adjusted for age and sex.

Health outcomes	Predictors	Response category	N	RR	L95%CI	U95%CI	P
Report of pain in the previous 7 days							
Adults reporting pain	History of carrying water	No History	130	1			0.962
		Previous	145	0.97	0.77	1.23	
		Currently	329	1.00	0.82	1.23	
Children reporting pain	History of carrying water	No History	228	1			0.640
		Previous	11	NA			
		Currently	139	0.89	0.55	1.44	
Locations of pain							
Abdominal pain	History of carrying water	No History		1			0.082
		Previous		1.43	0.76	2.69	
		Currently		1.70	1.07	2.69	
Chest/rib pain	History of carrying water	No History		1			0.054
		Previous		1.60	0.71	3.60	
		Currently		2.13	1.14	4.00	
Feet	History of carrying water	No History		1			0.394
		Previous		1.70	0.74	3.91	
		Currently		1.55	0.77	3.13	
Hands	History of carrying water	No History		1			0.020
		Previous		3.62	1.34	9.75	
		Currently		3.11	1.34	7.23	
Head	History of carrying water	No History		1			0.071
		Previous		1.16	0.67	2.02	
		Currently		1.53	1.03	2.27	
Hips/pelvis/legs	History of carrying water	No History		1			0.373

		Previous		1.13	0.74	1.72	
		Currently		0.85	0.61	1.20	
Lower back	History of carrying water	No History		1			0.828
		Previous		0.86	0.53	1.40	
		Currently		0.96	0.68	1.38	
Neck	History of carrying water	No History		1			0.512
		Previous		1.26	0.74	2.16	
		Currently		0.95	0.62	1.45	
Shoulders/arms	History of carrying water	No History		1			0.053
		Previous		0.91	0.52	1.60	
		Currently		0.59	0.38	0.92	
Upper back	History of carrying water	No History		1			0.017
		Previous		2.27	1.17	4.40	
		Currently		2.16	1.25	3.73	

A statistically significant relative risk of better ratings of general health in those who previously or currently carry water was found (**Table E-2**). This may indicate some general health benefits linked to water carrying, which for example, could potentially be derived from better cardiovascular fitness linked to being more physically active, or a greater sense of wellbeing linked to the positive social contribution or interactions associated with water carrying. Such positive health benefits were reported in previous qualitative research conducted with people who carry water (Geere et al. (2010a)).

Table E-2: Impact of water carrying history on self-rated general health (negative scores=increasing sense of health)

Health outcome	**Predictor variable**	**Response category**	**N**	**Regression parameter**	**L95%CI**	**U95%CI**	**P**
Rating of general health today (adults)	History of carrying water	No History		0			<0.000001
		Previous		-0.58	-0.80	-0.35	
		Currently		-0.91	-1.12	-0.70	
Rating of general health today (children)	History of carrying water	No History		0			0.003
		Previous		0.39	0.02	0.75	
		Currently		-0.20	-0.37	-0.31	

Factor analysis

Because reporting of pain at different sites was correlated, we undertook a factor analysis of the different pain location variables. It can be seen that factor 1 is correlated to pain in the chest/ribs, hands, feet, abdomen/stomach, head and upper back, whilst factor 2 is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs (**Table E-3**).

Table E-3: The rotated component matrix for first two factors of pain location variables, explain 54.8% of variance within the data.

Rotated Component Matrix[a]

Survey q28: Pain location	Component	
	1	2
Abdomen/stomach	.632	.131
Chest/ribs	.706	.151
Feet	.695	.221
Hands	.706	.266
Head	.616	.272
Hips/pelvis or legs	.179	.757
Lower back	.223	.750
Neck	.340	.696
Shoulders/arms	.238	.790
Upper back	.608	.347

Extraction Method: Principal Component Analysis.
Rotation Method: Equamax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

GEE with linear regression was then repeated for each factor and adjusted for age and sex. It can be seen that factor 1 is highly associated with currently or previously carrying water whereas factor 2 is marginally significantly negatively associated. There is biological plausibility in both the correlation of pain areas in each factor and the associations with water carrying. Sustained compressive loading through the cervical spine and upper back, as occurs with carrying water filled buckets on the head, is a plausible mechanism by which intervertebral discs of the cervical and upper thoracic spine may be adversely affected over time, or deformed during loading to compress and irritate other structures (Geere et al. (2010b)) and to cause the correlation of pain locations in factor 1. The pain from cervical degenerative disc disease tends to be in the posterior paraspinal muscles and is associated with headache and inter-scapular (upper back) pain. If degenerative disc disease in the cervical spine (cervical spondylosis) progresses, it can reduce space within the spinal canal to cause irritation or compression the neural tissues (myelopathy or radiculopathy) or their connective tissue coverings. For example early myelopathy due to spinal canal stenosis may mimic carpal tunnel syndrome, causing hand pain or dysaesthesia through dural irritation or neural tissue compression and eventually dysaesthesia in the feet and gait disturbance Clark (1996).

The correlation of pain locations in factor 2 (**Table E-4**), are more typical of simple non-specific musculoskeletal pain due to muscle or joint strain. Neck pain is commonly associated with referred shoulder or arm pain and back pain is commonly associated with pain in the lower quarter (hip/pelvis or legs). Non-specific spinal pain can be improved through remaining fit and active with regular physical activity, such as would occur by regularly walking to a shared water source.

Table E-4: Impact of water carrying history on factor 1 and factor 2

Health outcome	Predictor variable	Response category	N	Regression parameter	L95%CI	U95%CI	P
Factor 1 (chest/ribs, hands, feet, abdomen/stomach, head and upper back)	History of carrying water	No History		0			0.000045
		Previous		0.21	0.01	0.42	
		Currently		0.30	0.17	0.43	
Factor 2 (neck, shoulders/arms, lower back and hips/pelvis or legs)	History of carrying water	No History		0			0.023
		Previous		-0.03	-0.25	0.19	
		Currently		-0.18	-0.32	-0.04	

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Appendix 5. Published paper

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Carrying water may be a major contributor to disability from musculoskeletal disorders in low income countries: a cross-sectional survey in South Africa, Ghana and Vietnam

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Background The Sustainable Development Goals include commitments to end poverty, and promote education for all, gender equality, the availability of water and decent work for all. An important constraint is the fact that each day, many millions of women and children, and much less frequently men, carry their household's water home from off-plot sources. The burden of fetching water exacerbates gender inequality by keeping women out of education and paid employment. Despite speculation about the potential health impacts of fetching water, there is very little empirical evidence. We report the first large study of the health impacts of carrying water on women and children.

Methods A cross-sectional survey was conducted in South Africa, Ghana and Vietnam during 2012. It investigated water carrying methods and health status. Because areas of self-reported pain were correlated we undertook factor analysis of sites of reported pain, to interpret patterns of pain reporting. Regression analysis using Generalised Estimating Equations (GEE) investigated water carrying as a risk factor for general health and self-reported pain.

Results People who previously carried water had increased relative risk of reporting pain in the hands (risk ratio RR 3.62, 95% confidence interval CI 1.34 to 9.75) and upper back (RR 2.27, 95% CI 1.17 to 4.40), as did people who currently carry water (RR hand pain 3.11, 95% CI 1.34 to 7.23; RR upper back pain 2.16, 95% CI 1.25 to 3.73). The factor analysis results indicate that factor 1, 'axial compression', which is correlated with pain in the head and upper back, chest/ribs, hands, feet and abdomen/stomach, is associated with currently (0.30, 95% CI 0.17 to 0.43) or previously (0.21, 95% CI 0.01 to 0.42) carrying water. Factor 2, 'soft tissue strain', which is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs, is marginally negatively associated with currently (-0.18, 95% CI -0.32 to -0.04) carrying water. The factor 'axial compression' was more strongly associated with carrying water containers on the head.

Conclusions Participants who reported a history of current or past water carrying more frequently reported pain in locations most likely to be associated with sustained spinal axial compression in the cervical region. Given the fact that cervical spinal conditions are globally one of the more common causes of disability, our findings suggest that water carrying, especially by head loading is a major contributing factor in musculoskeletal disease burden in low income countries. Our findings support the proposed indicator for monitoring SDG6.1: "Percentage of population using safely managed drinking water services at home."

The United Nations Sustainable development goal (SDG) 6: 'to ensure access to water and sanitation for all' includes target 6.1: 'By 2030, achieve universal and equitable access to safe and affordable drinking water for all' [1]. The percentage of population using safely managed drinking water services *at home* has been proposed as the indicator for monitoring achievement of target 6.1 [2]. This represents a major shift toward recognising important differences in access, to distinguish water accessible within the home or yard, ('at-house' access), from water accessible at a supply point or source away from home ('off-plot' access). A difference is the work of water carriage required to bring water home from off-plot access. Perhaps the most influential study on the social and other impacts of water carriage was "Drawers of Water" [3], followed up some 30 years later by Drawers of Water II [4]. Conducted in East Africa, these studies raised awareness of the burden of fetching water for many Africans, especially women. The work of carrying water each day continues to mainly fall on women and girls, as reflected in a 2017 report of the WHO/UNICEF Joint Monitoring Programme, which found that women and girls were responsible for water collection in 'eight out of ten households with water off premises' with women responsible for water collection in 73.5% and girls in 6.9% of households of 61 DHS and MICs surveys [5]. Water carriage will be a major constraint on the achievement of diverse SDGs, including:

- SDG 1 "End poverty in all its forms" – when women have to spend much of their day fetching water they will not have the time to devote to activities that could increase their income.
- SDG 4 "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" – when children, most often girls, spend time carrying water this prevents them from accessing education.
- SDG 5 "Achieve gender equality and empower all women and girls" – it is difficult to see how girls and women could be fully empowered when they spend much of their time fetching water [6].
- SDG 8 "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all" – sustainable economic growth is less likely in those societies where half the work force spends much of its time fetching water.

Neither of the Drawers of Water studies were definitive about the impact of fetching water on health, or of health on capacity to fetch water. If carrying water adversely affects health, then it would also be a constraint on achieving SDG 3 "Ensure healthy lives and promote well-being for all at all ages". Although there has been speculation, there has been little concrete evidence on the adverse health impacts of water carrying [7]. Research on water access has focussed on water source type, location or distance to water source rather than the work of water carriage, and on health outcomes such as acute diarrhoeal disease affecting children under 5 rather than household members who fetch water [8]. For example, in a systematic review Wang and Hunter [9] found an association between distances to water source and diarrhoeal disease. In another study Pickering and Davis found that both diarrhoeal disease and mortality in children under 5 were associated with time taken to fetch water from the nearest source [10]. However, in both these studies the adverse health impact was on children in the home and did not address the health of the person carrying the water.

Studies have reported detrimental effects of load carriage on the head [11-15] and limited evidence suggests that musculoskeletal disorders may be associated with water carrying [7,16-19]. Carrying water containers, particularly on the head (head loading), may impart physical stress to the bones and soft tissues of the neck and upper back through vertical compression or 'axial loading', and/or shear forces generated by translation in the horizontal plane [7,12,20,21]. The stress may tend to be greatest at specific regions or vertebral levels of the spine due to differences in structural anatomy of the vertebrae, with some variation due to age or gender [22], or an individual's habits of posture and movement [23]. Peak or cumulative tissue stress loading during water carriage may be sufficient to produce pain, and if focussed at different regions of the spine may produce symptoms perceived in different locations of the body through well reported mechanisms of "referred" pain [7,23-26]. Therefore, given the substantial disease burden of musculoskeletal disorders in low and middle income countries [27,28], the substantial amount of women's time spent carrying water [6,10] and the small amount of evidence suggesting an association between water carriage and musculoskeletal disorders [7,16-18], it is important to investigate and better understand how water carriage affects health, especially women's and children's health. Because a key feature of musculoskeletal disorders is pain, we hypothesized that water carriage would be significantly associated with self-reported pain and general health. We report the first large scale study undertaken across three countries to attempt to identify adverse health impacts on people who collect and who have to carry their family's water home. Our objective was to evaluate the relationship between water carriage from an off-plot water source and physical health status as indicated by self-reported general health, pain and disability.

METHODS

Study design and setting

A cross-sectional survey was conducted, with recruitment and data collection occurring during June to December 2012 in Ghana, South Africa and Vietnam [29]. We selected geographical districts which were typical of low-income regions with sub-optimal water supply, and known to have communities with a mix of households with at-house and off-plot supplies, as the sampling frame in each country. We used a computer generated random number sequence to randomly select communities from each district to be included in the survey. In Ghana our research was conducted in four communities near Kumasi in the Ashanti region. All four communities were located around a main road and could broadly be defined as urban or peri-urban. Water was supplied through a combination of private taps, public taps, private boreholes and purchase of "sachet" water. In Vietnam our research was conducted in the remote, rural and mountainous Lao Cai province. The communities in Lao Cai were generally small scattered rural hamlets and most households accessed water from several sources, including piped water supply to the home, private boreholes and wells and public springs. In South Africa we carried out fieldwork in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province in South Africa. Two communities were located in the dry, flat area west of Makhado town. The water sources here were communal taps or private drilled wells with either a yard tap or in-house connection. The third community was located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while some households had yard-taps or in-house taps.

Sampling strategy

Assuming a sample size of 1000 participants and using the approach outlined by Hsieh et al [30], based upon simple logistic and linear regression, we calculated that a Power of 90% would be obtained even with a relatively small proportion of subjects with the outcome of interest. In South Africa 210 households were enrolled, in Ghana 255 and in Vietnam 208 generating a total of 997 participants who were asked about the variables of interest (**Table 1**). Stratified random sampling from within strata based on source of drinking water was used to recruit an even number of households with at-house and off-plot water supplies. All household members usually resident in selected households were eligible study participants.

Table 1. Demographic characteristics

	Ghana	South Africa	Vietnam	Total Number
Population of study communities	5160	–	–	N/A
Number of households (HH) in study communities	–	2113	264	N/A
HH enrolled in survey N (%)	255 (37.9%)	210 (31.2%)	208 (30.9%)	673 (100%)
Number of participants enrolled in survey N (%)	1326 (39.4%)	1230 (36.5%)	809 (24.1%)	3365 (100%)
Adults and children responding to pain, disability, general health and history of water carriage questions (1 adult and 1 child from each household) N (%)	397 (39.8%)	333 (33.4%)	267 (26.8%)	997 (100%)
Female gender whole survey: N (%)	753 (57.6%)	639 (52.0%)	401 (49.7%)	1793 (53.6%)
Female gender participants responding to pain, disability, general health and history of water carriage questions: N (%)	334 (84.8%)	234 (70.3%)	221 (82.8%)	789 (79.4%)
Mean age (standard deviation): whole survey	22.2 (23.5)	27.7 (21.3)	29.8 (20.9)	25.9 (22.4)
Mean age (standard deviation): participants responding to pain, disability, general health and history of water carriage questions	25.5 (16.3)	31.6 (22.2)	33.5 (20.5)	29.7 (19.8)
Adult* respondents to pain, disability, general health and history of water carriage questions with at home water supply N (%)	97 (43.1%)	103 (51.0%)	142 (77.2%)	342 (56.0%)
Adult* respondents to pain, disability, general health and history of water carriage questions with off plot water supply N (%)	128 (47.6%)	99 (49.0%)	42 (22.8%)	269 (44.0%)
Child† respondents to pain, disability, general health and history of water carriage questions with at home water supply N (%)	76 (45.5%)	73 (55.7%)	25 (30.5%)	174 (45.8%)
Child† respondents to pain, disability, general health and history of water carriage questions with off plot water supply N (%)	91 (54.5%)	58 (44.3%)	57 (69.5%)	206 (54.2%)

*Adult identified at Q14 as main survey respondent for households with at-house supply or usual water carrier for households with off-plot supply.
†Child identified at Q15 for response to health, disability and pain questions.

Variables

The household survey collected demographic information about all household members, and included a questionnaire which asked respondents about exposure variables; whether their main water supply was currently obtained from an at-house or off-plot supply point, whether they currently or had ever carried water and their usual method of water carriage. Health outcome variables included self-reported pain, general health, disability and functioning; questions about these variables were addressed to a subset of participants. The questions were administered to one adult respondent (93% women) and one child (57% girls) from each household. In houses with off-plot water supply, the questions were addressed to an adult and child identified by participants as a person in the household who would normally collect water, in households with at-house supply an adult and a child who would be responsible for collecting water if it were necessary. If a child was not present, the adult was asked to respond on their behalf.

A verbal descriptor of pain severity indicated as "mild", "moderate" or "severe", and experienced in the previous seven days [31-33], followed by additional questions to gather information about pain location, frequency and duration were used. To indicate general health, respondents were asked 'In general, how would you rate your health today?' and could select their response from a five point rating scale (1 = Very good; 2 = Good; 3 = Moderate; 4 = Bad; 5 = Very Bad). The short set of questions on disability developed and recommended for use in national surveys by the Washington Group on Disability Statistics [34] were used. Respondents were asked to rate whether they had difficulty in doing the activities of seeing, breathing, hearing, walking or climbing steps, remembering or concentrating, self-care and communicating. The response options were "no difficulty", "some difficulty", "a lot of difficulty" or 'cannot do it at all'. Questions on functioning used by Atijosan et al, shown to have excellent reliability and validity in developing country settings [35] were used to indicate impairment of functioning. Respondents were asked whether they had difficulty using their arms, legs, any other part of their body such as the back or neck and whether they have "fits" or "epilepsy". Response options were 'no', 'yes, lasted less than 1 month' or 'yes, lasted more than one month or is permanent'. Information was also gathered on the potential confounding factors of age and gender.

Prior to commencement of any fieldwork activities, the data collection tools and protocol were revised, refined and standardised at a project workshop attended by the principle investigator (PI), co-investigators and field work team leads for each country in June 2012. The questions were then separately piloted in all three project locations and fieldworkers trained to administer the survey by the team leads within each country.

We addressed potential sources of bias by using stratified random sampling of households to reduce selection bias, limiting information about pain severity to pain experienced in the previous 7 days to reduce recall bias, training field-workers in a standardised interview protocol and monitoring the quality of data collection during fieldwork to reduce interviewer bias, and surveyed households about exposure variables and outcome variables on separate days to minimise response bias.

Data analysis

Summary descriptive statistics for each country compare self-reported pain, general health, and disability of people with at-house supply to those using off-plot water supplies. Categorisation into at-house or off-plot water supply did not distinguish between people who did or did not engage in water carriage. Therefore, personal history of carrying water (by any method, categorised as currently carrying water, previously carried water or no history of water carriage) was used as the predictor variable. Analyses for health outcomes of pain reported in the previous seven days, pain location and self-rating of general health "today" were done using Generalised Estimating Equations (GEE) adjusted for age and gender and accounting for clustering at the household and country level. Participants with missing data were excluded from the analyses. Where the outcome variable was binary we used negative binomial regression with a log link, and where the outcome variable was scalar we used linear regression models. Because reporting of pain location at different parts of the body was correlated, we undertook a factor analysis of the different pain location variables. Two factors extracted from the overall data correlation matrix which accounted for the largest proportion of the total variance in the data were identified. Published literature was used to develop a theoretical construct offering a plausible explanation of the observed correlations between variables in each factor and to name each factor [36]. GEE with linear regression was then repeated for each factor and adjusted for age and gender, as well as to evaluate the strength of association with water carriage by head loading compared to other methods.

Ethical review

This study was approved by the Ethical Committee of the School of International Development at the University of East Anglia for work in South Africa, the University of Leeds Ethical Committee, for work in Vietnam and the University of North Carolina for work in Ghana. In South Africa ethical clearance was also granted by the Tshwane University of Technology central ethical clearance committee, and the research team were invited by local chiefs within the study area to present their proposed research. In Ghana ethical approval was obtained from both the District Director of Health Services for Atwima Nwabiagya and the Atwima Nwabiagya District Assembly. In Vietnam, ethical clearance was obtained by the ethical research board of the Hanoi School of Public Health. Participants were included only after they had given informed written voluntary consent if ≥18 years old or if they and their guardian had given informed voluntary consent if <18 years old.

RESULTS

Patterns of water carriage

Respondents with at-house or off-plot water supplies were recruited in each country (**Table 1**). In South Africa and Ghana, substantial numbers of adults (South Africa SA 36.9%; Ghana GH 61.9%) and children (SA 19.2%; GH 43.4%) with at-house supply who were asked questions about general health, pain and disability, categorised themselves as currently carrying water. Whilst proportionately more women and children with off-plot supply in Ghana carried water by head loading, a considerable proportion of women and children with at- house supply also did so. A larger proportion of people with at-house supply in South Africa carried water by head loading compared to those with off-plot supply, as 42.4% of respondents with off-plot supply used a wheelbarrow to transport water (**Figure 1**). In both countries, participants reported episodes of interruption to at-house water supplies requiring water carriage from off-plot sources, which has also been reported in previous literature [37,38]. In all countries, substantial numbers of women with at-house supply had previously carried water (SA = 56.3%; GH 21.6%; Vietnam V 26.8%). The mean number of years in which they had engaged with water carrying were 25.4 (SD = 19.4) for South Africa, 19.7 (SD = 14.5) for Ghana and 7.1 (SD = 10.2) for Vietnam (Table S11 in **Online Supplementary Document**).

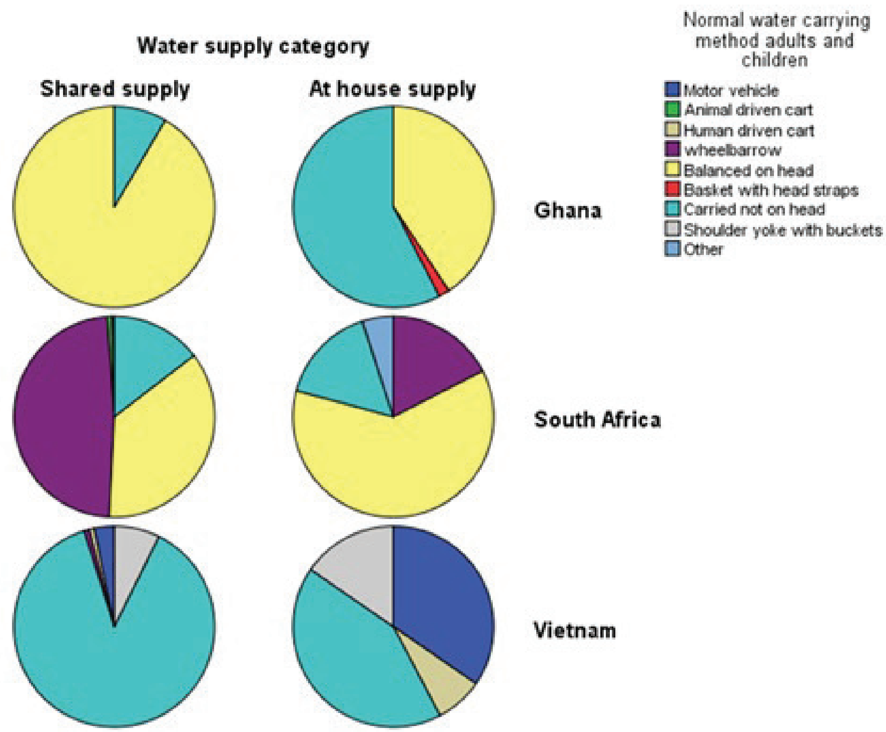

Figure 1. Water carriage method by supply type and country.

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Pain

Overall, comparing people with at-house vs off-plot supply within countries, there was no significant difference in reporting of pain experienced in the previous seven days (Table S1 and S4 in **Online Supplementary Document**). Irrespective of at-house or off-plot supply categorisation, in South Africa proportionately fewer adults and children reported feeling pain in the previous seven days (SA adults 36.1%; children 4.6%) than in Ghana (adults 57.3%; children 18%) or Vietnam (adults 54.3%; children 21.7%).

History of water carriage did not significantly affect likelihood of reporting pain experienced in the previous seven days (**Table 2**). However pain reported in particular locations of the body was related to personal history of water carriage. Compared to people who had never carried water, people who previously carried water had increased relative risk of reporting pain in the hands and upper back (**Figure 2**, **Table 3**), as did people who currently carry water (**Figure 3**, **Table 3**). The factor analysis [36] results (**Table 4**) indicated that factor 1, interpreted as representing the effects of 'axial compression' is correlated with pain in the head and upper back, chest/ribs, hands, feet and abdomen/stomach, and is associated with currently (0.30, 95% CI 0.17 to 0.43) or previously (0.21, 95% CI 0.01 to 0.42) carrying water (**Table 5**). Factor 2, interpreted as indicating 'soft tissue strain' is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs and is marginally negatively associated with currently car-

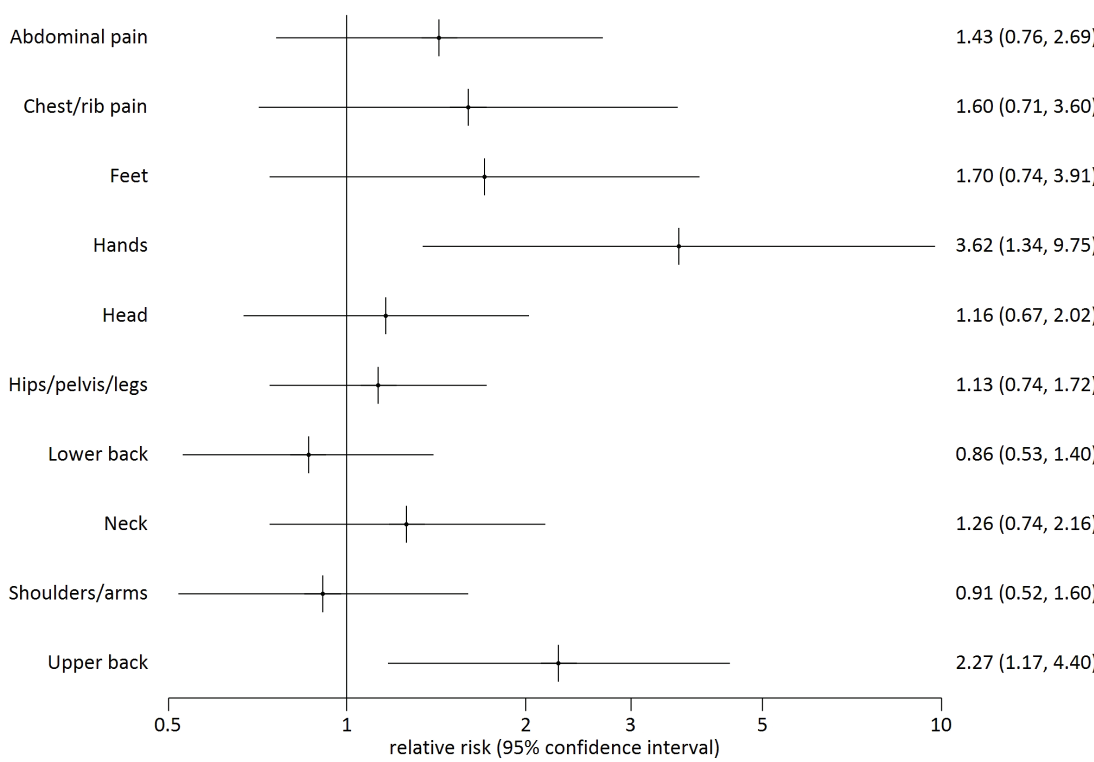

Figure 2. Sites of reported pain by past vs never water carrying.

Table 2. Adults and children self-report of pain in previous 7 days against history of water carriage

Pain previous 7 days	Predictor variable	N	RR	L95% CI	U95% CI	P-value
Adults	No history of water carriage	130	1			0.962
	Previous history of water carriage	145	0.97	0.77	1.23	
	Currently carries water	329	1.00	0.82	1.23	
Children	No history of water carriage	228	1			0.640
	Previous history of water carriage	11	NA			
	Currently carries water	139	0.89	0.55	1.44	

RR – relative risk, L95% CI – lower 95% confidence interval, U95% CI – upper95% confidence interval

Table 3. Relative risk of pain location from personal history of water carriage

Pain location	Predictor variable	N	RR	L95% CI	U95% CI	P-value
Abdominal pain	No history of water carriage	364	1			0.082
	Previous history of water carriage	159	1.43	0.76	2.69	
	Currently carries water	474	1.70	1.07	2.69	
Chest/rib pain	No history of water carriage	364	1			0.054
	Previous history of water carriage	159	1.60	0.71	3.60	
	Currently carries water	474	2.13	1.14	4.00	
Feet	No history of water carriage	364	1			0.394
	Previous history of water carriage	159	1.70	0.74	3.91	
	Currently carries water	474	1.55	0.77	3.13	
Hands	No history of water carriage	364	1			0.020
	Previous history of water carriage	159	3.62	1.34	9.75	
	Currently carries water	474	3.11	1.34	7.23	
Head	No history of water carriage	364	1			0.071
	Previous history of water carriage	159	1.16	0.67	2.02	
	Currently carries water	474	1.53	1.03	2.27	
Hips/pelvis/legs	No history of water carriage	364	1			0.373
	Previous history of water carriage	159	1.13	0.74	1.72	
	Currently carries water	474	0.85	0.61	1.20	
Lower back	No history of water carriage	364	1			0.828
	Previous history of water carriage	159	0.86	0.53	1.40	
	Currently carries water	474	0.96	0.68	1.38	
Neck	No history of water carriage	364	1			0.512
	Previous history of water carriage	159	1.26	0.74	2.16	
	Currently carries water	474	0.95	0.62	1.45	
Shoulders/arms	No history of water carriage	364	1			0.053
	Previous history of water carriage	159	0.91	0.52	1.60	
	Currently carries water	474	0.59	0.38	0.92	
Upper back	No history of water carriage	364	1			0.017
	Previous history of water carriage	159	2.27	1.17	4.40	
	Currently carries water	474	2.16	1.25	3.73	

RR - relative risk, L95% CI – lower 95% confidence interval; U95% CI – upper 95% confidence interval

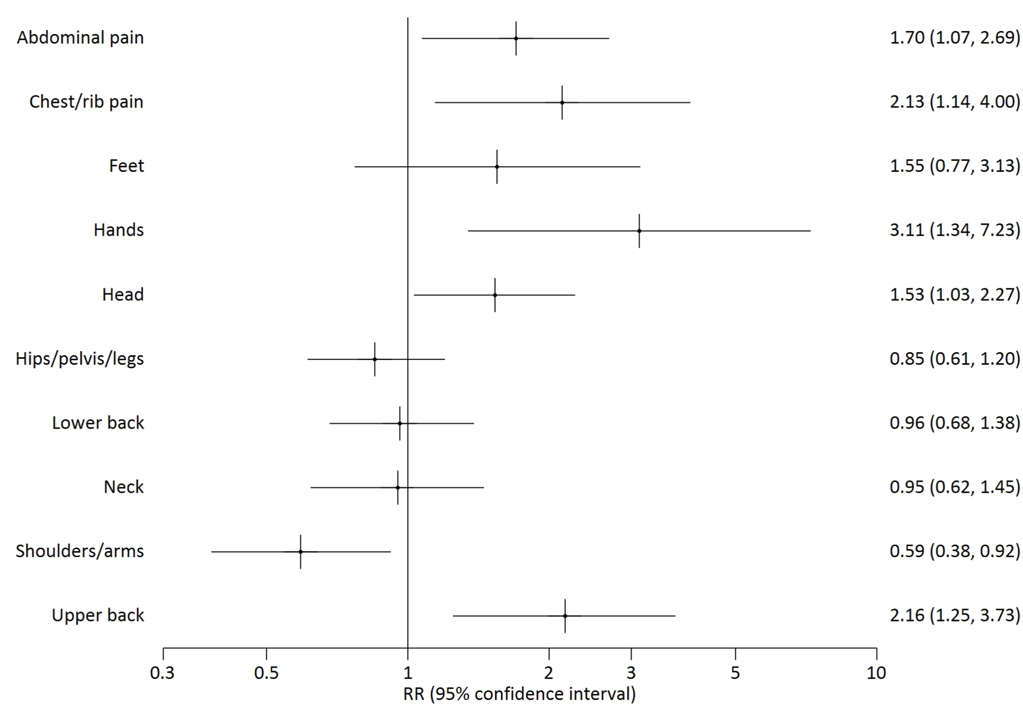

Figure 3. Sites of reported pain by current vs never water carrying.

Table 4. Factor analysis of self-reported pain locations*

Pain location	Factor 1: axial compression (correlation)	Factor 2: soft tissue strain (correlation)
Abdomen/stomach	0.632	0.131
Chest/ribs	0.706	0.151
Feet	0.695	0.221
Hands	0.706	0.266
Head	0.616	0.272
Hips/pelvis or legs	0.179	0.757
Lower back	0.223	0.750
Neck	0.340	0.697
Shoulders/arms	0.238	0.790
Upper back	0.608	0.347

*Extraction method: Principal components; rotation: Equamax. Variance explained: 54.8%.

rying water (-0.18, 95% CI -0.32 to -0.04) (**Table 5**). Further analysis of people currently carrying water showed that the factor axial compression is significantly increased in people reporting head loading compared to those carrying by other means (**Table 5**). In an ordinal logistic regression analysis, those with higher axial compression scores tended to report shorter pain duration. Soft tissue strain scores were not associated with change in pain duration (**Table 6**).

Physical functioning and disability

In Vietnam, proportionately more adults with at-house supply reported problems using their legs ($\chi^2=8.8$; $P=0.01$) or body ($\chi^2=8.8$; $P=0.01$) which had lasted for more than a month or was permanent (Table S7 and S8 in **Online Supplementary Document**).

Table 5. Linear regression analysis of personal history of water carriage on Factor 1 (axial compression) and Factor 2 (soft tissue strain)

Factor correlated pain locations	Predictor variable	N	B	L95%CI	U05%CI	P-value
Factor 1: Axial compression	No history of water carriage	364	0			0.000045
	Previous history of water carriage	159	0.21	0.01	0.42	
	Currently carries water	474	0.30	0.17	0.43	
	Currently carries water – no head loading	214	0			0.034
	Currently carries water – head loading*	260	0.36	0.03	0.70	
Factor 2: Soft tissue strain	No history of water carriage	364	0			0.023
	Previous history of water carriage	159	-0.03	-0.25	0.19	
	Currently carries water	474	-0.18	-0.32	-0.04	
	Currently carries water – no head loading	214	0			0.64
	Currently carries water – head loading[1]	260	-0.07	-0.35	0.22	

B – linear regression coefficient, L95% CI – lower 95% confidence interval; U95% CI – upper 95% confidence interval
*Subgroup "currently carries water – head loading" only contains participants from South Africa and Ghana, as no-one in Vietnam carried water by head loading.

Table 6. Ordinal logistic regression of pain duration against Factor 1 (axial compression) and Factor 2 (soft tissue strain) with pain defined in three categories as <1 months, ≥1 months <3 months and ≥3 months (n = 333)

Predictor	OR	L95%CI	U95%CI	P-value
Factor 1: "Axial compression"	0.61	0.44	0.84	0.003
Factor 2: "Soft tissue strain"	1.30	0.59	2.86	0.521

OR – odds ratio, L95% CI – lower 95% confidence interval; U95% CI – upper 95% confidence interval

Numbers of people reporting disability were very small and there were no significant differences in disability related to walking or self-care comparing people with at-house to those with off-plot supply within or across countries (Table S9 in **Online Supplementary Document**).

General health

Most people in South Africa and Ghana rated their health as very good, good or moderate with no significant difference according to whether they had at-house or off-plot water supply (Tables S9 and S10 in **Online Supplementary Document**). In Vietnam, most adults rated their general health as moderate or bad (76.1%), none rated it as very good. A larger proportion of adults in Vietnam with off-plot supply rated their health as bad, and a smaller proportion as moderate, compared to those with at-house supply ($\chi^2=9.8$; $P=0.01$) (Table S9 in **Online Supplementary Document**).

Interestingly, adults who previously carried water had a mean general health rating score 0.58 less (ie, healthier) than adults who never carried water ($\beta=-0.58$, 95% CI -0.80 to -0.35, $P<0.001$) and adults who currently carried water had a mean general health rating score 0.91 less (ie, healthier) than adults who had never carried water ($\beta=-0.91$, 95% CI -1.12 to -0.70, $P<0.001$) (**Table 7**). Children who currently carry water had a better mean score rating for general health than children who had never carried water ($\beta=-0.20$, 95% CI -0.37 to -0.31, $P=0.003$). Children who previously carried water had a worse mean score rating for general health ($\beta=0.39$, 95% CI 0.02 to 0.75), however the number of children in this category was very small (n = 10).

Table 7. Impact of personal history of water carriage rating of general health

General Health	Predictor variable	N	B	L95%CI	U95%CI	P-value
Rating of general health today (adults)	No history of water carriage	123	0			<0.000001
	Previous history of water carriage	143	-0.58	-0.80	-0.35	
	Currently carries water	325	-0.91	-1.12	-0.70	
Rating of general health today (children)	No history of water carriage	204	0			0.003
	Previous history of water carriage	10	0.39	0.02	0.75	
	Currently carries water	128	-0.20	-0.37	-0.31	

B - linear regression coefficient L95% CI – lower 95% confidence interval; U95% CI – upper 95% confidence interval

DISCUSSION

Current and past history of water carriage was associated with location of self-reported pain and ratings of general health. Reported pain locations were correlated and factor analysis revealed that Factor 1, which has been interpreted as the effects of 'axial compression', was associated with current or past water carriage, whilst Factor 2, interpreted as the effects of 'soft tissue strain' was slightly negatively associated with current water carriage. The factor 'axial compression' was most strongly associated with water carriage by head loading. The findings highlight that the experience of pain needs to be qualified in some detail to discriminate between people with different exposures to water carriage and with potentially different underlying causal mechanisms for their pain. The risk of reporting pain anywhere in the body indicated by a yes/no response to the question 'in the past week (7 days) have you had any physical pain?' was not significantly associated with different water supply or history of water carriage, likely reflecting the fact that physical pain is a common phenomenon in the general population. However, among those who did report pain, risk of reporting pain in specific parts of the body was significantly associated with history of water carriage. This is consistent with approaches to the clinical assessment of pain, in which location of pain is used to inform a differential diagnosis [39], and clinical pain research, in which the importance of pain location and multiple sites of pain is recognised [40]. Researchers should ask people where they feel pain, in addition to whether or not they have had any pain.

There is biological plausibility in the increased relative risk of pain in specific locations of the body in people with a current or past history of water carriage, as well as the correlation of pain areas in each factor and the association of axial compression with pain duration, water carriage and head loading in particular. Sustained axial compressive loading through the cervical spine and upper back, as occurs with carrying water filled containers on the head, is a plausible mechanism by which intervertebral discs or vertebrae of the upper cervical spine and cervico-thoracic junction may be stressed. Pal and Routal [22] described weight transmission through the cervical and thoracic spine and found that the second cervical vertebra and the cervico-thoracic junction anatomy indicate that load transference between the columns of the spine occurs at these levels, increasing tissue stress to make them more susceptible to bending or buckling deformity. Pal and Routal [22] cite Taylor and Twomey [41] to highlight that pubescent females have more slender spines and may be most vulnerable to adverse effects. Adverse effects due to axial loading stress could occur gradually, leading to degenerative changes in the intervertebral disc and associated zygoapophyseal joints, known as cervical spondylosis [12,13,42,43], or during head loading cause acute tissue stress or deformation to stimulate pain sensitive structures [20]. Through recognised pain referral mechanisms, such loading stress could cause pain to be perceived in the head, upper back and chest region, or hands. The pain from cervical degenerative disc disease tends to be associated with headache and inter-scapular (upper back) pain and may also cause irritation of spinal neural tissues to produce symptoms such as pain in the hands [24-26,44]. Because the cervical spinal canal protects both the spinal cord and peripheral nerve roots descending to lower regions of the spine, cervical problems can potentially cause more widespread symptoms and neurological impact than problems in the lumbar spine. Particularly in Africa, regular head loading has been linked to cervical spondylosis [12,13,42,43,45,46] and very heavy cervical loading to severe trauma and death [14]. People with cervical spondylosis causing spinal canal stenosis have been shown to be more at risk of serious spinal cord injury and its severely disabling consequences after even minor, indirect trauma to the cervical spine [47-51].

Our study is the first to find an association between water carriage and a pattern of correlated pain locations, which we believe is most likely due to a specific spinal musculoskeletal disorder caused by axial loading. Musculoskeletal disorders are within the top ten causes of years lived with disability in developing countries. Combined with fractures and soft tissue injuries they accounted for 20.8% of global years lived with disability in 2013, which would be even greater if years lived with disability due to sequelae of cervical disorders such as neurological impairment and headache were added [28]. Because water carriage is a modifiable activity, our study highlights at-house water supply as an important potential mechanism to reduce the burden of years lived with disability due to serious musculoskeletal disorders affecting children and adults, particularly women due to the gendered role of water carriage, in developing countries. Our findings also indicate that where people must continue to access their water from off-plot sources, enabling them to use alternative water carriage methods rather than head loading is a good first step. This could involve provision of affordable equipment, such as wheelbarrows, or improving access pathways to facilitate their use [16,19].

The correlation of pain locations with factor 2 (soft tissue strain) are more typical of simple non-specific spinal pain which produces somatic referred pain in the upper and lower limbs respectively. It may be due to the effects of soft tissue strain, for example generated by shear or translation stress, which can be reduced through better postural muscle control and functioning [23]. Water carriage and regularly walking to an off-plot water source could develop and maintain a level of muscle function and endurance which is slightly protective of joint or soft tissue strain [52-54]. It is plausible that whilst some individuals may experience pain associated with detrimental effects of axial compression; others may in fact benefit from the protective effect of exercise and better muscle control minimising soft tissue strain. Differential effects may be influenced by differences in total work load; for some water carriage may represent a major fraction of activity, and for others a minor fraction. Alternatively, water carriage patterns may be affected by unreliable water supplies [38], which could force women to collect as much water as possible when it is available, rather than pacing their work to avoid fatigue or pain due to tissue overload. Thus individual, task and environmental differences may lead to real differences in the experience of pain and therefore ability to fetch sufficient quantities of water, exacerbating inequalities in water access between households [16,27].

In all countries, proportionately more adults with off-plot supply, as compared to adults with at-house supply complained of pain lasting for less than a month, which was significantly associated with axial compression pain location patterns. The most common clinical pattern of degenerative disc disease or cervical spondylosis is episodic exacerbation or 'flare up' of symptoms followed by periods of remission or stability [44]. Constant pain is more typically a feature of serious pathology such as fracture, infection or cancer [55,56].

The better ratings of general health in those who previously or currently carry water may indicate some health benefits linked to increased physical activity. It could also indicate a greater sense of well-being linked to positive social interactions associated with water carriage. Results from the latest South African census also support the finding that the majority of the population in South Africa rate themselves as being in good health [57]. However, this finding may indicate that healthier people tend to become the household water carriers. Not everyone in a household will be tasked with carrying water and generally, people with more severe disabilities or illness are less likely to carry water [58]. Alternatively, in South Africa, the concept of 'good health' has been linked to ability to perform water carriage [17], an example of how cultural groups may define 'health' in terms of capacity to perform activities or to participate in society [59]. Such cultural differences in how health is conceptualised may to some extent influence self-rating of general health amongst water carriers, and may also explain the greater proportion of adults rating their health as moderate or bad in Vietnam.

The findings of no difference in perceived health with on-plot or off-plot supplies in Ghana and SA, yet better health among water carriers past and present than non-carriers indicate that there is an association with the activity of water carriage, but not with the type of household water supply. This is likely due to the large number of people categorised as having at-house water supply, who actually had previously carried water, or still have to carry water because of interruptions to supply, as shown in **Figure 1**. Our finding that water carriage is associated with pain location, and more weakly associated with better rating of general health may seem contradictory. However, it is possible to perceive that one's general health, as a broader indicator, is good, but at the same time experience pain related to specific activities. For example, trained athletes or people who engage with high levels of physical activity may perceive that they have good general health related to their level of physical fitness, but do commonly experience musculoskeletal pain related to the activities they participate in. Pain location or patterns of pain are frequently used to indicate the underlying pathology or type of disorder causing the pain.

Limitations

We did not include data about load carriage of materials other than water to reduce the size of the questionnaire and subsequent respondent burden, and to keep the focus on water access which was the primary aim of the research. However we do acknowledge that head loading of other materials, such as firewood [43,60], could be a confounding factor. In the multivariable analysis, we accounted for clustering at country, village and household level and this would have adjusted for the potential confounding effect of other activities associated with differences in geographic location, such as collecting wood, likely to be more similar within sites but different between the sites.

Although a limitation of the study was the use of a main survey respondent to answer health questions for household members if they were not present, the main respondent was most often an adult female who would be likely to have more insight into the health and medical history of her family members and have personal experience of water carriage herself. Clinical assessment of participants by a trained health professional would allow more informed interpretation of underlying causes of self-reported pain. Cause and effect must be established from a range of evidence including that derived from studies involving clinical assessment, and longitudinal cohort studies, which may reveal more complicated relationships between physical, psychological and social factors associated with water fetching and health. Nevertheless, previous studies have reported good correlation across populations between subjective symptoms and underlying radiological findings, and even in affluent countries, a diagnosis would usually be based on reported symptoms without reliance on ancillary investigations [44,61]. However, our study provides important evidence in support of the hypothesis that water carriage is significantly associated with pain and general health. Further research investigating the relationship between water fetching and health, ideally to include clinical assessment of water carriers by trained health professionals, is warranted.

CONCLUSIONS

We have shown that people reporting a past or current history of water carriage were much more likely to report pain in locations typically associated with cervical compression syndromes. Cervical compression is associated with far more serious sequelae than back pain and can lead to serious long term disability in later life. Given that in 2015, 663 million people still use unimproved drinking water sources [5] it is likely that the burden of musculoskeletal disease from water carriage is substantial. Our findings support the ambition of the SDG target 6.1: 'universal and equitable access to safe and affordable drinking water for all' and indicate that to achieve the target, individual differences in the health impacts of water carriage must be recognised and addressed. Where access to water is likely to remain off-plot, alternative methods to load carriage on the head should be supported. Our findings also support the proposed shift to monitoring the percentage of the population using safely managed drinking water services at home as a key indicator.

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Authorship declaration: JG conceived and designed the study, undertook data collection and data analysis, wrote the first draft of the paper and contributed to writing of final paper. PRH conceived and designed the study, undertook data analysis and contributed to writing of the final paper. JB, BE, NG and W-PS conceived and designed the study, and contributed to writing of the final paper. LB, LD, MF, BM and ARW designed the study, undertook data collection, and contributed to writing of the final paper. MMM, MSM, NVH, PDP undertook data collection, and contributed to writing of the final paper.

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Appendix 6. Published paper

GEERE, J. A., HUNTER, P. R. & JAGALS, P. 2010a. Domestic water carrying and its implications for health: a review and mixed methods pilot study in Limpopo Province, South Africa. *Environmental Health: A Global Access Science Source,* 9**,** 52. Available at http://www.ehjournal.net/content/9/1/52 [accessed 19/03/19]

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ENVIRONMENTAL HEALTH

RESEARCH Open Access

Domestic water carrying and its implications for health: a review and mixed methods pilot study in Limpopo Province, South Africa

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Abstract

Background: Lack of access to safe water remains a significant risk factor for poor health in developing countries. There has been little research into the health effects of frequently carrying containers of water. The aims of this study were to better understand how domestic water carrying is performed, identify potential health risk factors and gain insight into the possible health effects of the task.

Methods: Mixed methods of data collection from six were used to explore water carrying performed by people in six rural villages of Limpopo Province, South Africa. Data was collected through semi-structured interviews and through observation and measurement. Linear regression modelling were used to identify significant correlations between potential risk factors and rating of perceived exertion (RPE) or self reported pain. Independent t-tests were used to compare the mean values of potential risk factors and RPE between sub-groups reporting pain and those not reporting pain.

Results: Water carrying was mainly performed by women or children carrying containers on their head (mean container weight 19.5 kg) over a mean distance of 337 m. The prevalence of spinal (neck or back) pain was 69% and back pain was 38%. Of participants who carried water by head loading, the distance walked by those who reported spinal pain was significantly less than those who did not (173 m 95%CI 2-343; $p = 0.048$). For head loaders reporting head or neck pain compared to those who did not, the differences in weight of water carried (4.6 kg 95%CI -9.7-0.5; $p = 0.069$) and RPE (2.5 95%CI -5.1-0.1; $p = 0.051$) were borderline statistically significant. For head loaders, RPE was significantly correlated with container weight ($r = 0.52$; $p = 0.011$) and incline ($r = 0.459$; $p = 0.018$)

Conclusions: Typical water carrying methods impose physical loading with potential to produce musculoskeletal disorders and related disability. This exploratory study is limited by a small sample size and future research should aim to better understand the type and strength of association between water carrying and health, particularly musculoskeletal disorders. However, these preliminary findings suggest that efforts should be directed toward eliminating the need for water carrying, or where it must continue, identifying and reducing risk factors for musculoskeletal disorders and physical injury.

Background

Improved health-related water management could prevent one tenth of the current global disease burden and investments in improved access to safe drinking water may realize at least ten fold economic returns [1]. Yet lack of access to safe water remains the third most significant risk factor for poor health in developing countries [2]. The health impact of various interventions to improve access to safe water has been extensively reviewed, but primarily by focusing on rates of acute infectious diarrhoeal illness to evaluate outcome [2-5]. It is likely that more health impacts of sub-optimal water supply are frequently overlooked or underestimated, because effects other than acute diarrhoeal illness are not usually considered [1].

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Understanding the health impacts of sub-optimal water access more broadly is crucial for appropriate and sustainable water resource development. The benefits of investing in interventions to improve safe water access may be underestimated and, therefore, such interventions not prioritised, if the broader health impacts are not comprehensively evaluated. For example, many people must still collect and physically carry water from a source distant to their home, which may have important health consequences for those who perform the task [6].

Water filled containers are often carried on the head, however, transportation with wheel barrows, animal drawn carts or by rolling filled containers has also been observed [7,8]. These methods obviously create physical demands on the body and the potential for adverse physical stress from regularly carrying loads of water has been recognised [6,9,10]. Physical loading of the body within an individual's capacity for adaptive responses may lead to tissue strengthening, however, frequent loading beyond capacity for adaptation or repair may lead to injury through fatigue failure, accumulation of fatigue damage [11] or early degenerative changes in bone and soft tissues [12].

Assumptions have been made that water carrying is detrimental to health and associated with musculoskeletal disorders, such as spinal pain or other joint problems [8,13,14]. Such assumptions are supported by strong evidence that the physical demands of work such as handling heavy materials, bending, twisting and lifting, are risk factors for onset of simple low back pain [11,15] and other musculoskeletal disorders [16,17]. In particular carrying heavy loads on the head by professional porters has been documented to cause catastrophic injury, such as spinal fracture, dislocation or death [18] and has also been associated with early onset of degenerative changes in the cervical spine [12,17,19,20].

Although head loading due to occupational activities has been associated with degenerative changes in the cervical spine, the relationship between symptoms such as neck pain and activities which require head loading is not clear. Despite a much higher prevalence of upper cervical osteoarthritis in porters (91.6% in male porters compared to 6.8% in the control group) Badve et al. [17] stated that an association between symptoms and radiological changes was not found. Similarly, a recent systematic review did not find evidence that cervical disc degeneration is a risk factor for neck pain and reported variable evidence for a relationship between radiographic signs of degeneration and neck pain prevalence [21]. A recent study found that degenerative changes observed in cervical plain films were poorly related to the severity of symptoms or neck dysfunction in women with chronic pain and working in sedentary occupations [22].

However, very few studies have specifically investigated water carrying as it is performed by women and children in developing countries and used appropriate methodologies to investigate its association with health generally or musculoskeletal disorders specifically [10,23,24]. Most studies investigating the health impact of physical loading are of male adult workers [17,25-27] or are situated in high income countries [28] such that existing evidence may not be applicable to women and children who typically collect and carry water for domestic use [29]. Importantly, women and children have reduced injury tolerance for physical loading through the cervical spine compared to men [30-36] and in rural areas may be particularly vulnerable to physical injury due to high levels of poverty, poor health and chronic disease [37-42]. Therefore, it is not clear whether regularly carrying containers of water for domestic use leads to detrimental effects such as accelerated degenerative changes in the spine and other joints and whether or not any such effects are symptomatic and impact on health related quality of life.

Two recent reports indicate that some people may experience high rates of perceived exertion and pain sufficient to limit their capacity to carry water containers [7,43]. Reduced capacity of women or children to collect water due to pain or fatigue may have serious implications for the health of their families. However, water carrying is a physical activity which might also lead to beneficial health effects in some individuals. In researching the health impacts of water carrying, it is important to consider health impacts broadly [7] and recognise the limitations of applying existing evidence to this special activity and population group. Researcher assumptions about risk factors and health effects may introduce bias into research methodology in terms of determining the questions asked and outcomes measured and consequently how study participants report the health impacts of water carrying. For example, the use of leading questions or outcome measures which assume an association with symptoms such as pain might influence participant responses and their description of the health effects of water carrying.

As there is a lack of empirical data specifically related to water carrying, the aims of this study were to better understand how water carrying is performed and experienced by people who perform the task, identify health risk factors potentially related to carrying water and gain insight into the possible health effects of the task. The following research questions are addressed in this report

- Who carries domestic water sourced outside of the home?
- How do people carry domestic water?

• What factors considered to a pose risk of injury or disease in higher income countries and occupational settings, are people exposed to during water carrying?

• Are reports of pain during qualitative interview and ratings of perceived exertion during water carrying correlated with exposure to water carrying related risk factors?

• Are there significant differences in exposure to potential water carrying related risk factors between people who report pain during qualitative interview and those who do not?

• How does pain impact on the ability to carry water?

Methods

A mixed methods approach was taken, utilising both quantitative and qualitative data to better understand domestic water carrying as it is performed and experienced by adults and children in Limpopo Province, South Africa. Ergonomic principles were used to develop the approach to quantitative data collection. An 'ergonomic' evaluation of work incorporates assessment of a broad range of potential risk factors related to the environment, organisation of work, the nature of the task or the individual [44].

Qualitative enquiry in this study was influenced by the principles of phenomenology as described by Creswell [45] and used to explore the lived experience of water carrying. Individuals with direct experience of water carrying will have unique understanding of the task and can provide insight into how it might impact upon their own health and functioning. As the health effects of water carrying are unknown and might be experienced and interpreted variably by different individuals, such insights can indicate the domains of health which are relevant to people who perform water carrying and, therefore, important to evaluate for a potential association with the activity.

This report will focus on the analysis of the quantitative data, combined with some specific findings from content analysis of the qualitative data generated during individual semi-structured interviews. This approach was used to evaluate the relationship between pain, which was a specific health outcome revealed to be of concern to many of the study participants, and potential risk factors observed to occur during water carrying. More extensive and detailed analysis of the qualitative data will be reported separately [7] and will incorporate the findings of additional data generated from 'natural informal group interviews' which were conducted according to the methods described by Green and Thorogood [46].

Sampling strategy, participant recruitment and consent

Data was collected from six villages in Limpopo Province, South Africa. Limpopo was chosen as the study area because it is a district with high levels of poverty and where suboptimal water supply is likely to have considerable health impact [47]. It is also a region which is broadly comparable with other poor rural districts of South Africa and other developing countries. The predominant cultural group in the area are the Venda people.

The six villages in the study area were visited on two occasions; over a three-week period in March 2008 and a two-week period in October 2008. The first period was for initial qualitative and quantitative data collection. The second period was to feedback preliminary study findings to participating communities, create an opportunity for community members to comment on the initial interpretation of qualitative data and explore levels of support for future research into water carrying.

The villages were purposively selected to include a range of water service situations and environments which might have different physical effects or expose people to different risk factors for injury or disease. Villages and the water source points within them were chosen to include variations in terrain which might influence methods and effects of water carrying in different ways. For example, many people in one village relied on water sourced from a mountain spring, accessible via steep, slippery and rocky footpaths. Another village, located on a flat plain relied mainly on communal taps accessed via sandy pathways or roads.

Before commencing research, permission for the researchers to work in each village was sought from the 'headman' of each village by the research assistant (RA), a twenty-nine year old Venda male, fluent in several languages including Venda and English and intimately familiar with local customs. All headmen gave verbal permission for the researchers to access their village. Each village was then visited over a period of two to three consecutive days by the principal investigator (JG) and the RA, during which qualitative interview data and quantitative observational data was gathered. Work was ceased in each village when qualitative and quantitative data had been collected from a sample with representation of people with a range of ages, of each gender and with variation in the terrain, type of path and distance over which they walked to collect water. In each village, specific water source points were chosen according to what was available in the village and to include representation in the study of varying water sources (a river, natural springs and communal taps) and infrastructure (e.g. water pumping station overflow pipes or communal taps with differing construction design).

People observed to be intending to collect water were initially approached by the RA and briefly informed in their preferred language of the study purpose and procedures. Those willing to participate were provided with more detailed explanation of the study both verbally and with participant information sheets written in TshiVenda. It was assumed that all participants may have had poor literacy skills as it was not possible to evaluate the literacy level of each participant in the field. Therefore the study purpose and procedures and the request for voluntary participation were fully explained verbally to all participants in their preferred language. Participants were also provided with information and consent forms written in their preferred language and an 'easy to read' version which included graphic illustrations rather than any sections of lengthy text. Both versions of the information and consent forms were translated from English into Venda by the RA and then independently back translated by a local native Venda speaker. The back translation indicated that conceptually accurate and meaningful translation of the documents was achieved.

If informed voluntary consent was granted, consent forms were signed and individuals were recruited to the study. Where children were observed to collect water with an adult relative or guardian, informed signed consent for the child to participate was sought from the adult. Agreement was also sought verbally from the child in a non-coercive manner by the RA, who as a Venda male was sensitive to culturally appropriate ways to interact with the children. Care was taken by the principal investigator and RA to monitor from children's behaviour that they were not adversely affected by participating in the study. No behaviour to indicate that any adverse effects occurred as a result of participation in the study was observed.

Although five children collected water in the company of an adult, eleven collected water without adult supervision. In such instances, the study purpose and procedures were first explained to the children by the RA in a manner appropriate to their age and level of understanding. Once voluntary verbal agreement was obtained from the children, measurements of their weight and height and the weight of filled containers they intended to carry were taken. They were then video recorded and observed while filling containers and carrying water from the collection point to their home. On arrival at the house, a parent or adult guardian was identified through discussion conducted in Venda between the RA, child and adults present. The adult identified in this way as guardian for the child was advised of the study purpose and procedures, and formal written consent for the child's participation sought. This created opportunity for the video capture and observational data to be erased in the event of the parent or guardian not consenting to participation of their child, however, such a situation did not arise.

Of those invited to participate in the study only three declined. Forty-three people were recruited to the study for collection of observational data and/or semi-structured interviews. Four participated in semi-structured interviews (one female child, two women and one man) but were not observed carrying water, leaving a total sample of 39 people from whom observational data was collected (Table 1). Twenty-nine of the people observed carrying water were also participants in semi-structured interviews, purposively chosen to meet the inclusion criteria and ensure representation of males and females with a range of ages from each village (Table 2). Ethical approval for the study was obtained from the International Development Ethics Committee, University of East Anglia, Norwich and the Higher Degrees and Ethics Committee for the Faculty of Health Sciences, University of Johannesburg.

Inclusion and exclusion criteria

To be included in the study, people were:

- Male or female adults or children of any age
- Individuals usually residing within the study villages and providing informed voluntary consent to participate
- Individuals physically carrying or intending to physically carry water containers as part of their usual activities

People were excluded from participation if they:

- had no personal experience of carrying water for domestic use
- were using methods of transporting containers which did not involve them physically carrying the filled water containers from the water source to a home, for example through use of donkey carts or motor vehicles

Data Collection

Demographic data and information on the usual frequency and quantity of water carried was obtained from each participant or their guardian verbally and documented in a recruitment form and structured observation form. Qualitative data reported in this paper was collected through semi-structured interviews according to the methods described by Green and Thorogood

Table 1 Participant demographics all water carrying methods (n: 39)

	Mean (sd)	Minimum	Maximum
Age (years)	25 (15.5)	6	64
Height (cm)	151.49 (17.55)	110	176
Weight (kg)	49.55 (21.74)	16	106
BMI	20.53 (6.32)	13.15	41.41
Female: male	34:5		
Adults (F, M): children (F, M)	(22, 1): (12,4)		
A children: U children	5:11		

F: female; M: male; A: children accompanied by an adult during water carrying; U: children unaccompanied by and adult during water carrying

Table 2 Participant numbers per village and data collection methods

Village (population)	Water system	Alternative water sources	Observed carrying water	Observed carrying water & SSI[1]	Observed carrying water & NGM[2]
1 (2,830)	28 CT[3]	River, mobile water tanker	9	8	1
2 (2,457)	43 CT	Stream or borehole	5	5	0
3 (5,286)	45 CT	River, canal, borehole or pumping station over-flow pipe	13	8	3
4 (1,129)	2 springs	Plastic water tank filled by water tankers	8	6	2
5 & 6 (719)	23 CT	River, spring or borehole	4	1	3

[1]SSI = semi-structured interview; [2]NGM = Informal natural group meeting; [3]Communal Taps

[46]. Participant's verbal accounts, or 'self-report' [48] of their own experiences of water carrying were fully audio-recorded during semi-structured interviews which were conducted in a location chosen by the participants near to or in their own home. The interviews were conducted using open interview guide questions such as 'Can you tell me about your experiences of carrying water?' or 'How do you think carrying water affects you?' to reduce researcher influences on the type of health impacts discussed by participants. The interview discussions were conducted with immediate verbal translation between Venda and English (on one occasion between Pedi and English) performed by the RA, to facilitate communication between the RA, principal investigator and participant. The English questions and the RA's English translation of the participants' responses were fully transcribed.

Quantitative data were gathered from each participant's verbal report in response to a set of structured interview questions, as well as simple measurements and observation. A tape measure was used to measure each participant's height, using a level flat standing-platform and a clipboard placed horizontally on the head to provide level points for measurement. The weight of participants as well as that of the filled water containers they carried was measured in kilograms using bathroom scales and calculated from the mean value of three consecutive weighing scores to reduce measurement error. The principal investigator and RA observed the manner in which participants carried water from the source point to their home. Observations were recorded through video capture, photography and documentation in field notes. Specifically, time taken for the water carrying trip from source to home, body postures adopted during lifting and handling as well as while carrying containers, carrying methods and the environment in which water carrying occurred were captured with video-recording using a Panasonic Mini-DV digital video camera (Model NV-GS320). A GPS unit (Garmin CSX 60) was used to measure the distance (in metres) travelled from the water source to the home in one direction whilst carrying a filled water container.

The modified Borg scale (RPE) [49] was used to gain insight into the intensity of work performed by study participants. The modified Borg scale is a twelve grade category rating scale with ratio properties, which combines verbal and numerical descriptors that can be used to measure a person's rating of their perceived exertion during a specific task [49]. A numeric score of 0 equates to a verbal descriptor of 'nothing at all', 10 to 'very, very strong' and 12 to 'maximal'. It has been validated for used in diverse populations and used with Xhosa speaking women carrying containers of water in a laboratory setting [43]. In this study participants were presented with a printed Venda version of the scale which was verbally explained to them by the RA. They were asked to estimate the sensation of the effort required for carrying water immediately on completion of a water carrying trip and to point to or choose the verbal descriptor or number most closely matching their sensation of effort.

Qualitative and quantitative data collection procedures were piloted in the study area with a Venda speaking woman during and immediately after a water carrying trip. This was done to ensure that interview questions were easily understood and facilitated relevant discussion and that measurement methods to collect quantitative data were feasible for use in the field.

Data Analyses

Quantitative data were entered into SPSS 15.0 and descriptive statistics were generated for all participants observed collecting water and for participants carrying water by head loading (Table 3).

Content analysis of participant responses recorded in 29 semi-structured interview transcripts was used to identify participants complaining of pain in particular body regions and used to calculate the prevalence of spinal pain (defined in this study as self reported head, neck or back pain), back pain and neck pain. It was also used to determine subgroups of participants who did and did not report pain, for comparative statistical analysis of other variables.

Two techniques were used to gain insight into the level or intensity of work which the participants

Table 3 Descriptive statistics for all water carrying methods and for head loaders only

	All water carrying methods				Head loaders only			
	No.	Mean (sd)	Min	Max	No.	Mean (sd)	Min	Max
Distance (m)1	35	330 (178)	40	650	29	337 (190)	40	650
Total weight carried (kg)	33	28.9 (22.8)	4	111				
Container weight (Newtons)					27	191 (60)	39	265
Number of containers carried	39	1.4 (1)	1	5	30	1	1	1
Filled container weight (kg)	33	20.2 (6.7)	4	27.8	27	19.5 (6.1)	4	27
Container Weight/Body Weight (%)	33	58.7 (42.7)	16.3	200.7	27	41.4 (14.6)	16.3	77.8
Carry time per trip (minutes)	37	6 (4)	1	15	29	6 (4)	1	15
TDCT2 minutes	22	18 (13)	1	46	17	18 (13)	1	45
Frequency water collection per/day	24	3.4 (2)	1	8	18	3.4 (2.2)	1	8
Frequency water collection days/week	24	6 (2)	1	7	20	6 (2)	2	7
Rating of Perceived Exertion (RPE)	35	7 (3)	2	10	26	7 (3)	2	10

[1]Distance is reported in meters as that from the water source to the home in one direction whilst carrying a filled water container; [2]TDCT total daily carrying time = observed carrying time multiplied by reported usual daily frequency of water carrying

performed. Firstly, the participants rated their level of perceived exertion using the modified Borg scale. Secondly, the weight of water carried (kg) was calculated as a percentage of body weight for all carrying methods and in Newtons of force (N) for head loading. Force in Newtons (N) is equal to mass (kg) multiplied by gravity (9.8 m/s^2) such that 1 kg is approximately equal to 9.81 N [11]. The force generated by an object of a known weight carried on the head can therefore be calculated using a simple biomechanical model as described by Oatis [50], if the container is assumed to be in static equilibrium. The forces generated during head loading are simplified in this study and assumed to be the force generated purely by the weight of the water and container carried, directed vertically downward onto the head and spine, with no moment arm.

For analyses of the videoed material, the task of collecting and carrying water in containers was divided into four subtasks: 1) preparing and filling, 2) lifting, 3) carrying and 4) lowering and placement of containers. The video material was analysed by a musculoskeletal physiotherapist (JG) with 21 years of experience in the clinical assessment of human movement and musculoskeletal function, including task and postural analysis. The analysis was performed to distinguish between subtasks and for simple visual observation of the whole body postures and movements commonly occurring during water carrying. Specific criteria developed in this study (shown in Additional file 1) to visually identify and record cut-off time points between the subtasks were applied on two separate occasions and the time taken for each subtask calculated twice to minimise simple calculation errors. The two calculated times for each subtask, were then used to generate an average subtask time value for each participant.

Linear regression modelling was used to identify significant correlations between variables and RPE or self reported pain. Information on self-reported pain was drawn from content analysis of transcripts generated from audio recordings of qualitative semi-structured interviews held with 29 participants.

Sub-group analysis was performed on the 21 of 29 interviewed participants who performed water carrying by head loading by grouping those who reported spinal pain and those who did not, as well as participants who reported head/neck pain and those who did not. There were insufficient numbers for sub-group analysis of study participants using other methods of carrying water. Independent t-tests were used to compare the mean values of container weight, distance, carrying time, total daily carrying time (observed carrying time × reported usual daily frequency of water carrying), container weight as a percentage of body weight (CW/BW %) and RPE between the groups.

Results

Methods of carrying water

Three methods of carrying water were observed. These were 1) head loading of water-filled containers (n = 30), 2) rolling a water-filled drum (n = 2) and 3) pushing a wheelbarrow weighted with filled water containers (n = 7). Women most commonly used head loading to carry water, 28 of 34 (82%) females compared to two of five (40%) of males. The two boys observed head loading were walking along steep and rocky pathways.

Potential health impacts of domestic water carrying

Pain was commonly reported as an effect of carrying water in semi-structured interviews. Of the 29 participants, 20 (69%) reported spinal pain, defined in this study as pain reported or indicated through gesture by participants to be in the head, neck, thoracic or lumbosacral region during qualitative interview. Of these 11 (38%) reported back pain and 12 (41%) neck or head pain.

Potential health risk factors

Individual factors

The age range of participants was six to 64 (Table 1). Only women and children (aged 16 or less) were observed carrying water, other than one 18 year old unmarried man. Initial analysis of qualitative data supports that water carrying is usually a woman's task, performed by men only when there are no women or female children available to collect water for them.

> "male wont collect water, female has to collect water, but its not everybody who support the ideas. There are also possibility in other household that you find the male people without girls so those males has to go an collect water' (young girl, informal natural group meeting 8)

Weight of water carried

The most commonly used containers were fully filled 20 to 25 litre plastic buckets or drums (Figure 1). Because of the head loading method, women typically carried one container per trip. However if using a wheelbarrow, people carried up to five containers, so that although the mean individual container weight for all water carrying methods was 20 kg with a maximum of 28 kg, the mean total weight carried was 29 kg, ranging up to 111 kg (Table 2). For all carrying methods, the mean filled container weight as a percentage of body weight was 59%, with a maximum weight transported by wheelbarrow at 200% of body weight (Table 2). For head loading the mean container weight as percentage of body weight value was 41% ranging from 16 to 78% (Table 3).

The mean container weight carried by head loading was 19.5 kg (maximum 27 kg), indicating that due to the weight of water alone, this method generated a mean of 191 Newtons (N) and up to 265N of compressive force through the cervical spine (Table 3). Of the children observed carrying water, older children tended to carry higher container weights and therefore higher loading forces (Figure 2).

Equipment and environmental factors

The containers and carrying equipment were generally in poor condition and not suited to the environment, for example, wheelbarrows to suit adult physical proportions and with completely worn and damaged tyres were used by very young children on sandy pathways. Container sides were smooth and often wet, making them difficult to grasp securely, particularly as they usually had inadequate or absent handles.

The environment presented potential safety hazards and many physical obstacles to lifting and carrying filled water containers. Most participants, including young children, completed part of their journey on a road way. Particularly at non-tap water sources, such as a river or springs, footpaths were narrow and slippery and required walking across uneven sandy and/or rocky ground. For example, sections of one 'footpath' were actually a stream bed coursing down a steep hillside from a natural spring.

> I: 'can you tell me about your experiences of carrying water?'
> T: 'The bad thing might be accidents that happens when you have carried the water and you just hit the road and the stone on the road they have possibility that you might fall with the container on your head, that's something that is very bad by carrying water.' ((T: translated response, participant 2, 39 year old woman; I: interviewer question)
> 'what I can say is that the containers are heavy to me, when it is raining we slip on the way when we come back, we've gotten a problem of the knees when we walk down the hill that its painful, the necks also are painful too, even though you have (gotten) a container on top of the head, the shoulders become painful because they have to lean on that container and it become painful too' (translated response, participant 37, 55 year old woman)

Physical obstacles included barbed wire fences, raised and often worn, jagged edges of concrete platforms at taps (Figure 3), gates, large rocks and pipes as well as other containers, people, equipment and vehicles. Communal taps were most often positioned at a low height and usually required awkward body posture, such as full spinal bending, to lift a filled container up onto the head from ground level. Use of awkward posture was also evident when containers were stored at ground level, or placed inside dwellings with low doorways.

Distance

The mean distance over which water was carried by all water carrying methods was

330 meters and ranged from 40 to 650 meters (Table 3). Of interviewed participants who carried water by head loading, the distance walked by those who reported spinal pain was significantly less than those who did not (173 m 95%CI 2-343; $p = 0.048$; equal variances not assumed) (Table 4). This might represent pain related disability. Preliminary analysis of qualitative data supports that pain may be related to functional disability which may impact on other family members including the ability to carry water, as illustrated in quotes from

Figure 1 Typical container used for carrying water.

adult Venda women who participated in semi-structured interviews.

> 'sometimes it happens that after collecting all eight containers, and filling that big drum its become a problem for her that she couldn't even cook or she couldn't do another work so, she will have to wait for the kids to cook for her and bring some water for her because of what happened just after she collected water' (translated response, participant 10, 33 year old woman)
>
> T: 'the container pressurise my neck as my neck has to hold the head and that container on top, and then by so doing that when the container pressurise me it affect my neck in such a way I feel pain when I just arrive at home... I think it takes a lot of my time because I was supposed to look after these babies making food for them, taking care for the family and also myself rather than to go and collect water, but due to the fact of I have to collect water it takes a lot of my time'
>
> (T: translated response from participant 39, 31 year old mother of five children including four month old triplets; I: interviewer question)
>
> 'yes it does affect me sometimes because when I went to some farming and helping on planting some tomato and chillies I have to come back late afternoon and go and help and collect some water, then my body's painful. I cannot collect more water such as I want to collect so that's another problem that collecting water it's affecting me' (translated response, participant 20, 38 year old woman)

Rating of Perceived Exertion

The RPE score ranged from two to ten with a mean value of seven for water carrying by head loading (Table 3), as well as when all methods were included in the analysis (Table 2). For head loaders, RPE was significantly correlated with container weight ($r = 0.520$; $p = 0.011$) and incline ($r = 0.459$; $p = 0.018$). This suggests that the volume of water carried and environmental factors, particularly the incline or gradient of the path along which water is carried, are likely to influence the physical work of water carrying as indicated by RPE. For head loaders reporting head or neck pain, the differences in weight of water carried (4.6 kg 95%CI -9.7-0.5; $p = 0.069$; equal variances not assumed) and RPE (2.5 95%CI -5.1-0.1; $p = 0.051$; equal variances not assumed) were borderline significant (Table 5).

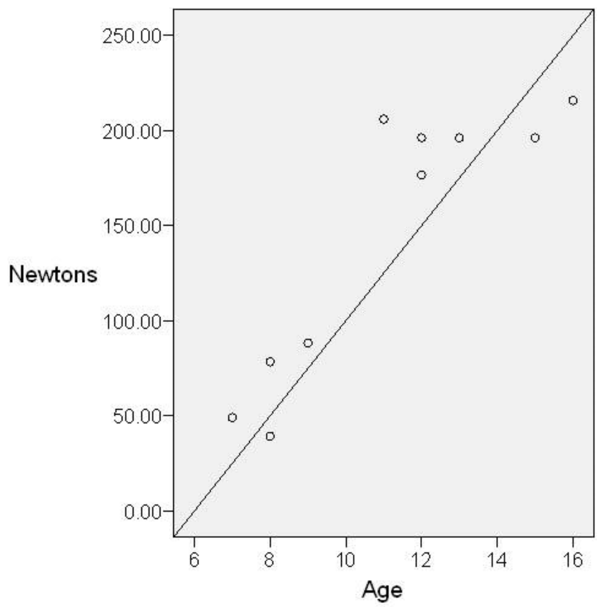

Figure 2 Scatter plot showing a strong correlation between force due to weight of water against age of children head-loading containers.

Discussion

The prevalence of back pain among this mixed group of children and adults, at 38% was higher than that reported in two South African studies included in a recent review [27], and which reported point prevalence for low back pain of 14% for children and 25% for adults. Importantly, we may have underestimated the prevalence of pain in the study sample due to our data collection methods. In keeping with a phenomenological approach, open questions about the health effects of water carrying were asked during semi-structured interviews to capture the potentially varied impacts which people who carry water might perceive the task to have. Participants complaining of pain were identified from their responses to the open interview questions and therefore volunteered pain as a health effect without direct prompting or suggestion that it would be linked to water carrying. In most studies investigating pain, structured outcome measures which directly ask about pain intensity or quality are used. Such direct questions may encourage pain reporting which might not be recalled or mentioned in response to more open interview questions.

Figure 3 Communal tap and concrete surround.

A recent Danish study found that women are more likely to report spinal pain than men [51], therefore it is possible that the high proportion of women in this study, due to their role as water carriers, may explain the high prevalence of self reported pain. However, reasons for a potential association between pain reporting and gender may be different in this study population and are as yet unknown. It may be relevant that women in sub-Saharan Africa are disproportionately affected by HIV disease. HIV is associated with rheumatological conditions such as reactive arthritis [37], osteoporosis, fragility fractures and impaired fracture healing [42] and a high prevalence of pain, linked with significant psychological and functional morbidity [39]. How and why pain is reported will vary in different cultural and social contexts [15] and the relationships between physical, psychological and social influences on pain reporting amongst Venda women have not been determined. Future research should investigate the association between bio-psychosocial factors, co-morbidity and pain reporting amongst women who carry heavy water loads as well as pain impact, through participant ratings of pain intensity, duration, frequency and pain-related disability.

This study supports Cleaver's [52] claim that males more commonly use methods of water carrying which utilise equipment. However, in this study, two boys who used a steep and rocky pathway, which made use of any transportation equipment such as a wheelbarrow impossible, were also observed to carry water containers on their heads. Therefore, environmental factors such as path quality and incline gradient may also determine which carrying methods are used. Generally, this study suggests that women and children carry water and women are more likely to carry water in a way (head loading) which will focus and transmit forces through the cervical spine.

Others have reported load-weight as a percentage of body weight and tested for its association with outcomes such as self reported pain [53]. In the United States Moore et al. [53] concluded that backpack weights for children should remain below 10% of body weight and a recent review reported recommendations from several authors that back pack weights for children should be limited to 10-15% of body weight or less [54]. However conclusions drawn from studies set in high income

Table 4 Subgroup analysis: head loaders with/without report of spinal pain

	Spinal pain	N	Mean (sd)	Std. error	Mean difference (95% CI)	P value
Container weight (kg)	No	4	13.7 (8.5)	4.2	8.2 (-21.4-4.9)	0.146
	Yes	15	22.0 (3.2)	.8		
Distance (m) [1]	No	5	470 (132)	59	173 (2-343)	0.048
	Yes	15	297 (188)	49		
Carrying time (min)	No	5	7 (1)	37.2	2.6 m (10sec-5 m)	0.038
	Yes	15	5 (4)	58.7		
TDCT (min) [2]	No	4	22 (7)	3.5	7.1 (-5.5-19.8)	0.240
	Yes	9	15 (14)	4.5		
CW/BW%	No	4	40 (19)	9.3	2 (-29.6-25.7)	0.856
	Yes	15	42 (15)	3.9		
RPE	No	4	6.2 (4.3)	2.2	1.0 (-7.6-5.6)	0.681
	Yes	15	7.3 (2.6)	0.2		

[1]Distance is reported in meters as that from the water source to the home in one direction whilst carrying a filled water container; [2]TDCT total daily carrying time: equals observed carrying time multiplied by reported usual daily frequency of water carrying; CW/BW%: container weight as a percentage of body weight; RPE: rating of perceived exertion measured with the Modified Borg Scale

countries may not be generalisable to poorer rural communities, where factors such as childhood health, development and general levels and types of physical activity are likely to differ in significant ways. Nevertheless, in comparison, the high container weights in proportion to body weight carried by women and children in this study seem a potential risk factor for self reported pain. A recent South African study found that a large majority of children who collected water and reported that their health had worsened complained of neck or back pain [23].

Compression forces generated purely by the weight of water carried through head loading in this study may be unlikely to exceed tissue tolerances described in cadaveric studies [30,36,55,56], if applied briefly during a single loading occasion. Older children tended to carry heavier loads than the younger children in the study and their tolerance limits may be closer to those of adults. However, injury tolerance limits based on cadaver studies can only provide estimates of living tissue strength [31] which may be reduced by factors such as malnutrition or chronic illness [57], both of which are highly prevalent in poor rural areas [58] such as can be found in Limpopo Province. In particular, individuals living with HIV disease may suffer from osteopenia and are known to be more at risk of fragility fractures and delayed

Table 5 Subgroup analysis: head loaders with/without report of head or neck pain

	Head or neck pain	N	Mean (sd)	Std. error	Mean difference (95% CI)	P value (2 tailed)
Container weight (kg)	No	10	18.06 (6.5)	2.05	4.61 (-9.72-0.49)	0.069
	Yes	9	22.68 (3.4)	1.14		
Distance (m)	No	12	334 (209)	60.3	15.8 (-19.4-16.2)	0.854
	Yes	8	350 (167)	59.2		
Carrying time (min)	No	11	6 (3)	0.9	12.7 sec (-3.4-3.8m)	0.901
	Yes	9	5 (4)	1.4		
TDCT (min)	No	7	17 (12)	4.4	0.16 (-16.1-15.8)	0.983
	Yes	6	17 (14)	5.6		
CW/BW%	No	10	39 (15)	4.8	5.6 (-20.7-9.6)	0.448
	yes	9	45 (16)	5.3		
RPE	No	11	6.0 (3)	0.9	2.5 (-5.1-0.1)	0.051
	Yes	8	8.5 (2)	0.8		

[1]Distance is reported in meters as that from the water source to the home in one direction whilst carrying a filled water container; [2]TDCT total daily carrying time: equals observed carrying time multiplied by reported usual daily frequency of water carrying; CW/BW%: container weight as a percentage of body weight; RPE: rating of perceived exertion measured with the Modified Borg Scale

fracture healing [42] and may therefore be vulnerable to injury from regular compressive loading through the cervical spine.

Frequent loading beyond capacity for adaptation or repair may also lead to early degenerative changes in bone and soft tissues [12]. A threshold of 250 Newtons of sustained cyclic loading (15% of failure stress, approximately 6MPa) applied to articular cartilage in vitro has been reported as a threshold above which cell death occurs and increases in proportion to the applied load [59]. Cell death in mature cartilage can lead to degradation of the tissue and is associated with onset of osteoarthritis [59]. Although the actual forces sustained by the cervical spine during water carrying have not been directly quantified, this study indicates that they are likely to exceed 250 Newtons for many individuals, when the weight of the head and effects of muscle contraction are added to the weight of water carried. Whilst pain, stiffness and functional impairment are clinical features of osteoarthritis, the correlation between symptoms such as pain and radio-graphically observed degenerative changes is not clearly established. Therefore future research should investigate the relationships between loading intensity, frequency and duration, history of physical loading exposure and symptoms such as neck or back pain and functional disability, rather than radiographic examination findings alone.

Guidance on good manual handling techniques for safety when pushing loads in high income countries suggest that worn wheelbarrow tyres and lack of grip padding on various types of equipment can increase the work of pushing and affect grip force and comfort [60,61]. This can be particularly plausible on sandy pathways such as those along which water was frequently carried by the participants in this study. Water is also an inherently unwieldy load, which moves within the containers during handling. Although the participants had clearly developed skills to lift and balance containers, maintenance of a secure grip would be difficult during sudden or unexpected posture changes, as might occur when walking along routes shared with vehicles and domestic animals.

Sudden or unexpected posture changes may lead to injury through generation of high peak compressive forces. These can occur due to muscle action on the spine [11] which in the cervical region is required to support the weight of the head and loads applied to it to prevent spinal buckling [62,63]. Rapidly or awkwardly lifting objects or accidents during manual handling can generate peak compressive forces higher than injury threshold, but may also create torsional, shear or bending moments which injure the spine if it is inadequately stabilised [11]. Hazards for slips, trips and falls include wet and uneven surfaces, obstacles, exposure to traffic, poor equipment and unwieldy loads [64,65], all of which were typical environmental and task related factors of domestic water carrying.

Distance walked between water source points and the home may be a useful indicator of exposure time to sustained compressive loading. As the distance walked by those who reported spinal pain was significantly less than those who did not, our results might indicate pain-related disability. People with spinal pain may experience difficulty carrying water over distance and be more likely to enlist the help of other family members and children, or continue to carry water only if it is accessible close to home. Such functional disability may have further implications for families, for example, by leading to a reduction in the usual volumes of water collected for household use to support health and adequate hygiene.

Our study suggests that the volume of water carried and environmental factors, particularly the incline or gradient of the path along which water is carried are likely to influence the physical work of water carrying as indicated by RPE. It also suggests that people reporting neck or head pain may be those who carry heavier containers and also perceive the task to be more difficult, as for head-loaders reporting head or neck pain, the differences in weight of water carried and RPE were almost statistically significant. Distance walked whilst carrying water, volume of water carried and path gradient are therefore important quantifiable factors which might be useful to indicate the physical work load of water carrying.

Conclusions

This study has highlighted the potential association between spinal pain and water carrying in South Africa. This association is complex with water carrying probably contributing to the aetiology of spinal pain and spinal pain interfering with people's ability to carry water with potential impact on household water availability. Typical methods of carrying water containers as observed in this study impose physical loading with potential to produce symptoms typical of musculoskeletal disorders and related disability. Risk of musculoskeletal injury or pain may be high as it is usually a task for women and children, including those who may be affected by chronic poor health, and is often performed with inadequate equipment in potentially hazardous environments. Water carrying is not the only manual work performed by women and children in lower income countries and future research should also investigate the additional burden from other physical tasks.

Carrying distance could be used together with total volume or weight of water carried and path gradient to indicate the level of physical work imposed by water carrying. These factors together with the modified Borg scale and water carrying method should be investigated in future research, to better understand the type and strength of association between water carrying and health, particularly symptoms typical of musculoskeletal disorders such as pain and related disability. Identifying risk factors for musculoskeletal disorders and pain related to water carrying may also highlight appropriate interventions to reduce risk exposure.

Despite the small study size and associated lack of power, our preliminary findings still highlight the potential impact that carrying water may have on health, in particular through the effects of symptoms typical of musculoskeletal disorders, such as neck or back pain, and related functional disability. This is an important but neglected public health issue. There is a need for more research on the impact of water carrying on neck and back pain and how such pain impacts on the water carriers lives. There is also a need for research into how water can be carried in a way that reduces the potential for adverse im.pacts on musculoskeletal health.

Additional material

Additional file 1: Criteria for identifying work phases. Criteria used for identifying duration of work phases from observation of video material.

Abbreviations

RPE: Rating of Perceived Exertion; kg: kilograms; m: metre; RA: Research Assistant; GPS: Global Positioning System; SPSS 15.0: Statistical Package for the Social Sciences version 15.0; N: Newtons of force; m/s^2: metre per second squared; CW/BW%: Container Weight to Body Weight percentage; HIV: Human Immunodeficiency Virus.

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Authors' contributions

JG conceived of the study and its design, collected, analysed and interpreted the data and drafted the manuscript. PH contributed to conception of the study, performed statistical analyses, participated in interpretation of the data and helped to draft the manuscript. PJ participated in the study conception, design and coordination, interpretation of data and helped draft the manuscript. All authors read, critically revised and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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Appendix 7. Published paper

GEERE, J. L., MOKOENA, M. M., JAGALS, P., POLAND, F. & HARTLEY, S. 2010b. How do children perceive health to be affected by domestic water carrying? Qualitative findings from a mixed methods study in rural South Africa. *Child: care, health and development,* 36**,** 818-826.

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How do children perceive health to be affected by domestic water carrying? Qualitative findings from a mixed methods study in rural South Africa

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Africa, child health, ICF, musculoskeletal, qualitative research, water

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Abstract

Background Nearly 50% of South African children lack access to clean safe water and many regularly carry water loads. The health effects of carrying water have not been well researched or considered when estimating the burden of disease due to suboptimal water supply. Improved access to safe water has potential to create important health and economic benefits, by reducing childhood exposure to risk factors for injury or disease. The aim of this study was to identify which domains of health children perceive as affected by water carrying.

Methods Qualitative research was used within a broader mixed methods design to investigate children's perceptions about health and water carrying in Limpopo Province, South Africa. Qualitative data from eight semi-structured interviews and three 'natural group meetings', involving a sample of 30 children, were analysed using the framework approach of Ritchie and Spencer. The results were mapped to the International Classification of Functioning Disability and Health (ICF).

Results Children broadly conceptualize and describe health to include the functions they perform and activities in which they participate. They perceived water carrying as impacting upon health in various ways, for example to make life better by facilitating water usage, or to make life worse through accidents and pain. Children's accounts demonstrate that they can identify and explain complex interactions between activities, participation and health.

Conclusions The ICF framework facilitates the communication of children's perceptions of health and of relationships between health and water carrying. The model thus derived from their views incorporates not only commonly accepted conceptualizations of health condition, body structure and physiological function, but also of functioning through activities and social participation. Children's accounts suggest a possible association between water carrying and symptoms typical of musculoskeletal disorders. However, further research into the strength of association between water carrying and musculoskeletal disorders is needed.

Introduction

Limited access to safe water disproportionately affects children in developing countries, accounting for more than 20% of deaths and disability-adjusted life years in children up to 14 years of age (Prüss-Üstün *et al.* 2008). In South Africa, the health of poor children is declining and is profoundly affected by their living conditions, with nearly 50% of children living in

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poor rural areas which lack access to safe water (Kingi *et al.* 2006).

The disease burden from limited access to safe water may be underestimated by the predominant research focus on acute diarrhoeal disease (Clasen *et al.* 2007; Haller *et al.* 2007) with a concomitant lack of focus on the broader health effects of carrying water (Cleaver *et al.* 2005; Hemson 2007). Women and children frequently carry water by head-loading containers (Crow 2001). Head loading has been observed to cause death or paraplegia (Levy 1968) and has been linked to early degenerative changes in the cervical spine (Joosab *et al.* 1994; Jager *et al.* 1997). There is also strong evidence that manually handling loads is associated with musculoskeletal disorders (Adams *et al.* 2002).

Water carrying is defined in this study as any method of transporting water for domestic use, on or by a person, from a source outside of the home. Children may be particularly affected by the task, as they have lower tolerance limits for physical stress (Nuckley *et al.* 2007) and greater risk of injury with exposure to environmental hazards (Briggs 2003). However, the health effects of carrying water may be complex and manifest in ways other than through musculoskeletal impairment. For example, carrying water may affect health through reducing time for income generation or education (Haller *et al.* 2007). Alternatively, it may lead to beneficial health effects from regular physical activity (Bergman 2007) or engagement with culturally appropriate roles. A broad conceptualization of 'health', functioning and disability may be necessary to fully appreciate how carrying water might impact upon children.

The International Classification of Functioning, Disability and Health (ICF) provides a coherent view of different perspectives of functioning and disability in relation to health and a common language through which to communicate ideas (WHO 2001). It broadly categorizes functioning in relation to health at the levels of body structure and functioning, engagement with activities and social participation all within specific contextual environments (WHO 2001). The ICF is legally binding as an information standard and has been ratified by 192 countries worldwide including South Africa. Therefore coding and mapping children's perceptions about the effects of carrying water to ICF categories is seen as a strategy to promote clear identification and communication about the health domains potentially affected by the task.

The aim of this study was to identify which domains of child health, in relation to the ICF, are potentially affected by carrying water. Children who regularly carry water will have varied experiences and unique insight into how the task affects them. Children have been shown to be competent reporters of physical disability (Young *et al.* 1995) and may also be able to convey their experiences of the relationship between other aspects of health and their activities. The views of children with experience of water carrying were therefore considered important perspectives from which to identify the domains of health potentially affected by the task. The specific research questions which this study sought to answer through qualitative enquiry and are discussed in this paper are

1 Which domains of health are perceived by children to be affected by carrying water?
2 Do children perceive that carrying water should change?

Methods

Qualitative and quantitative research methods were used to gather data from adults and children. This report will present the findings of qualitative data collected from children through individual and group interviews. Quantitative data collected through simple physical measurements and observation will be reported elsewhere; however, Figs 1–3 are included to illustrate the environmental context and methods of water carrying which children discussed.

Sampling, recruitment and consent

Limpopo province was chosen as the study area because it is a region with high levels of poverty and where sub-optimal water

Figure 1. Head-loading water container and pushing a wheelbarrow: 'the head was painful, I mean my neck was painful' (girl, group meeting 8).

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Figure 2. Rolling a water container: 'when I'm pushing the drum I feel the pain on my muscle of my hand' (8-year-old boy).

Figure 3. Water carrying with donkey cart: 'I've done a little bit of exercise by carrying the container from the bottom and put on top of the donkey cart so I am feeling happy' (boy, group meeting 7).

supply may have considerable health impact (Hope & Gowing 2003). The predominant cultural group in the area are the Venda people.

Six villages were purposively selected to include a range of water service situations and environmental factors which might influence water carrying. They were chosen to reflect variations in terrain (for example some pathways were steep, rocky, wet and slippery, while others were flat and sandy) and the variety of water sources in the villages, such as rivers, communal taps or protected springs. Differences in such environmental factors are likely to influence the methods and work of carrying water and may result in different experiences and perceptions of the health impact of the task.

Prior to data collection, the research assistant (RA), met with each village headman to inform him of the study purpose and methods. The principal investigator (PI), RA and field research supervisor then met with each headman and sought verbal permission to access their village. Each village was visited over two to three consecutive days.

Participant recruitment was from a convenience sample of people who were intending to collect water when the researchers visited specific water source points. From the convenience sample, individuals were purposively selected to have representation of both boys and girls with a range of ages, using different water carrying methods (Figs 1–3). Such factors are likely to influence physical capacity for work (Kumaresan *et al.* 2001; Nordander *et al.* 2008) and therefore experiences of the health impact of the task. Participant inclusion criteria were current or past personal experience of carrying water and informed voluntary consent to participate. Exclusion criteria were having no experience of carrying water and refusal to participate.

Of 35 children invited to participate in the study, three declined. When children were collecting water with an adult, consent for the child to participate was sought from the adult. Following brief explanation of the study, those who expressed interest were provided with a participant information form written and verbally explained in Venda. Participant information and consent forms were developed in English, translated to Venda and back-translated by a second native Venda speaker from the study area. Individuals who consented were recruited and their demographic information was entered onto a recruitment form.

Children collecting water were often unaccompanied by an adult. In such circumstances, the study purpose and procedures were explained in a manner appropriate to their level of understanding. Voluntary, non-coercive agreement was sought verbally from each child, taking care to monitor the child's behaviour initially and throughout the encounter to check that they were not adversely affected by participation. On arrival at their home, a parent or adult guardian was advised of the study purpose and procedures and consent for the child's participation sought.

We used opportunistic recruitment of children to 'natural group meetings' as described by Green and Thorogood (2004). Groups of children already gathered together were invited to participate when it was observed that the group included children with a different age range and gender mix from previous group meetings. Adults in the vicinity were informed of the

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study purposes and procedures. It was made clear that group members were free to express their views, did not have to offer comments and remained free to withdraw from participation at any time. Additional children were free to join the groups during the discussion. Verbal consent to participate was obtained. To maintain confidentiality, children were not identified by name during the meeting and recorded discussion.

Table 1. Children interviewed individually and in group meetings ($n = 19$)

Variable	Frequency (%)
Age: mean (SD; range)	11 (3; 6–16)
Female gender	13 (68)
Attends school	18 (95)
TshiVenda preferred language	19 (100)
Carry method: head loading	10 (53)
Carry method: wheel barrow	2 (10)
Carry method: rolling container	2 (10)
Carry method: donkey cart	4 (21)

Demographic data were collected from 19 of 32 participants.
Frequency count and percentage unless otherwise stated.
Carry method information missing for one child.

Ethics

Ethical approval for the study was obtained from the International Development Ethics Committee, University of East Anglia, Norwich and the Ethics Committee for the Faculty of Health Sciences, University of Johannesburg. Participation was voluntary. However, participants were potentially vulnerable because of age, limited formal education and variable literacy skills and may have felt obliged to participate in the study for a variety of reasons. Therefore, participants were informed that they were entitled to withdraw consent and cease participation at any point without consequence.

The researchers were sensitive to cultural norms and expectations in relation to the topics discussed. Care was taken to avoid raising expectations for change or advising against performing particular tasks, which might disrupt or be at odds with cultural norms. Data collection was conducted at a time convenient to participants to minimize disruption to usual activities. Participants were assigned a number upon recruitment to the study, thereby preserving participant anonymity in records of data. All data are securely stored with access only granted to members of the research team.

Data collection and analysis

Individual semi-structured interviews were conducted with 10 children. Three 'natural group meetings' as described by Green and Thorogood (2004), with a combined total of 22 participants, were also conducted. This gave a total initial sample size of 32 children. Demographic data were collected from the 10 children who were interviewed individually and nine of the children who participated in group meetings and were also observed carrying water (Table 1). However, detailed demographic data were not collected from 13 additional children who joined the group meetings. This approach was used to encourage participation and maintain an informal atmosphere, but avoid disruption of conversation and keep discussion focussed on relevant topics when individuals joined the groups.

All of the 10 semi-structured interviews and three natural group meetings were audio-recorded and conducted with immediate translation between the PI, RA and participants. For all interviews, the English questions and RA's immediate English translation of participant responses were fully transcribed by the PI. After transcription and initial analysis, two semi-structured interview recordings were excluded from further analysis, as in each case, the child being interviewed offered minimal verbal responses to the interview questions, indicating refusal to participate. The final sample therefore included data from 30 children; eight who participated in individual interviews and 22 who participated in one of the three group interviews.

These methods of data collection provided two separate sources of data, the individual interviews giving an opportunity for in-depth exploration of issues, ideas and perception and the natural groups meetings maximizing participation between researchers and participants (Green & Thorogood 2004). Interview guide questions were developed in English, translated into Venda, back-translated and piloted in the study area. They were modified in response to piloting and discussion with the RA, a 29-year-old Venda man with tertiary level education, fluent in English and Venda, with experience of verbal and written translation work for social and scientific research projects. Two semi-structured interview recordings were fully translated and transcribed by a second, independent translator.

For the eight individual interview transcripts and the three group meeting transcripts, thematic content analysis was manually performed drawing on 'framework' analysis methods of Ritchie and Spencer (1999). All transcript data were independently coded into units of meaning by two researchers, who then compared interpretation of the data and agreed the final coding strategy. Codes with similar meanings were categorized together to generate sub-themes and sub-themes were considered in light of the original research questions to generate themes. Data from individual interviews were triangulated with that from group interviews.

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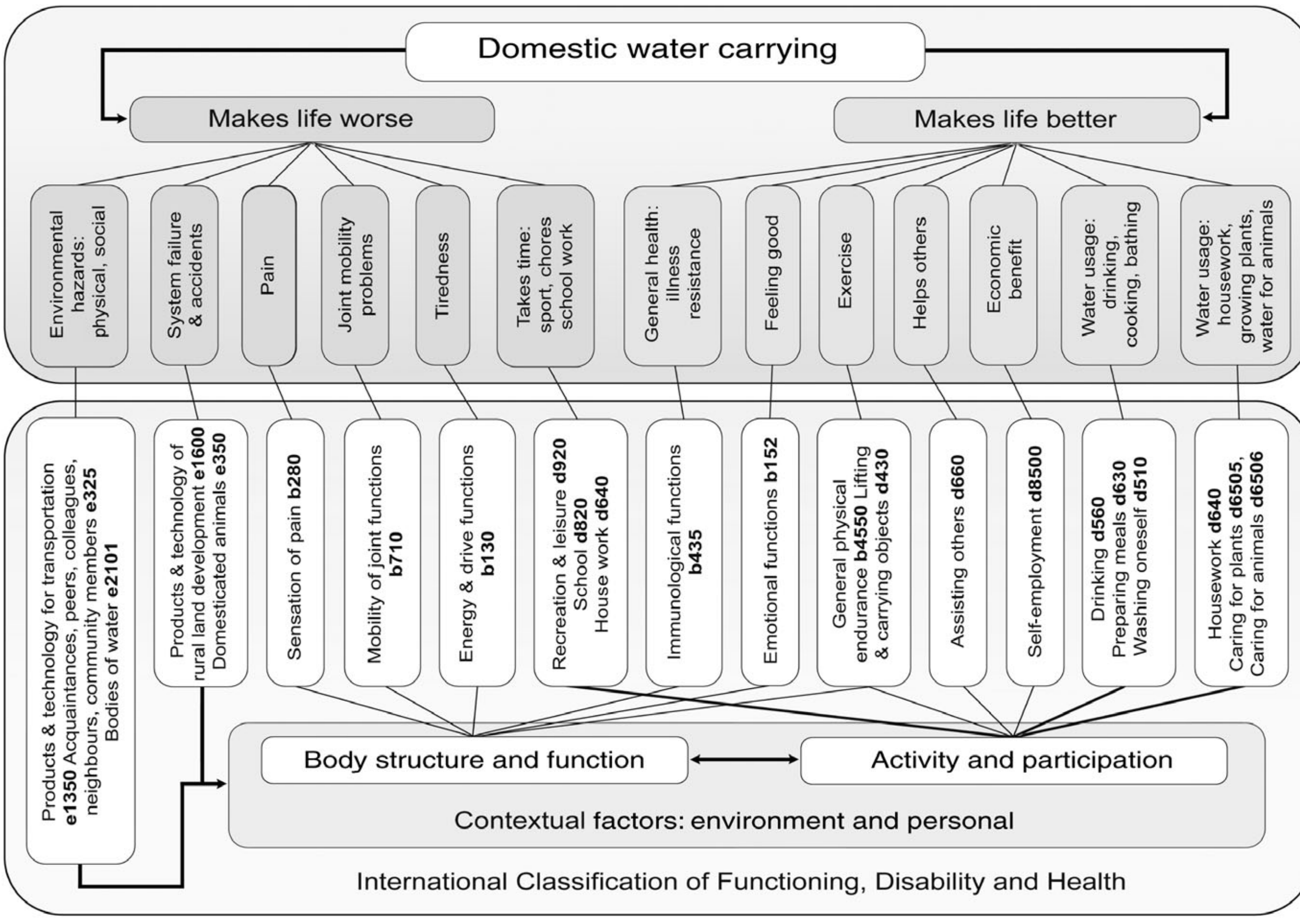

Figure 4. The potential relationships between water carrying and health.

Results

A key theme, drawn from the data and relevant to the first research question, is that children perceived water carrying to affect health and health-related quality of life in various ways, which can be mapped to the categories of the ICF (Fig. 4). The model is *not* intended to depict a quantitative comparison of whether water carrying has a more 'positive' or more 'negative' effect on health, but rather to illustrate the variety of health impacts which it might have. The main upper box of the model represents conclusions drawn from qualitative data in this study. The main lower box represents the ICF. Codes derived from qualitative data and related ICF categories are contained in smaller boxes, with similar items grouped together in some boxes for clarity. The model highlights how water carrying might influence health through effects on functioning.

Children's perceptions of health encompassed a broad variety of conceptual and experiential domains (Table 2). For example, when asked to explain what 'being healthy or unhealthy' meant to them, children related 'health' to feelings, physique and capacity for activities. Children also raised issues of fair workloads and meeting basic needs. The model in Fig. 5 therefore represents 'Health', comprising varied domains found to be relevant to children in Limpopo Province. Lines adjacent to each sphere represent a continuum between different potential states within the domain. For instance, one child used having 'flu or cold' as the explanation for being 'unhealthy', which may be located somewhere between 'absence of infectious disease' and 'presence of severe life threatening or chronic illness'.

Children's talk highlighted a wide variety of potentially positive and negative impacts of carrying water (Tables 3 & 4). Their accounts also revealed that children can perceive the effects of water carrying to be inter-related and complex. For example one child described links between good health, exercise and mood to explain relationships between water carrying and health

Table 2. Domains of children's perceptions of health

Health is related to:	Interview and group meeting evidence
Activity	I: 'does anyone else have any ideas of what it means to be healthy, what its like?' T: 'by collecting water' (NGM 9, f.ch)
Feelings and emotions	I: 'what does it mean if someone is a healthy person?' T: 'I think it's when somebody is happy and then having a joyful life like sometimes you can just sing on the road when you are walking' (PT12, 12yo boy)
Physique	T: 'the good body size shape that's what she think is a healthy person' (PT11, 14yo girl)
Fair workload	T: 'yeah they don't have much to do, we as the girls we need to clean the house make some cooking and see that the house is made but they don't have much to do so we need to give them job to collect some water' (NGM 7, f.ch)
Meeting basic needs	T: 'somebody who is being abused by not being given proper clothes, without given a proper food to eat, a healthy food for himself or herself, then I can say that particular person is not healthy' (NGM 9, f.ch)
Illness	I: 'what's it like when someone's unhealthy or sick?' T: '. . . it's when a person has got a flu or a cold' (NGM 9, m.ch)

f.ch: female child; I: interviewer's question; m.ch: male child; NGM: natural group meeting; PT: participant number; T: translated response of child; yo: year old.

Table 3. Negative effects of water carrying

Effect	Interview and group meeting evidence
Pain	T: '. . . the problem is that it's painful one. It (carrying water) can make my body strong but painful' (PT11, 14yo girl)
Tiredness	T: 'when you collect water from the tap you get tired by collecting water' (PT12, 12yo boy)
Joint mobility problems	T: 'our shoulder together with the neck' I: 'and what is the feeling? Does it just feel like muscles working or is it pain or anything else?' T: 'it's the pain and a feeling like its moving, ah its moving outside' (NGM 9, f.ch)
Takes up time	I: 'if they didn't have to carry water, what would they do instead?' T: 'cleaning the dishes' T: 'ah cleaning the floor of the house' T: 'playing' T: 'making some decoration with the cattle dung around the household' (NGM 9 m & f children)
Causes accidents or injury	I: '. . . can carrying water make life worse?' T: 'you might as well ah hit the stone while you carrying a container on the head and fall down' (NGM 9, f.ch)

f.ch: female child; I: interviewer's question; m.ch: male child; NGM: natural group meeting; PT: participant number; T: translated response of child; yo: year old.

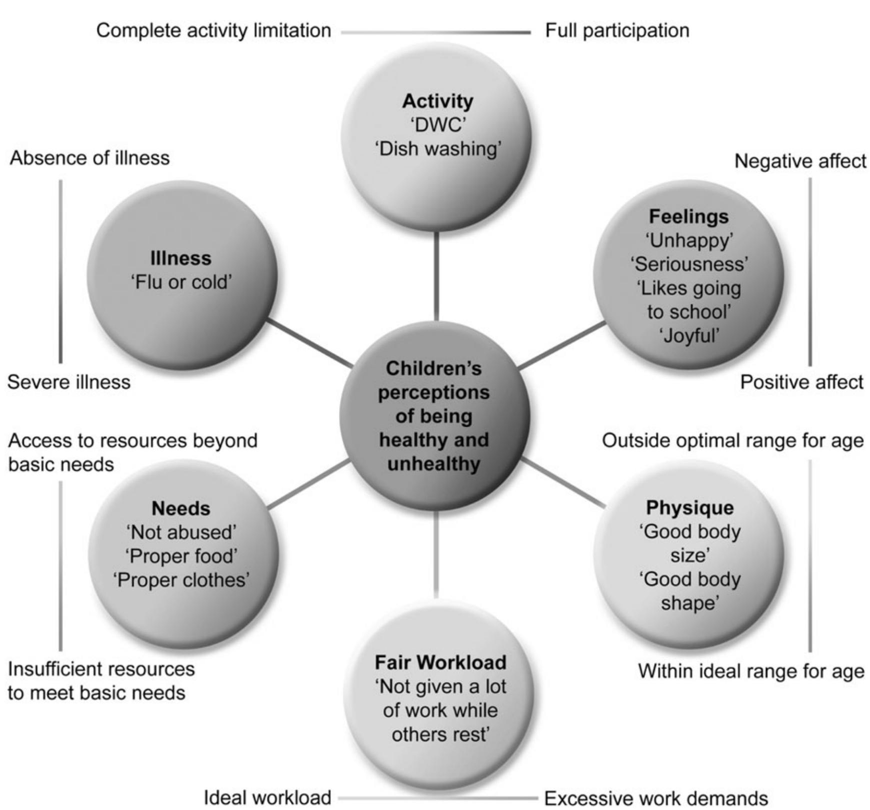

Figure 5. Children's perceptions of being healthy and unhealthy. DWC, domestic water carrying.

Table 4. Positive effects of water carrying

Effect	Interview and group meeting evidence
Improves health	T: 'I think I will be fit enough in such a way I cannot be targeted by different kind of diseases like an flu' (PT12, 12yo boy)
Feeling good	T: 'we feel better and healthy' I: 'in what way?' T: 'I think my body will be healthy because sometimes I've done a little bit of exercise by carrying the container from the bottom and put on top of the donkey cart so I am feeling happy' (NGM 7, m.ch)
Helps others	T: 'it help my household because the water that I collected does help to make a laundry for the kids' (PT41, 11yo girl)
Meets basic needs	T: 'they will make us to have enough water to bath, secondly to drink and also to help our sisters so that they cook and clean the yard and the household and also do their laundries, he included both first answers for him and for the family as a whole' (NGM 7, m.ch)
Economic benefit and food growth	I: 'we also get a bit of money by collecting water to the people' (NGM 7, m.ch) T: 'I like to water my tree' I: 'and why does he like to water his tree?' T: 'because we get some fruit out of that tree' (PT12, 12yo boy)

f.ch: female child; I: interviewer's question; m.ch: male child; NGM: natural group meeting; PT: participant number; T: translated response of child; yo: year old.

Table 5. Changing domestic water carrying

Change	Interview and group meeting evidence
Reduce distance	T: 'sometimes by reducing the distance where we collect water' and 'its when the people if the pipe, the standpipe has been brought closer or inside the yard' (PT11, 14yo girl)
Improve pathway	T: 'I think if they can clean up the road which we use to walk to the water station' (NGM 9, f.ch)
Outcomes	T: 'secondly as myself I won't have any pain like what I used to feel before because I will be collecting water at a closer place' (NGM 8, f.ch) T: 'no longer going to collect water because the water will be closer' (PT8, 7yo boy) T: 'I think after I have the water in the yard and then I can start planting the crops and many people will see that there is a different because crops will be there and they have to come and buy it, that will help me to have some money for trip where ever I want to go with my school or who so ever is taking me out I can buy, pay for some trip' (PT12, 12yo boy) I: 'is there anything else you think you would notice as a difference?' T: 'we can wash in our household and do laundries in the household' I: 'o.k. where do they normally wash?' T: 'the river' (PT41, 11yo girl)

f.ch: female child; I: interviewer's question; m.ch: male child; NGM: natural group meeting; PT: participant number; T: translated response of child; yo: year old.

('feeling good' Table 4). Another explained the co-existence of both positive and negative effects ('pain' Table 3).

With respect to the second research question, children indicated that it is important and desirable to improve access to water, mainly by reducing the distance over which water is carried and supplying water directly to homes (Table 5). They also talked about a range of expected consequences of the changes they suggested, including reduced pain, economic benefit, food growth and changes to activities.

Discussion

Health is now widely acknowledged to be multi-dimensional, incorporating physical health, mental health, general perception of wellbeing, activities and social functioning (Ware 1987). The children's perceptions of health are concordant with such a view; in their discussions children linked health to capacity for activities and social participation as well as to body functions and structure. This indicates that the health status of children in poor rural areas such as Limpopo should not only be evaluated in terms of disease and impaired body structure and function, but also in terms of functioning through activities and social participation in specific contexts. This is also in concordance with 'disablement' as defined by the ICF.

An important property of well-designed health evaluation systems is that the content assessed should include elements that the target population perceive as relevant and important to their health and health-related quality of life (Atkinson & Lennox 2006). We therefore used the perceptions of children who carry water as the first step in identifying which domains of health are important to them and worthy of further investigation in relation to water carrying. The findings of this study suggest that to assess the health impact of carrying water on children in rural areas such as Limpopo, the domains detailed in Fig. 4 should be evaluated. At the level of body functions children perceive that pain, joint mobility, energy and drive, general physical endurance, immunological and emotional functions can be affected. In terms of activity and participation, their accounts indicate that schoolwork, housework and leisure activities can be affected by water carrying, particularly through time loss. Key ways in which collecting water was perceived to improve health-related quality of life were by facilitating water usage or generating income, so that the impact of water carrying

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on meeting basic needs for cooking, drinking and washing should be considered as well as activities such as caring for plants and animals.

Children linked pain and joint mobility problems to carrying water, indicating that they perceive them to be important effects. This suggests that the task might be associated with these typical symptoms of musculoskeletal disorders. Recent reviews suggest that the prevalence of musculoskeletal disorders in less developed countries is rising and recommend that research into effective prevention and management is needed (Woolf 2003; Louw *et al.* 2007). There is recognition that the underlying causes of work- or task-related musculoskeletal disorders should be investigated and action taken to prevent them (Buckle 2005) and that ergonomic type interventions can be effective to reduce both exposure to risk factors and the prevalence of musculoskeletal disorders (Schierhout *et al.* 1995), particularly where exposures are high (Buckle & Devereux 2002). Studies have also suggested that childhood reports of pain should be investigated as there may be an association between them and the development of musculoskeletal disorders in adults (Harreby *et al.* 1997; Leboeuf-Yde & Kyvik 1998). While the findings of this study suggest a potential relationship between water carrying and symptoms of musculoskeletal disorders such as pain and movement dysfunction, the children's perspectives should be considered along with adult perspectives and observational data. Further research is required to determine whether water carrying during childhood is associated with the development of chronic or recurrent musculoskeletal disorders and the extent of any related disability.

Children expressed clear expectations that reducing the distance over which water is carried would bring about changes to which they attach importance, such as reducing pain and tiredness, increasing time for alternative activities, increasing food production and economic benefit. A key recommendation, drawn from their accounts, is that efforts should be directed towards eliminating the need for water carrying by providing piped water to houses or yards, or, where it must continue, reducing the distance and frequency of the task. Improved maintenance of infrastructure, equipment and access paths may be important avenues for interventions to improve water access. Children did not discuss ergonomic interventions such as improved communal tap design. However, such ideas may be beyond the scope of their experiences, or might not be easily expressed by them in an interview situation. Measures to reduce potentially detrimental effects of carrying water are at the same time likely to maintain or increase the beneficial health effects, as benefits are mainly realized through water usage.

The potential influence of the researchers on data collection and translation is acknowledged. Approaches described by Birbili (2000) were taken to address problems of cross-cultural communication. The RA was from the study region, with proficient understanding of Venda language and culture and linguistic issues important to data collection and interpretation. Independent translations of two interview transcripts suggest that the RA was able to accurately convey children's responses. We therefore have confidence that the English transcripts accurately represent children's responses to interview questions.

Key messages

- Children perceive carrying water to affect their health in various ways, which can be mapped to the International Classification of Functioning, Disability and Health domains.
- The health status of children in poor rural areas such as Limpopo should not only be evaluated in terms of body structure and function, but also in terms of functioning through activities and social participation.
- There may be an association between water carrying during childhood and symptoms typical of musculoskeletal disorders, which requires further research to understand the type and strength of association and the extent of any related disability.

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Appendix 8. Published paper

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Factors that impact on access to water and sanitation for older adults and people with disability in rural South Africa: An occupational justice perspective

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Factors that impact on access to water and sanitation for older adults and people with disability in rural South Africa: An occupational justice perspective

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ABSTRACT

Limited access to water and sanitation is a risk to health, dignity, and ability to engage in occupations. This article aims to: 1) discuss the current and historical factors affecting access to water and sanitation in rural South Africa, and 2) explore the occupational implications of water access, particularly for older adults and people with disability in rural South Africa. A literature review was carried out through searching JSTOR, Scopus, and MEDLINE databases and using framework analysis to interpret the retrieved documents. This paper also reports a thematic analysis of semi-structured interviews, conducted in 2012 in a rural area of South Africa. Environmental, political, social-economic and attitudinal factors were identified as impacting water access and occupation, in both the documentary analysis and the semi-structured interviews. Due to South Africa's history, injustice has occurred in the forms of occupational apartheid and occupational deprivation. We argue that supply systems must enable people to easily access more water than is essential for survival, so that people can participate in meaningful and productive occupations. Therefore, access to water should be considered part of an occupational right. Recognising this right will be an integral step in ensuring that water supplies are improved to support better livelihoods, and to achieve economic and social empowerment, and quality of life for all, in line with many of the United Nations' new Sustainable Development Goals.

ARTICLE HISTORY
Accepted 9 April 2017

KEYWORDS
Water; Sanitation; Disability; Older adults; History; Occupational justice

Although the United Nation's (2015) Millennium Development Goals have been hailed as "the most successful anti-poverty movement in history" (p. 3), progress has been uneven and inequalities endure. The United Nations (2015) reported that the Millennium Development Goal target 7c, which aimed to halve the proportion of the global population without sustainable access to safe drinking water, was met 5 years ahead of schedule. 'Safe' drinking water is water obtained from a source considered unlikely to be contaminated with faeces or other pollutants (UNICEF & WHO, 2015). However, even with this achievement, in 2015 the global population who access unsafe drinking water is approximately 663 million people (UNICEF & WHO, 2015). Particularly in sub-Saharan Africa, most of those who access unsafe water, together with many of those whose water supply is 'safe', must still carry their water home from off-plot sources (Evans et al., 2013; UNICEF & WHO, 2015).

The South African government have defined the acceptable basic level of service of safe

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drinking water to be a piped water supply to within 200 meters of a dwelling (African Ministers' Council on Water, 2011) and in 2013 it reported that 85.9% of households had access to piped water supplies (StatsSA, 2014). That water standard was experienced during apartheid and has continued in the current era (Department of Water Affairs, 1994, 2005), however Majuru, Jagals, and Hunter (2012) indicated that the actual round trip distance to water points in rural areas of South Africa can be 600 meters or more. Within this high level of 'coverage' or access to piped water, the minimum standard allows inclusion of households in which people must still carry water home from the supply or access point, with 15.2% of households relying on water from communal taps, 2.6% from neighbour's taps, and 4.2% from surface water. In 2013, the Limpopo province had the poorest access to water, with 62.1% of households reporting interruptions to municipal supply lasting more than 2 days at a time or for more than 15 days in the preceding 12 months (StatsSA, 2014). In households with off-plot supply, or with unreliable services, people may struggle to access water (Evans et al., 2013; Majuru, 2015) which impacts on their ability to engage in essential and meaningful occupations.

It is also acknowledged that disparities in the distribution of water persist, particularly among disadvantaged groups of people (Jones, 2013). People with disabilities represent one of the largest socially excluded groups, and in low and middle income countries they have disproportionately limited access to water and sanitation (WaterAid, 2011). These limitations can have significant health implications. Reports show that due to inadequate access people with disabilities consume less water, and are at a higher risk of disease, infection, and poverty (Groce, Bailey, Lang, Trani, & Kett, 2011; World Health Organization, 2011). People with disability who access water from publically shared water sources have also reported experiencing physical, verbal, and sexual abuse during water fetching. This can be because people with disability are stigmatised and targeted for abuse simply because they look, sound or move differently to others, or because people believe that disability may be transferred from one person to another through contact or by association with the person with disability, or that disability is due to some misbehaviour of an individual (or a disabled child's mother) and indicate subsequent punishment (e.g. as a direct consequence or through witchcraft), or that disability is a consequence of having an infectious disease such as HIV, which is also still stigmatised in some areas (Groce et al., 2011). Within households with inadequate water access, people with disability may consume less water because they are not able to physically access enough water themselves, and may be 'rationed', or given less water than non-disabled household members when they are dependent on another person to provide their basic needs (Groce et al., 2011).

In South Africa, the Human Rights Commission confirmed in 2013 that the impact of poor water and sanitation services disproportionately affects women, children, and people with disability (Govender, 2014). Older adults in rural South Africa, particularly those on low incomes, have also been highlighted as vulnerable to water insecurity when water supply service levels are poor or unreliable (Geere, Hunter, & Jagals, 2010; Majuru, 2015; Mudau, 2016), and they frequently also contend with disabilities linked to age-related changes in health. Furthermore, difficulties have been observed in families affected by ill-health due to HIV/AIDS, either child-headed households or households in which the mother could no longer access sufficient volumes of water and depended on the children to collect it. This resulted in absenteeism from school and hence infringed upon children's rights to education (Hemson, 2007; Makaudze, du Preez, & Potgieter, 2012).

The evidence that unsafe drinking water and poor sanitation affect health is very strong (Bartram, Lewis, Lenton, & Wright, 2005; Fewtrell et al., 2005; Prüss-Üstün, Bos, Gore, & Bartram, 2008; Wang & Hunter, 2010), however much less attention has been paid to how unsafe water or the work of fetching water from supply points outside of the home impacts on people's ability to engage in essential or meaningful occupations. Water is needed for people to be able to live well and function, and participate in diverse occupations including those that require people to be clean and tidy (e.g. going to school or university, working in a shop or office, teaching, nursing or working in other health care professions, working as a domestic cleaner or in a kitchen); or to wash themselves and clothing or equipment after strenuous/dirty work e.g. mechanic, manual labourer, farm worker, fruit/vegetable picker; or to use water as part of the occupation e.g. doing laundry for others, growing food for yourself or to sell, cooking or preparing food for self, family or for sale, or raising livestock. Water also forms a significant component of self-care occupations, such as washing clothes, maintaining personal hygiene, and cleaning the home and household items such as bed linen, soft furnishings, cooking utensils, dishes, tables and cooking surfaces, floors, toilets, water containers and any special assistive equipment, such as wheelchairs.

According to the World Health Organization, 7.5 litres of water per day "meets the requirements of most people under most circumstances" and "20 litres per day is needed for basic personal hygiene and food hygiene" (WHO, 2017). In the South African context, 25 litres per person per day is the minimum amount considered to be sufficient (Majuru, 2015). An occupational perspective is a useful addition to the public health, economic and development discourse surrounding access to water and sanitation, because it highlights the need to improve access to resources and services beyond the minimum required for survival, taking into consideration levels of water access required to meet diverse needs and preferences for occupation across the lifespan.

Further, the United Nations' Sustainable Development Goal 8 is to "promote inclusive and sustainable economic growth, employment and decent work for all" by 2030. That goal aligns with Wilcock and Townsend's (2009) definition of occupational justice as "the right of every individual to be able to meet basic needs and to have equal opportunities and life chances to reach toward her or his potential, but specific to the individual's engagement in diverse and meaningful occupation" (p. 193). Similarly, Whalley Hammell and Iwama (2012) described an occupational right as the right to engage in meaningful occupations. Unsafe or limited water and sanitation access can be a barrier to essential occupations, such as self-care, but also affect people's ability to engage in other meaningful or productive occupations for various reasons, such as poor health (Geere, 2015), time lost due to water fetching (Geere, Mokoena, Jagals, Poland, & Hartley, 2010), or inability to maintain expected standards of personal presentation and hygiene. For example, limited access to water and sanitation can prevent children going to school and adults accepting certain jobs (Groce et al., 2011). This indicates that to meet Sustainable Development Goal 8 and achieve occupational justice, improvements to water supply must provide access beyond that required for survival and simple subsistence.

Improvements must also enable fulfilment of occupational rights for all, including people with disabilities, children, and older adults. Wilcock and Townsend (2000) maintained that in occupationally just environments, people have equal and sufficient access to resources to allow them to engage in meaningful occupations; occupational injustice ensues when people are deprived of the necessary resources and opportunities to participate in those occupations (Wolf, Ripat, Davis, Becker, & MacSwiggan, 2010). Without access to sufficient water and sanitation it is difficult to envisage how occupational justice could be achieved. The concept of occupational justice is therefore a useful lens through which to frame the impact of access to water and sanitation facilities, because it emphasises the human right to resources beyond the basic minimum required for survival. Thus the concept of occupational justice can be used to argue for levels of service that support participation in society, economically productive livelihoods and meaningful occupations across the lifespan.

Investigations into access to water and sanitation for people with disabilities have been conducted in Uganda and Zambia (Wilbur, 2014), and low and middle income countries more broadly (Groce et al., 2011; Jones & Reed, 2005). The development discourse on inequality has addressed complex issues that can limit people's ability to access resources (Sen, 2001) and it is clear that institutional or social discrimination is a potent process which may disadvantage vulnerable groups from access to resources, including water (Govender, 2014). However, most research into access to water and sanitation for people with disabilities or older adults living in low income settings has tended to focus on existing barriers and current statistics rather than questioning historical factors that have influenced *how* inequality has been produced and maintained in a specific context (Hansen & Sait, 2011). In order to understand existing barriers it is important to investigate the past (Coclanis, 2015). This is especially pertinent for South Africa, where many of the structures formed during the apartheid era continue to perpetuate poverty and inequality (Dube, 2005). For instance, Govender's (2014) first key finding was that "areas which lack water and sanitation mirror apartheid spatial geography" (p. 14). Therefore, it is important to reflect on history to understand the roots of inequalities.

This paper aims to take an occupational justice perspective to highlight how limited access to water and sanitation can impact on occupational participation, particularly for older adults or people with disability, living in rural South Africa. This is pertinent in light of many of the new Sustainable Development Goals including 1, 3, 6, 8 and 10, which aim to end poverty, reduce inequalities, promote wellbeing and to ensure healthy lives, access to water and sanitation, decent work and economic growth for all by 2030 (United Nations, 2016).

The research questions addressed in this study were:

1) What are the current and historical factors affecting access to water and sanitation in rural South Africa?
2) What are the occupational implications of access to water and sanitation for older adults and people with disability living in rural South Africa?

Methodology

Data were collected from two key sources: a review of published literature and six key informant interviews.

Documentary analysis

The literature review was conducted to obtain a broad picture of relevant macro environmental factors that would help to give context to the interviews. The review focussed on documents reporting factors that affect access to water and sanitation in South Africa. It spanned the period 1948 to 2014, in order to include both the apartheid era (1948–1994) and 20 years of the democratic era (1994–2014), up until the most recent general election in 2014. Both eras are pivotal moments in South Africa's history; the apartheid era created inequality and the democratic era began the process of dismantling it. As the 2014 general election was South Africa's fifth democratic election, it is an important time to reflect on South Africa's history and what has been achieved so far.

A search was carried out in April 2015 using Journal Storage (JSTOR), Scopus and MEDLINE databases. These databases were selected in order to retrieve sources from a range of disciplines, including history, economics, politics, geography, law and health. A search was conducted by combining the following terms:

- "South Africa"
- "water or sanitation"
- "histor* or politic* or policy or law or legislation"
- "disab* or impairment or 'older people' or elderly or senior."

These words were selected in order to capture the country (South Africa), the resource (water or sanitation), influential factors (historical and current) and the population (people with disabilities and older adults). Variations of the terms were used in an attempt to obtain all relevant literature. The JSTOR interface limits the number of words used in a search and thus requires a more concise search. For this reason, the words "law, legislation and older people" were removed as these had minimal effects on the search results. The search terms were searched for in the title, abstract and key words in Scopus and MEDLINE. Since JSTOR articles do not all have abstracts, the term "South Africa" was searched for in the title and the rest of the terms were searched for in the full text.

Inclusion criteria for the literature review were:

- study population residing in South Africa and included people with disabilities or older adults

- access to water and/or sanitation was a focus of the paper.

Framework analysis was used to provide a "systematic process of sifting, charting and sorting material according to the key issues and themes" (Ritchie & Spencer, 1999, p. 177). The analysis followed five stages to ensure a systematic approach: "familiarization, identifying a thematic framework, indexing, charting, mapping and interpretation" (Ritchie & Spencer, 1999, p. 177). Framework analysis was selected as it can be informed by a priori reasoning and permits previously identified questions or issues to be considered in the analysis, while allowing new themes to emerge from the data. After the familiarization process the following questions were identified:

- What natural and man-made environmental factors have affected access to water and sanitation?
- How has the legacy of the apartheid era affected access to water and sanitation?
- What political factors have affected access to water and sanitation since the apartheid era?
- What economic factors have affected access to water?
- What social factors have affected access to water and sanitation?

The data were then indexed and charted within a framework table, headed by these questions. This facilitated the mapping and interpretation of the data where potential answers to these questions emerged.

Semi-structured interviews

Six key informant interviews and two group interviews, one with five women and one with six men all aged 65 years or older, were conducted at the beginning of a cross sectional survey comparing the health and social impacts of at-house versus off-plot water supplies in three villages in Limpopo Province, South Africa (Evans et al., 2013). The interviews were conducted to gain subjective understandings of the historical and contextual factors affecting access to water supply and sanitation facilities in the study communities. Key informants who could recall and offer special insight into the impact of changes to water supply and sanitation services within the study communities were invited to participate. The sample included people with disabilities, carers of people with disabilities, older adults, and local councillors who were elderly and resided in the study area. They were selected because of their insight into issues affecting access to water in their community, and particularly the situation for vulnerable groups. People with disability and carers of people with disability were included to ensure representation of people with relevant personal experience of how people with disability access and are affected by water and sanitation services. We also ensured representation of older adults, as disorders associated with aging are a significant cause of disability in low and middle income countries, particularly for those living in rural areas with limited access to health services (Hoy, Geere, Davatchi, Meggitt, & Barrero, 2014) and because older adults were highlighted as vulnerable to water insecurity in a previous pilot study in the same region (Geere, Hunter, et al., 2010). There is also an increasing demand to mainstream both disability and aging in water and sanitation programmes (Jones, 2013).

A 'snowballing' technique was used to accumulate the sample, where a researcher had discussions with household survey participants, local community researchers and interview participants about the people in the community. This was an appropriate method to include people with disability, as people with disabilities in low and middle income countries can be difficult to locate due to discrimination and consequential social isolation (World Health Organization, 2011). Key informants were selected according to the following criteria:

1. An individual normally residing within the study survey area
2. An individual with understanding of how water for their own household's needs is usually supplied and accessed for use by household members
3. An individual with unique insight into the impact of water access and service levels on community members vulnerable due to disability or age, because of:

a. Their own disability or role as a carer for a person with disability, or
b. Older age and low income, or
c. A person of older age with a role as a community councillor, to whom other community members voice problems.

When the key informants were identified, they were provided with verbal and written information about the study, given the opportunity to ask questions, and then invited to take part. Once consent had been obtained, a suitable time and place for the interview was arranged.

Semi-structured interviews were conducted where the interviewer asked the participants about: 1) things that had happened in their lifetime to them or their village that they felt were important, 2) current issues in their community that they felt were important, and 3) their hopes for the future. The participants could relate their responses to any issue and were then also asked about water issues and people that they felt faced challenges with access to water in particular. There was an interpreter to translate the questions (asked in English) into the local language, Tshi-Venda. Participants spoke in English and/or Tshi Venda, according to their preference, frequently using a bit of both languages in their responses, or making a point in English and then elaborating on it in Tshi Venda. The interpreter assisted with relaying answers back in English for the interviewer to respond. Interviews were audio-recorded, fully transcribed, and translated from the local language into both English and Tshi-Venda to enable the researchers to confirm the accuracy of the transcription and cross-check that the translation had captured the participants' meaning.

The English language transcripts were analysed using thematic analysis as it provides a systematic approach for "identifying, analysing, and reporting patterns within data" (Braun & Clarke, 2006, p. 6). The analysis was completed by one researcher who followed six key stages: 1) familiarisation with the data; 2) coding the data; 3) searching for themes; 4) reviewing themes; 5) defining and naming themes; and 6) reporting the information. Interpretations of the data were discussed with the researchers who had conducted and translated the interviews, to explore alternative explanations of transcript content. It was a recursive process and involved moving back and forth between the data, the coding and the different factors. This flexibility is permitted and encouraged in the analysis process as it promotes a rigorous approach (Braun & Clarke, 2006).

Ethical approval for the study was obtained from the University of East Anglia, Tshwane University of Technology and local chiefs of the participating villages. All participants gave informed consent.

Findings

Literature search results

The search yielded 233 papers. The selection process was completed independently by one researcher (figure 1) and suggests that there is limited research on historical factors affecting access to water and sanitation for older adults and people with disabilities in South Africa. The seven papers selected for analysis are mainly narrative reviews, including two scholarly reviews, two conference papers, two empirically based articles and one book chapter. The papers offer different insights into the interplay of factors: Van Koopen and Jha (2005) and Frances (2005) offered a broad view of the law and the political climate, Brown (2011, 2013) provided a political focus in a geographical context, Von Schnitzler (2008) presented an urban and economic perspective, and Bannister (2004) and Matsebe's (2006) conference papers focused on barriers for people with disabilities in particular (appendix 1).

Documentary analysis findings

From the framework analysis, factors relating to the natural and man-made environment, the legacy of the apartheid era and political, economic and social factors since the end of apartheid were identified as affecting access to water and sanitation. These findings are summarized below.

Environmental factors (natural and man-made)

South Africa is a water scarce country, making access to water challenging from the outset.

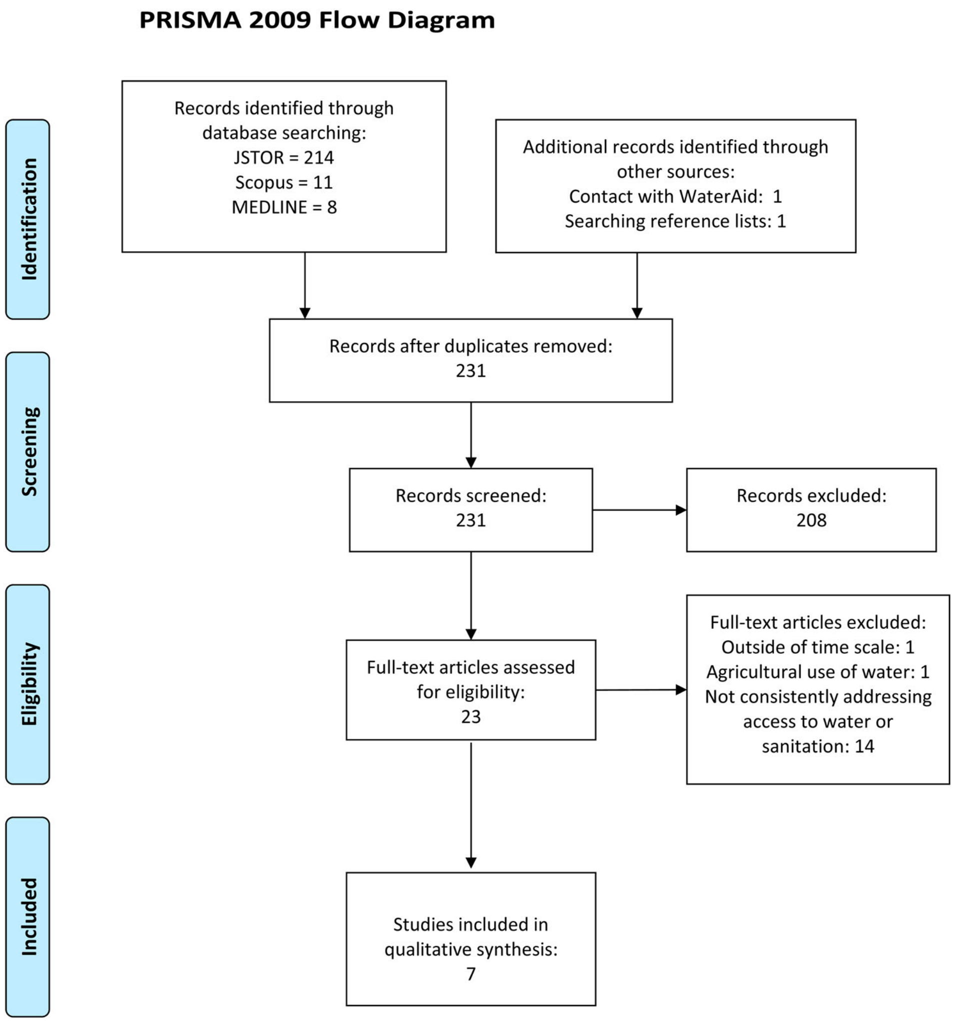

Figure 1. Adapted PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart (Moher et al., 2009)

However, instead of populations settling around water sources, human settlement in South Africa developed around mineral deposits, creating "geographical inertia" (Brown, 2013, p. 271) and incompatibility between water demand and water availability (Francis, 2005). This geography of water was perpetuated during the apartheid era when huge disparities in terms of access to water and sanitation developed across the country, particularly in rural and peri-urban communities where water has been less accessible (Francis, 2005; Van Koopen & Jha, 2005).

Furthermore, pollution levels have risen over the years due to faecal contamination and the expansion of industrial and mining sectors (Francis, 2005). Such pollution is a barrier to access and could be detrimental to health. For those who do not have water piped to their premises, or when supply systems break down (StatsSA, 2014), obtaining sufficient safe water to support essential or meaningful occupations means that environmental challenges, such as walking up and down steep slopes or over distance to functioning public taps, are unavoidable (Geere, Hunter, et al., 2010). Environmental factors therefore create substantial barriers to water access and occupational engagement for people with disability or older adults who have problems with mobility.

The legacy of the apartheid era

Under apartheid, around three and a half million black people were forced to resettle in territories called "homelands" (Brown, 2013; Van Koppen & Jha, 2005). Not only did these areas tend to be where there was low and irregular rainfall with limited access to water, but they became weak economically (Brown, 2013; Francis, 2005; Van Koppen & Jha, 2005). Conversely, infrastructure projects, such as dams, irrigation systems and subsidized schemes, supported white populations and industries (Brown, 2013; Van Koppen & Jha, 2005). Thus "first-world and third-world economies developed side by side" (Francis, 2005, p. 154). This was enforced by apartheid law and facilitated separate social development, where the black population had limited experience of irrigated farming, resource management, participatory governance and above all, education (Brown, 2011). Such limitations have disempowered and put the black population at a historic disadvantage. Thus the legacy of apartheid and its philosophy of "separate development" entrenched the geography of water and established inequitable social stratification and access to water. The challenges linked to accessing sufficient water to engage with meaningful occupation in older age or when living with disability are therefore additional to a historical disadvantage for people in or from former homelands.

Political factors

The authors of many of the articles have recognised the progressive nature of The National Water Act (NWA) (1998) and the great potential that it has as a tool to redress inequities of the past (Brown, 2011, 2013; Francis, 2005; Van Koppen & Jha, 2005). Under the NWA, water became recognised as a national asset and private ownership of water was abolished (Brown, 2011, p. 174). The act established a decentralised participatory model where self-financing Catchment Management Agencies were set up in 19 areas, with public participation representing the rights of all water users (Van Koppen & Jha, 2005). However, despite being a progressive form of legislation, some local organisations have been unsuccessful due to insufficient funding for water resource management (Francis, 2005), poor technical planning (Bannister, 2004), and conflicting interests amongst a heterogeneous population (Brown, 2013). Furthermore, de facto rule of apartheid-era actors appears to continue (Brown 2011, 2013; Francis, 2005) and participatory meetings are not always inclusive of vulnerable groups (Brown 2011, 2013; Van Koppen & Jha, 2005). There has been limited provision of infrastructure that addresses the needs of people living with a disability, which would enable them to access sufficient water and engage in occupations which require access to water (Bannister, 2004, p. 59).

Economic factors

In 1996 the government adopted neoliberal policies, which embraced free markets, globalisation, privatization, cost recovery, and restrictions on public spending, in an attempt to attract foreign investment and encourage economic growth. However, such economic measures frame water as a commodity and not a right. As Francis (2005) and Von Schnitzler (2008) pointed out, neoliberalism and lack of state assistance can have devastating effects, exacerbating rather than alleviating poverty. As part of South Africa's cost recovery policy, the provision of water needed to be paid for through fees. However, many citizens have not been able to afford the fees which, according to Francis (2005), has resulted in "increasing household debt, widespread water service cut-offs, citizen unrest and cholera epidemics" (p. 170).

In some parts of the country pre-paid meters were installed, which required citizens to pay for water before it was allocated. For many people in these areas, water is subject to the availability of funds and requires constant scrutiny of their daily practices and water consumption (Von Schnitzler, 2008). Furthermore, some water services are being operated by private companies that aim to increase profit and do not always consider the needs of vulnerable groups of people (Francis, 2005). Although South Africa has a Free Basic Water Policy, which attempts to guarantee a minimum basic "lifeline" of potable water, it has been a "distant ideal" for millions (Van Koppen & Jha, 2005, p. 205). There is evidence that in Limpopo, this lifeline minimum quantity of 25 litres per person per day is rarely accessed for free (Majuru, 2015).

Additionally, it is not sufficient for people to easily engage in meaningful occupations, such as home gardening, or playing sport, which generates the need for additional drinking water when played in hot weather, as well as water to wash oneself to remove sweat and dirt (Geere, Hunter, et al., 2010; Geere, Mokoena, et al., 2010). Water shortage also restricts cleaning of sports equipment and sports uniforms, in addition to every day clothes and linen, and maintenance of sports fields which, during the dry season, may have no grass at all. Because of the time taken to fetch water from an outside source, people, particularly children, report that they do not have time to train or play sport (Geere, Mokoena et al., 2010). The impact is likely to be amplified for people with disability or their carers, who face additional challenges and may need more time to do daily tasks such as fetching water because of problems with mobility.

Social factors

There are huge disparities in power and wealth across the country; approximately 5% of the population controls 80% of the country's wealth (Francis, 2005). People from poor communities have historically been excluded from water management and so have limited experience to draw from. In addition, there was "separate" education according to race, which for black South Africans was limited in terms of quality of educational service provision and opportunities/expectation to attend (particularly for girls), which meant limited knowledge to enable them to do so effectively (Brown, 2011). Such inequality has the potential to marginalise and exclude vulnerable groups from access to the country's resources. Furthermore, Bannister (2004) reported that there has been a stigma around disability and a fear that disability can be "transferred to others" (p. 59). These attitudes are barriers to inclusion and access to water and sanitation. Lack of access to water and sanitation, resulting from social factors such as these, has the potential to cause and keep people in a state of poverty. Living in poverty increases the likelihood of injury and impairment and is a risk to health, dignity and occupational engagement.

Findings from the interviews

Through thematic analysis, environmental, political, socio-economical and attitudinal themes were identified. Table 1 provides a list of key quotes and information about each participant to support each theme.

Environment impacts on ease of water access and water quality for essential and productive occupations

The physical environment, and the location in which people live, makes people's access to water difficult and challenges their ability to engage in essential occupations, such as bathing, cooking or cleaning clothes, surfaces and household utensils (interviews 5, 7, 8) or productive occupations, such as growing food (interview 8). For example, some villagers have to travel long distances to access alternative or unsafe water sources, such as rivers, whilst others have to carry the water up a steep hill. Participants' comments included:

> *Here at home … if there is no water you must go to the fountain [spring]. It's a problem. We did not bath. This is not the colour of my skin. … It is difficult to climb this hill. I cannot carry [20 litre water containers] because of this hill. If it was a flat area you could put them in a wheelbarrow.* (interview 5)

> *Interviewee: It is water shortage. All these taps do not have water and it is already a month now without water.*
>
> *Interviewer: Does this happen every time or is it just happening now?*
>
> *Interviewee: It happens most of the time. The machines that have been placed initially have been placed down and when they have to make pressure to pump water up they always break down.*
>
> *Interviewer: Where do you normally get water?*
>
> *Interviewee: It is at the main river.* (interview 7)

> *Interviewee: They have problems, those people, because they fetch water down the*

Table 1. Themes and key supportive quotes

Factor	Theme	Interview number (participant description)	Quotes
Environment	Environment impacts on ease of water access and water quality	5 (Elderly man living alone; low income)	It is difficult to climb this hill. I cannot carry [water containers] because of this hill. If it is a flat area you can put them in a wheelbarrow.
		8 (Group meeting with older women; 5 participants)	It is a challenge for those who stay over the hill. They are suffering. It could be a month and going to the second month without water here. Even the taps are not repaired and we are suffering. We have just returned to our old ways of doing things.
		8	There is something that I need to explain. I had developed a culture of avocados using water at my home, when I got the tap in my home. In the beginning, when I was still working, I planted the avocado trees and even ploughing at an empty space and I was able to water the plants using that tap. Now I am suffering. I am an elderly person. Now I can no longer carry the bucket of water and there is no water at the reservoirs. When water comes, it would only reach this house and not the next house. There are people who are connecting water illegally and the water is not reaching our homes and we do not know what to do anymore. Some day we get the water and would fill the drums and buckets to their capacity. We had to buy drums for water.
		7 (Group meeting with older men; 6 participants)	Interviewee: It is water shortage. All these taps do not have water and it is already a month now without water.
			Interviewer: Does this happen every time or is it just happening now?
			Interviewee: It happens most of the times. The machines that have been placed initially have been placed down and when they have to make pressure to pump water up they always break down.
			Interviewer: Where do you normally get water?
			Interviewee: It is at the main river.
			Interviewee: They have problems, those people, because they fetch water down the hills. You must also remember that when they fetch water down the hills and take it up the hills they encounter problems. After some years you would hear people complaining about their backs.
			Interviewer: Do they have any challenges with the capacity of water that they are taking home?
			Interviewee: It has a very big problem because they will have to cook, wash and bath and at the same time they are using 20 litre containers.
		8	I am an elderly person now. I can no longer carry the bucket of water.
		3 (Grandmother; low income)	The road is not in good condition … They have been damaged by water, they have potholes.
		7	There are so many potholes.
		6 (Carer of a child with a disability)	If she is forced to go there, she crawls with her knees … What I was thinking of is to have a path so that she can use it to move around.
		7	We have a problem with people who pollute.
		1 (Person with a disability)	We are forced to drink this water if we do not have the municipality water but it is very salty.
		8	Now we are drinking the water from the springs … they will find many diseases in us.

Political	Governance and lack of transparency is a barrier to development	1	The problem is that we cannot see where our development is going.
		2 (Grandmother and granddaughter; low income)	It the responsibility of land owners. The chief is the one who can say.
		3	We know that it should be people from the parliament and senior people in the government.
		8	People who put up that reservoir used old pipes that were put underground but it was a contractor. It means that they have robbed the government.
		8	The taps are not repaired and we are suffering we have just returned to our old ways of doing things.
		7	The system that is working is the one that is making people suffer.
		1	The money is getting lost.
		1	The problem that I have while I am staying here at home is that we need development but our leaders are blocking that.
		1	He keeps himself safe by not getting involved in many things in community.
Socio-economic	People struggle to access or afford enough water for household and self-care occupations	8	There are people who able to have water taps in their homes but those who cannot afford to do so, they are suffering, they do not have water.
		8	Those who are able to get water now are not paying. They are stealing.
		1	It expensive for me.
		2	Other places it is expensive while it is cheaper at some places”
		2	There is not enough water. Interviewer: If you may have water in your home, what is it that is going to change? Grandmother: There will be change because one may be able to plant things like carrots, spinach and onions so may have good health. Interviewer: Except for planting vegetables, what else can water help with if you have it in your home? Grandmother: It would help to bath. Now we wash things with dirty water and put it aside and reuse it to wash pots; that is not a good thing to do. Interviewer: Does this mean that you look after these children when their mother is not around? Interviewee: Yes, if their mother is not around I stay with them here at home. They go to school and after school they would need food and I would have to give them. This one is still young and does not go to school.
		4 (Grandmother; carer of child with disability)	Interviewer: Do you get enough water for the activities in the house when you fetch water from wherever you are getting it; that is either from the people or from the chief’s place? Grandmother: No it is not enough; I get only a few drums.
		5	If there is no water there if I draw this two (2x 5 litre containers). I can bath and cook and to wash hands and legs, but to wash the body is not enough. Here at home, if there is no firewood you must go and fetch the firewood. If there is no water, you must go to the fountain. It’s a problem. We did not bath. This is not the colour of my skin.
		8	There are people who are connecting water illegally and the water is not reaching our homes.
Attitudinal	Attitudes create barriers to water access	3	These days we no longer trust each other.
		4	People do not accept disability. They think if they may look after her, they will be transferring the disability to their families.
		4	People hide away disabled people, they do not want people to see them.

hills. You must also remember that when they fetch water down the hills and take it up the hills, they encounter problems. After some years you would hear people complaining about their backs.

Interviewer: Do they have any challenges with the capacity of water that they are taking home?

Interviewee: It has a very big problem because they will have to cook, wash and bath and at the same time they are using 20 litre containers. (interview 7)

It is a challenge for those who stay over the hill, they are suffering. It could be a month and going to the second month without water here, even the taps are not repaired and we are suffering. We have just returned to our old ways of doing things. (interview 8)

There is something that I need to explain. I had developed a culture of avocados using water at my home. When I got the tap in my home in the beginning, when I was still working, I planted the avocado trees and even ploughing at an empty space and I was able to water the plants using that tap. Now I am suffering. I am an elderly person. Now I can no longer carry the bucket of water and there is no water at the reservoirs. When water comes, it would only reach this house and not the next house. Some days we would get the water and fill the drums and buckets to their capacity. We had to buy drums for water. (interview 8)

Thus the physical terrain can hinder access and reports show that carrying water can be problematic for people's backs and difficult for older adults or those who have a disability. This impacts on a person's time, energy and physical capacity to engage with essential or productive occupations. Furthermore, there were also accounts of poor road conditions, with an increasing number of potholes hindering access, particularly for people who use wheelchairs and already struggle with the steep slopes in the village. Indeed, because of this terrain, it was reported that a person with a disability is forced to "*crawl on her knees*" to get to her destination (interview 6). It was explained that because the place where the wheelchair could be used was steep, "*she needs somebody who is strong and can manage to brake it and drive it slowly downhill*". It would be extremely difficult or impossible for that individual to access and bring home water from a public standpipe, creating a barrier to independence in performing essential, or any, occupations which require water, such as self-care, cleaning or cooking food. Crawling to sanitation facilities is also unhygienic and harmful to a person's health and dignity. In addition, one village is having problems with pollution and others question the quality of the water; pollution can be detrimental to health, increase the risk of disease and impairment, and require a person to access more distant water sources. These environmental factors are consistent with findings in East Africa, where such barriers in the physical environment hinder access, particularly for those with physical impairments in rural areas (Rukunga, Mutethia, & Kioko, 2006).

Governance and lack of transparency is a barrier to development

Access to water is also affected by political factors, particularly at a local level. Different participants identified various people that they believed had roles and responsibilities to supply and maintain the water services. One participant thought that it was the land owner's and chief's role (interview 2), whilst another supposed that it was the responsibility of "*parliament and senior people*" (interview 3). Another villager suggested that contractors were accountable for poor installation and service delivery and were effectively "*robbing the government*" (interview 8).

The chief is the one who is supposed to solve the problems of this community. It is his. He should treat people fairly and provide good things for his people. Who can renew this place if it is not him?… We are just residents of this place, but the village has got its owner. He is the one who can take action about his people who are struggling. He can see that we are struggling, but he is the one who can stand up

> *for his people and say that they are struggling.* (interview 2)
>
> *Interviewer: As you are expecting that water taps should be installed at home, who do you think has the responsibility to do so?*
>
> *Interviewee: We know that it should be people from the parliament and senior people in the government.* (interview 3)

Whoever is responsible, it is clear that some of the government water supply systems are faulty and unreliable, and the coping strategies that people employ may impact upon their opportunities for engaging with productive occupations. For example, one participant explained his decision to sell his cows and use the money to sink his own borehole, because of his progressive disability and the expense of buying water. He would supply water to neighbours without boreholes, but was reluctant to ask them to pay, and therefore had exchanged his productive occupation for some degree of water security which benefited himself and his neighbours in times of water scarcity.

> *Interviewer: How were you coping with fetching water before you had water at home?*
>
> *Interviewee: I used to pay.*
>
> *Interviewer: Was it very expensive for you or could you afford that?*
>
> *Interviewee: It expensive for me.*
>
> *Interviewer: Did you make this borehole that you have here at home yourself?*
>
> *Interviewee: We used to have cows here at home. By the time I realised that I was no longer able to look after them, I sold them [to pay for the borehole].*
>
> *Interviewer: She is saying that it looks like everyone in this community has a borehole at home [rather] than getting water from the communal taps in the streets?*
>
> *Interviewee: Yes, but you cannot have a borehole if there is water at the communal taps in the streets. The reason we have boreholes is because it was difficult. Just imagine others may be able to have boreholes, but what would happen to those who cannot afford to have one? Here at my neighbours they do not have water. Sometimes we get water from the government but it may take up to 2 or 3 weeks without water, but these people would come here and ask for water and we give them. Sometimes when you think to make a person pay for water is not fair.* (interview 1)

One village even raised money to address the problem, however the money seems to have got "*lost*" (interview 1). The same participant also explained that:

> *The problem is that we cannot see where our development is going.* (interview 1)

The participant went on to suggest that that local leaders are "*blocking*" development (interview 1). It seems, therefore, that political factors have played a role in access to water but that the role of various levels and types of governance in water management is not fully understood. It is also possible that some villagers face barriers to voicing concerns. For example one participant explained that he "*keeps himself safe*" by not involving himself in the community (interview 1). Political uncertainty and poor water management thus appear to have impacted on people's access to water, with direct effects on opportunities to maintain productive occupations, as illustrated in the case of a participant with progressive disability.

People struggle to access or afford enough water for household and self-care occupations

Access to water and sanitation also appears to be affected by socio-economic factors. Participants explained that they simply did not have the money to afford water. Whilst the government had been supplying water to some, it was reported to be "*expensive*" (interviews 1 and 2) and "*not enough*" (interviews 2, 4 and 5), and this was reported to impact on engagement with household and self-care occupations. For example, two female participants (interviews 2,

4) were retired from formal employment but had carer roles within their family; one for her grandchildren whilst their mother worked and the other as a full-time carer for her grandchild with severe disability. One older adult living alone (interview 5) specified that he could not access enough water to wash, affecting his self-care.

> *Interviewer: Do you get enough water for the activities in the house when you fetch water from wherever you are getting it, that is, either from the people or from the chief's place?*
>
> *Grandmother: No it is not enough; I get only a few drums.* (interview 2)
>
> *Interviewer: If you had water in your home, what is it that is going to change?*
>
> *Grandmother: There will be change because one may be able to plant things like carrots, spinach and onions so may have good health.*
>
> *Interviewer: Except for planting vegetables, what else can water help with if you have it in your home?*
>
> *Grandmother: It would help to bath. Now we wash things with dirty water and put it aside and reuse it to wash pots; that is not a good thing to do.* (interview 4).
>
> *If there is no water there I draw this two [2x 5 litre containers]. I can bath and cook and wash hands and legs, but to wash the body is not enough.* (interview 5)

Socio-economic factors therefore impact on people's access to water and many who cannot afford water are "*suffering*" (interview 8). For older adults, people with disabilities, and carers of people with disabilities, there may be fewer opportunities to earn an income, which could affect their ability to afford water.

> *I would like to work. Pension money is too little, and if anyone may come and request that I should come to clean/plough for them anywhere, I will not be able to go as I am looking after the child.* (interview 2)

Whilst some villagers have returned to their old ways of collecting water from rivers, others have resorted to stealing it. Participants report:

> *There are people who are connecting water illegally and the water is not reaching our homes. … Those who are able to get water now are not paying, they are stealing.* (interview 8)

Perhaps poverty is the trigger for this action, causing those with a low income to rely on illegal connections, which can impact on other people's access to water. Furthermore, the crime in some villages seems to have led to a lack of trust; *"These days we no longer trust each other"* (interview 3). This situation has the potential to create divisions in the community at a time when unity is needed to address social problems.

Attitudes create barriers to water access and impact upon caring occupations

Attitudes towards disability also appear to affect people with disabilities', or their carers', access to water. For example, in interview 4 a grandmother who was the sole carer of a child with disability stated *"even if I ask someone to look after her, people do not accept disability. They think if they look after her they will be transferring the disability to their families"*. Because of this attitude, she did not have any assistance to care for the child from friends, family or neighbours. Accessing water therefore meant leaving the child at home alone whilst she walked to the public standpipe and returned. She explained that this was not safe for the child;

> *Interviewee: Except for looking after her, I have to go to the chief's place to fetch water using a wheel barrow. When I go to fetch water from there I have a very serious problem of leaving her alone in the house.*
>
> *Interviewer: What problem do you have when you have left her alone?*
>
> *Interviewee: My problem is that, these days it is no longer safe. I may have locked her inside the house and somebody may come and break in or burn the house. What people would say I have done, they would say I ran away from her.*

> *Interviewer: What you are saying is a problem is when you think of what people may do when you have left her alone, right?*
>
> *Interviewee: Yes, when I have left her alone, because when you walk around you will hear people say that there is a child who is alone in this house. You will hear older people thinking of doing bad things to a child who is unable to walk. It is really bad.*

This finding is consistent with those of Groce et al. (2011), who reported that people with disabilities often face stigma, abuse, discrimination and fears of contamination when using public and household facilities.

The interviews highlight factors affecting access to water and sanitation, particularly for people with disabilities and older adults. Due to discrimination and unequal access to resources and opportunities, people face challenges engaging with the occupations of daily life, indicating that there is occupational injustice. Indeed, across the set of interviews, the words "*suffer*" and "*struggle*" appeared numerous times, reflecting the hardship these people are facing and the quality of their occupational performance.

Summary synthesis of semi-structured interviews and documentary analysis

Findings from the interviews were synthesised with those from the documentary analysis to develop a more comprehensive understanding of the broader historical context and how this has impacted on access to water and sanitation for people, particularly those with disabilities and older adults. Limited access to water and sanitation creates barriers to occupational engagement, which were discussed in relation to the basic daily occupations of maintaining hygiene, safety and self-care as well as productive occupations. Figure 2 shows how the historical and current context (identified as factors in the documentary analysis) has impacted on the current barriers (identified as themes from the interviews), resulting in occupational injustice. The following section will expand on these results and will reflect on occupational justice.

Discussion

In this study we found that environmental factors (natural and man-made), the "legacy of the apartheid", and political, economic and social factors since the apartheid (including socio-economic and attitudinal), have affected access to water and sanitation, and can create particularly challenging barriers for older adults or people with disabilities. Our findings are consistent with a recent study on water, sanitation and hygiene services (WASH) in Uganda and Zambia, which found that the main barriers for people with disabilities accessing these services were "Environmental barriers: facilities are not inclusive; Attitudinal barriers: negative attitudes lead to exclusion; Institutional barriers: lack of consultation or involvement in decision making on WASH policy" (Wilbur, 2014, p. 2).

Our findings are also consistent with Groce et al.'s (2011) literature review, Jones and Reed's (2005) book, and studies recently conducted in the same region (Geere, Hunter, et al., 2010; Geere, Mokoena, et al., 2010; Majuru, 2015; Mudau, 2016). Indeed, participants reported environmental challenges such as hilly terrain and poor road conditions. The literature also revealed physical barriers in terms of facilities not catering for wheelchair users (Bannister, 2004) and having to travel large distances in rural areas to collect water (Francis, 2005). Both the interviews and literature revealed negative attitudes around "*transferring*" disability (Bannister, 2004), and the interviews also reported institutional barriers, where there was confusion over who was in charge and frustration over the lack of development.

However, the documentary analysis has added a new dimension, taking into consideration the historical factors that have caused these barriers, and providing more context and understanding of the political, economic and socio-cultural climate (see figure 2). For example, the interviews do not mention the apartheid era, however the literature identifies apartheid policies and their legacy as a key historical factor that has affected access to water and sanitation (Brown, 2011, 2013; Francis, 2005; Van Koppen & Jha, 2005).

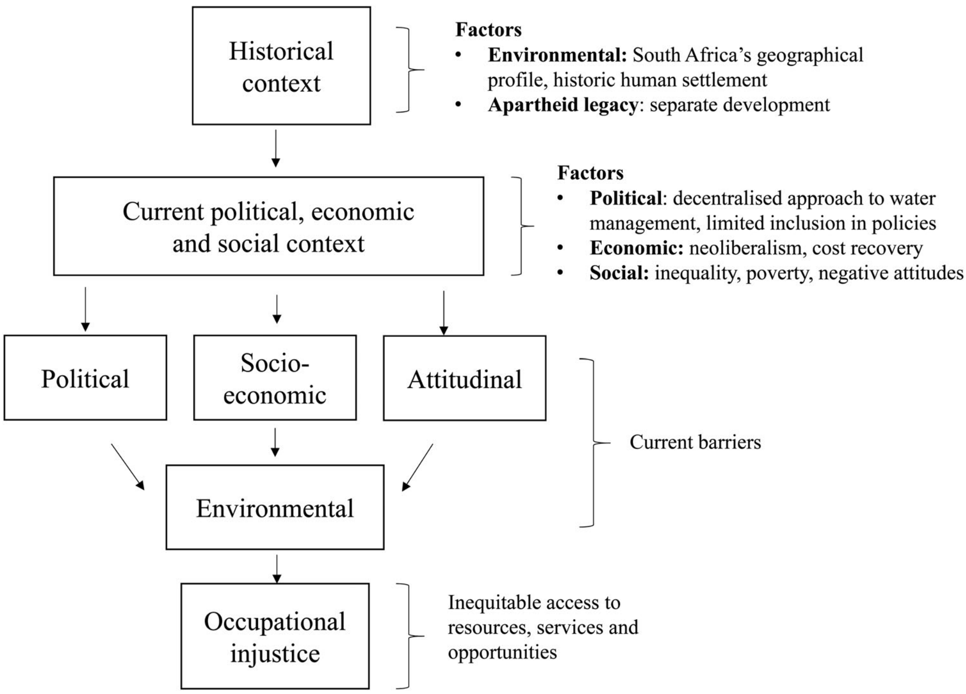

Figure 2. Summary of findings

The geography of water was laid down during the mining revolution and was entrenched during the apartheid regime (Brown, 2013; Francis, 2005). That regime created separate development, where different environments developed side by side according to race (Van Koopen & Jha, 2005). Whilst attempts to undo the inequities of the past and redistribute water have been made, this has been in the context of neoliberalism, with a decentralised participatory approach to water management (Brown, 2011). The approach has not been accessible to all groups, has lacked funding and has allowed de facto control of old actors to persist (Brown, 2013; Francis, 2005; Van Koopen & Jha, 2005). Lack of communication and poor consultation have been reported as the main barriers to good service delivery (Hosking & Jacoby, 2013) and poor service delivery, lack of access to water and inadequate sanitation have been reported to lead to social tension, whereby communities resort to violence and unrest (Tapela, 2012). Similar issues of concern as a consequence of poor governance were highlighted in the interviews. Thus historical factors have contributed to the existing environmental, attitudinal and institutional barriers, perpetuating widespread poverty, inequality and occupational injustice.

What are the occupational implications for people with disabilities and older adults?

Occupational injustices (Stadnyk, Townsend, & Wilcock, 2011) have occurred in South Africa due to environmental, political, socio-economic and attitudinal factors affecting access to water and sanitation. Figure 2 demonstrates how historical and current contexts can impact on these factors, resulting in occupational injustice. In addition, the policy that allows practices established in the apartheid era to continue, because of the minimum standard to access water from off-plot supply points, has contributed to occupational injustice impacting on older adults and people living with disability (Department of Water Affairs, 1994). The terms occupational apartheid and occupational deprivation can be applied to South Africa's case and capture the type of occupational injustice that has occurred.

Occupational apartheid was most blatant during the apartheid era (Christiansen & Townsend, 2011, p. 420), but has informally continued since the apartheid, for example where people with disabilities have not been included in sanitation policies or decision making processes. In South Africa some people have enjoyed unlimited access to water and sanitation facilities, whereas other people have experienced social exclusion and inadequate access to water and sanitation, resulting in deprived occupational participation (Stadnyk et al., 2011). In our interviews, this was particularly apparent as insufficient water access for occupations essential to maintain health, well-being and dignity, such as bathing, cleaning and washing things, and cooking. However, poor water access also limited capacity to maintain a safe environment to support caring occupations, which are commonly a responsibility of older adults in the region (Schatz & Gilbert, 2014), or to maintain productive occupations, such as growing food or raising cattle, while living with disability or the effects of aging.

Pollard, Sakellariou, and Kronenberg, (2009) asserted that South Africa's apartheid system is an extreme example of occupational apartheid, where occupations were restricted based on racial features. Indeed, apartheid created physical, legal and social barriers in its separate development, producing a disabling environment with unequal access to water and sanitation. Furthermore, black people with disabilities had unequal access to employment, education and health care services and thus faced double discrimination (Dube, 2005). The occupational apartheid has perpetuated widespread poverty and, as Hansen and Sait (2011) have argued, created dependency for people with disabilities. For example, in under resourced rural areas with poorly maintained, steep roads, wheelchair use can be impossible, and special equipment to suit the environment unaffordable. Thus limited mobility creates dependence on others for access to water when it must be collected away from home, and such dependence removes occupational choice and restricts occupational participation.

Indeed, many people have been dependent on the free basic water provided by the government. However, as highlighted by the findings, this free amount is "*not enough*" and deep inequalities, "*suffering*" and occupational deprivation persist. Whilst some people in wealthy areas use water for swimming pools and to irrigate gardens, in poorer areas water use and occupations are under constant scrutiny. For example, children are precluded from playing with water and people have to restrict their daily water consumption (Von Schnitzler, 2008). Inadequate access to water and sanitation facilities in poor areas can also prevent children with disabilities going to school (Bannister, 2004; Groce et al., 2011), resulting in occupational deprivation. Collecting water takes time away from other occupations (Geere, Hunter, et al., 2010; Geere, Mokoena, et al., 2010) and occupations such as bathing, cooking and cleaning are limited by the amount of water that can be carried, which people with disabilities or older adults may not be able to do. Such occupational injustice is a threat to health, wellbeing and dignity, and restricts opportunities to engage in other occupations that people value.

Despite becoming a democratic nation in 1994 there are still environmental, political, economic and social barriers affecting access to water and sanitation. Francis (2005) quoted Pilger when arguing that the dividing line is no longer about race but about class: "Economic apartheid has replaced legal apartheid with exactly the same consequence for exactly the same people" (p. 160). Therefore poverty, a product of the apartheid regime, continues to be constructed by society creating unequal conditions and access to resources, thus causing occupational injustice. Not only is access to water and sanitation a human right but it should also be considered part of an occupational right, allowing people to participate in occupations that they choose, value and find meaningful.

Limitations

The use of an interpreter to communicate questions and answers during the interviews could have interrupted the flow of the conversation, leading to the truncation of answers. Furthermore, answers and questions could have also been misinterpreted or misunderstood, however full audio-recording and professional translation and transcription of the recordings into both

Tshi-Venda and English were performed to mitigate this risk. The interviews took place in villages of one province, and may not be generalizable to other rural or urban areas in South Africa.

The number of people interviewed with disability or who cared for someone with disability was small and additional participants may have provided more depth to the data about the challenges to water access faced by people with disability. However, our findings are consistent with themes reported by other researchers.

The search identified limited literature on access to sanitation and water for people with disabilities and older adults in South Africa, which could be a reflection of the limited research in this area. Some literature may have been missed due to the use of English language sources, however our electronic searches were not limited to English and should have identified papers published in languages other than English.

Conclusions

It is evident that there have been environmental, political, economic and social factors affecting access to water and sanitation in South Africa, particularly for people with disabilities or older adults who are poor. The interviews provided insight into the current factors affecting access to water and sanitation in a rural area. The documentary analysis identified the legacy of apartheid as a key historical factor, and helped to provide a broader picture of some of the macro environmental factors that have affected the physical and social environment today. South Africa's past has created a disabling environment where occupational injustice has occurred in terms of occupational apartheid and occupational deprivation.

The minimum standard for access to water described in current policy is a significant risk factor for occupational injustice affecting people with disabilities and older adults. Water supplies that are accessed off-plot or are unreliable can create barriers to essential occupations, such as care of self and others, because of difficulties obtaining sufficient quantities of water for bathing, cooking and cleaning. The minimum standard level of service can also limit opportunities for more diverse or productive occupations, such as growing food, raising cattle, attending school or accepting formal employment. Further research is needed to identify factors and processes which facilitate or impede the translation of government plans for improving WASH access into action, and which support the realisation of health, social and economic benefits to enable the most vulnerable communities and community members to engage with essential, meaningful and productive occupations. Programmes which achieve occupational justice through better access to water will also facilitate achievement of many Sustainable Development Goals, by ensuring access to water and decent work for all to reduce poverty and inequality.

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Appendix 1.

Table 2. Summary of the literature.

Author	Type of source	Aim of literature	Key findings	Strengths and limitations
Bannister (2004)	Conference paper	Define disability and gender needs and discuss how they can be incorporated into sanitation programmes.	Needs of people with disabilities not always considered. Greater awareness needed to improve infrastructure, hygiene and safety for all.	Highlights some gender and disability issues, based on personal experiences in one rural area.
Brown (2011)	Empirical research	Explore the institutionalisation of participatory water resource management in post-apartheid South Africa.	Weaknesses in the participatory model, with need for reassessment of the role of the state, where greater intervention could support the interests of marginalised groups.	Uses empirical research to explore participatory water management, but detail of methodology not provided and application to other areas in South Africa unclear.
Brown (2013)	Empirical research	Evaluate the potential of both participation and institutional reform to change the geography of water in South Africa.	Participation has not changed the geography of water. Need for state-directed water resource management.	Based on 2011 study. Claim of rigor, but no explanation of how rigor was achieved.
Francis (2005)	Periodical / scholarly review	Explore the history of water law and policies, and analyse the legal right to water.	Suggests a need for civil society to coerce policymakers into amending existing laws to redistribute water, thereby alleviating inequalities and injustices.	Uses a variety of sources and provides an environmental law perspective, but does not evaluate the quality of the sources or explain how the sources were located.
Matsebe (2006)	Conference paper	Review sanitation policies and their inclusion of people with disabilities.	People with disabilities have been excluded from sanitation policies. Introduction of economic measures such as subsidies, incentives and fines suggested.	Offers a succinct overview of how people with disabilities are excluded from sanitation policies.
Van Koppen & Jha, (2005)	Book chapter	Review attempts to redress racial inequities through water law, exploring the interaction between legal frameworks.	The National Water Act (1998) has the potential to redress inequalities but old laws, the power of old rulers and poor technical leaders are hindering progress.	Considers the interaction between legal frameworks and uses a case study example, but authors acknowledge that some evidence is fragmentary.
Von Schnitzler (2008)	Scholarly review with some empirical evidence	Investigate 'Operation Gcin'samanzi' (a project initiated by Johannesburg Water) and provide a history of prepayment technology.	Suggests that prepayment meters are political tools under the guise of a life line tariff, which force citizens to scrutinize their daily practices and consumption of water.	Provides an urban perspective, which affects over five million people, but not representative of the whole population and methodology not fully explained.

Appendix 9. Appraisal tool for observational cohort and cross-sectional studies

National Institute of Health (NIH) 2014. Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies [Online]. USA: Department of Health and Human Services. Available: https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools/cohort [Accessed 03/08/2017].

Appendix 9

NIH Quality Assessment Tool for Observational Cohort and Cross Sectional Studies

Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies

https://www.nhlbi.nih.gov/health-pro/guidelines/in-develop/cardiovascular-risk-reduction/tools/cohort

Author	
Year of publication	
Title	

Criteria	**Yes**	**No**	**Other (CD, NR, NA)***
1. Was the research question or objective in this paper clearly stated?			
2. Was the study population clearly specified and defined?			
3. Was the participation rate of eligible persons at least 50%?			
4. Were all the subjects selected or recruited from the same or similar populations (including the same time period)? Were inclusion and exclusion criteria for being in the study prespecified and applied uniformly to all participants?			
5. Was a sample size justification, power description, or variance and effect estimates provided?			
6. For the analyses in this paper, were the exposure(s) of interest measured prior to the outcome(s) being measured?			
7. Was the timeframe sufficient so that one could reasonably expect to see an association between exposure and outcome if it existed?			
8. For exposures that can vary in amount or level, did the study examine different levels of the exposure as related to the outcome (e.g., categories of exposure, or exposure measured as continuous variable)?			
9. Were the exposure measures (independent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?			
10. Was the exposure(s) assessed more than once over time?			

11. Were the outcome measures (dependent variables) clearly defined, valid, reliable, and implemented consistently across all study participants?			
12. Were the outcome assessors blinded to the exposure status of participants?			
13. Was loss to follow-up after baseline 20% or less?			
14. Were key potential confounding variables measured and adjusted statistically for their impact on the relationship between exposure(s) and outcome(s)?			

Quality Rating (Good, Fair, or Poor) (see guidance)
Rater #1 initials:
Rater #2 initials:
Additional Comments (If POOR, please state why):

*CD, cannot determine; NA, not applicable; NR, not reported

Guidance for Assessing the Quality of Observational Cohort and Cross-Sectional Studies

The guidance document below is organized by question number from the tool for quality assessment of observational cohort and cross-sectional studies.

Question 1. Research question

Did the authors describe their goal in conducting this research? Is it easy to understand what they were looking to find? This issue is important for any scientific paper of any type. Higher quality scientific research explicitly defines a research question.

Questions 2 and 3. Study population

Did the authors describe the group of people from which the study participants were selected or recruited, using demographics, location, and time period? If you were to conduct this study again, would you know who to recruit, from where, and from what time period? Is the cohort population free of the outcomes of interest at the time they were recruited?

An example would be men over 40 years old with type 2 diabetes who began seeking medical care at Phoenix Good Samaritan Hospital between January 1, 1990 and December 31, 1994. In this example, the population is clearly described as: (1) who (men over 40 years old with type 2 diabetes); (2) where (Phoenix Good Samaritan Hospital); and (3) when (between January 1, 1990 and December 31, 1994). Another example is women ages 34 to 59 years of age in 1980 who were in the nursing profession and had no known coronary disease, stroke, cancer, hypercholesterolemia, or diabetes, and were recruited from the 11 most populous States, with contact information obtained from State nursing boards.

In cohort studies, it is crucial that the population at baseline is free of the outcome of interest. For example, the nurses' population above would be an appropriate group in which to study incident coronary disease. This information is usually found either in descriptions of population recruitment, definitions of variables, or inclusion/exclusion criteria.

You may need to look at prior papers on methods in order to make the assessment for this question. Those papers are usually in the reference list.

If fewer than 50% of eligible persons participated in the study, then there is concern that the study population does not adequately represent the target population. This increases the risk of bias.

Question 4. Groups recruited from the same population and uniform eligibility criteria

Were the inclusion and exclusion criteria developed prior to recruitment or selection of the study population? Were the same underlying criteria used for all of the subjects involved? This issue is related to the description of the study population, above, and you may find the information for both of these questions in the same section of the paper.

Most cohort studies begin with the selection of the cohort; participants in this cohort are then measured or evaluated to determine their exposure status. However, some cohort studies may recruit or select exposed participants in a different time or place than unexposed participants, especially retrospective cohort studies–which is when data are obtained from the past (retrospectively), but the analysis examines exposures prior to outcomes. For example, one research question could be whether diabetic men with clinical depression are at higher risk for cardiovascular disease than those without clinical depression. So, diabetic men with depression might be selected from a mental health clinic, while diabetic men without depression might be selected from an internal medicine or endocrinology clinic. This study recruits groups from different clinic populations, so this example would get a "no."

However, the women nurses described in the question above were selected based on the same inclusion/exclusion criteria, so that example would get a "yes."

Question 5. Sample size justification

Did the authors present their reasons for selecting or recruiting the number of people included or analyzed? Do they note or discuss the statistical power of the study? This question is about whether or not the study had enough participants to detect an association if one truly existed.

A paragraph in the methods section of the article may explain the sample size needed to detect a hypothesized difference in outcomes. You may also find a discussion of power in the discussion section (such as the study had 85 percent power to detect a 20 percent increase in the rate of an outcome of interest, with a 2-sided alpha of 0.05). Sometimes estimates of variance and/or estimates of effect size are given, instead of sample size calculations. In any of these cases, the answer would be "yes."

However, observational cohort studies often do not report anything about power or sample sizes because the analyses are exploratory in nature. In this case, the answer would be "no." This is not a "fatal flaw." It just may indicate that attention was not paid to whether the study was sufficiently sized to answer a prespecified question–i.e., it may have been an exploratory, hypothesis-generating study.

Question 6. Exposure assessed prior to outcome measurement

This question is important because, in order to determine whether an exposure causes an outcome, the exposure must come before the outcome.

For some prospective cohort studies, the investigator enrolls the cohort and then determines the exposure status of various members of the cohort (large epidemiological studies like Framingham used this approach). However, for other cohort studies, the cohort is selected based on its exposure status, as in the example above of depressed diabetic men (the exposure being depression). Other examples include a cohort identified by its exposure to fluoridated drinking water and then compared to a cohort living in an area without fluoridated water, or a cohort of military personnel exposed to combat in the Gulf War compared to a cohort of military personnel not deployed in a combat zone.

With either of these types of cohort studies, the cohort is followed forward in time (i.e., prospectively) to assess the outcomes that occurred in the exposed members compared to nonexposed members of the cohort. Therefore, you begin the study in the present by looking at groups that were exposed (or not) to some biological or behavioral factor, intervention, etc., and then you follow them forward in time to examine outcomes. If a cohort study is conducted properly, the answer to this question should be "yes," since the exposure status of members of the cohort was determined at the beginning of the study before the outcomes occurred.

For retrospective cohort studies, the same principal applies. The difference is that, rather than identifying a cohort in the present and following them forward in time, the investigators go back in time (i.e., retrospectively) and select a cohort based on their exposure status in the past and then follow them forward to assess the outcomes that occurred in the exposed and nonexposed cohort members. Because in retrospective cohort studies the exposure and outcomes may have already occurred (it depends on how long they follow the cohort), it is important to make sure that the exposure preceded the outcome.

Sometimes cross-sectional studies are conducted (or cross-sectional analyses of cohort-study data), where the exposures and outcomes are measured during the same timeframe. As a result, cross-sectional analyses provide weaker evidence than regular cohort studies regarding a potential causal relationship between exposures and outcomes. For cross-sectional analyses, the answer to Question 6 should be "no."

Question 7. Sufficient timeframe to see an effect

Did the study allow enough time for a sufficient number of outcomes to occur or be observed, or enough time for an exposure to have a biological effect on an outcome? In the examples given above, if clinical depression has a biological effect on increasing risk for CVD, such an effect may take years. In the other example, if higher dietary sodium increases BP, a short timeframe may be sufficient to assess its association with BP, but a longer timeframe would be needed to examine its association with heart attacks.

The issue of timeframe is important to enable meaningful analysis of the relationships between exposures and outcomes to be conducted. This often requires at least several years, especially when looking at health outcomes, but it depends on the research question and outcomes being examined.

Cross-sectional analyses allow no time to see an effect, since the exposures and outcomes are assessed at the same time, so those would get a "no" response.

Question 8. Different levels of the exposure of interest

If the exposure can be defined as a range (examples: drug dosage, amount of physical activity, amount of sodium consumed), were multiple categories of that exposure assessed? (for example, for drugs: not on the medication, on a low dose, medium dose, high dose; for dietary sodium, higher than average U.S. consumption, lower than recommended consumption, between the two). Sometimes discrete categories of exposure are not used, but instead exposures are measured as continuous variables (for example, mg/day of dietary sodium or BP values).

In any case, studying different levels of exposure (where possible) enables investigators to assess trends or dose-response relationships between exposures and outcomes–e.g., the higher the exposure, the greater the rate of the health outcome. The presence of trends or dose-response relationships lends credibility to the hypothesis of causality between exposure and outcome.

For some exposures, however, this question may not be applicable (e.g., the exposure may be a dichotomous variable like living in a rural setting versus an urban setting, or vaccinated/not vaccinated with a one-time vaccine). If there are only two possible exposures (yes/no), then this question should be given an "NA," and it should not count negatively towards the quality rating.

Question 9. Exposure measures and assessment

Were the exposure measures defined in detail? Were the tools or methods used to measure exposure accurate and reliable–for example, have they been validated or are they objective? This issue is important as it influences confidence in the reported exposures. When exposures are measured with less accuracy or validity, it is harder to see an association between exposure and outcome even if one exists. Also as important is whether the exposures were assessed in the same manner within groups and between groups; if not, bias may result.

For example, retrospective self-report of dietary salt intake is not as valid and reliable as prospectively using a standardized dietary log plus testing participants' urine for sodium content. Another example is measurement of BP, where there may be quite a difference between usual care, where clinicians measure BP however it is done in their practice setting (which can vary considerably), and use of trained BP assessors using standardized equipment (e.g., the same BP device which has been tested and calibrated) and a standardized protocol (e.g., patient is seated for 5 minutes with feet flat on the floor, BP is taken twice in each arm, and all four measurements are averaged). In each of these cases, the former would get a "no" and the latter a "yes."

Here is a final example that illustrates the point about why it is important to assess exposures consistently across all groups: If people with higher BP (exposed cohort) are seen by their providers more frequently than those without elevated BP (nonexposed group), it also increases the chances of detecting and documenting changes in health outcomes, including CVD-related events. Therefore, it may lead to the conclusion that higher BP leads to more CVD events. This may be true, but it could also be due to the fact that the subjects with higher BP were seen more often; thus, more CVD-related events were detected and documented simply because they had more encounters with the health care system. Thus, it could bias the results and lead to an erroneous conclusion.

Question 10. Repeated exposure assessment

Was the exposure for each person measured more than once during the course of the study period? Multiple measurements with the same result increase our confidence that the exposure status was correctly classified. Also, multiple measurements enable investigators to look at changes in exposure over time, for example, people who ate high dietary sodium throughout the followup period, compared to those who started out high then reduced their intake, compared to those who ate low sodium throughout. Once again, this may not be applicable in all cases. In many older studies, exposure was measured only at baseline. However, multiple exposure measurements do result in a stronger study design.

Question 11. Outcome measures

Were the outcomes defined in detail? Were the tools or methods for measuring outcomes accurate and reliable–for example, have they been validated or are they objective? This issue is important because it influences confidence in the validity of study results. Also important is whether the outcomes were assessed in the same manner within groups and between groups.

An example of an outcome measure that is objective, accurate, and reliable is death–the outcome measured with more accuracy than any other. But even with a measure as objective as death, there can be differences in the accuracy and reliability of how death was assessed by the investigators. Did they base it on an autopsy report, death certificate, death registry, or report from a family member? Another example is a study of whether dietary fat intake is related to blood cholesterol level (cholesterol level being the outcome), and the cholesterol level is measured from fasting blood samples that are all sent to the same laboratory. These examples would get a "yes." An example of a "no" would be self-report by subjects that they had a heart attack, or self-report of how much they weigh (if body weight is the outcome of interest).

Similar to the example in Question 9, results may be biased if one group (e.g., people with high BP) is seen more frequently than another group (people with normal BP) because more frequent encounters with the health care system increases the chances of outcomes being detected and documented.

Question 12. Blinding of outcome assessors

Blinding means that outcome assessors did not know whether the participant was exposed or unexposed. It is also sometimes called "masking." The objective is to look for evidence in the article that the person(s) assessing the outcome(s) for the study (for example, examining medical records to determine the outcomes that occurred in the exposed and comparison groups) is masked to the exposure status of the participant. Sometimes the person measuring the exposure is the same person conducting the outcome assessment. In this case, the outcome assessor would most likely not be blinded to exposure status because they also took measurements of exposures. If so, make a note of that in the comments section.

As you assess this criterion, think about whether it is likely that the person(s) doing the outcome assessment would know (or be able to figure out) the exposure status of the study participants. If the answer is no, then blinding is adequate. An example of adequate blinding of the outcome assessors is to create a separate committee, whose members were not involved in the care of the patient and had no information about the study participants' exposure status. The committee would then be provided with copies of participants' medical records, which had been stripped of any potential exposure information or personally identifiable information. The committee would then review the records for prespecified outcomes according to the study protocol. If blinding was not possible, which is sometimes the case, mark "NA" and explain the potential for bias.

Question 13. Followup rate

Higher overall followup rates are always better than lower followup rates, even though higher rates are expected in shorter studies, whereas lower overall followup rates are often seen in studies of longer duration. Usually, an acceptable overall followup rate is considered 80 percent or more of participants whose exposures were measured at baseline. However, this is just a general guideline. For example, a 6-month cohort study examining the relationship between dietary sodium intake and BP level may have over 90 percent followup, but a 20-year cohort study examining effects of sodium intake on stroke may have only a 65 percent followup rate.

Question 14. Statistical analyses

Were key potential confounding variables measured and adjusted for, such as by statistical adjustment for baseline differences? Logistic regression or other regression methods are often used to account for the influence of variables not of interest.

This is a key issue in cohort studies, because statistical analyses need to control for potential confounders, in contrast to an RCT, where the randomization process controls for potential confounders. All key factors that may be associated both with the exposure of interest and the outcome–that are not of interest to the research question–should be controlled for in the analyses.

For example, in a study of the relationship between cardiorespiratory fitness and CVD events (heart attacks and strokes), the study should control for age, BP, blood cholesterol, and body weight, because all of these factors are associated both with low fitness and with CVD events. Well-done cohort studies control for multiple potential confounders.

Some general guidance for determining the overall quality rating of observational cohort and cross-sectional studies

The questions on the form are designed to help you focus on the key concepts for evaluating the internal validity of a study. They are not intended to create a list that you simply tally up to arrive at a summary judgment of quality.

Internal validity for cohort studies is the extent to which the results reported in the study can truly be attributed to the exposure being evaluated and not to flaws in the design or conduct of the study–in other words, the ability of the study to draw associative conclusions about the effects of the exposures being studied on outcomes. Any such flaws can increase the risk of bias.

Critical appraisal involves considering the risk of potential for selection bias, information bias, measurement bias, or confounding (the mixture of exposures that one cannot tease out from each other). Examples of confounding include co-interventions, differences at baseline in patient characteristics, and other issues throughout the questions above. High risk of bias translates to a rating of poor quality. Low risk of bias translates to a rating of good quality. (Thus, the greater the risk of bias, the lower the quality rating of the study.)

In addition, the more attention in the study design to issues that can help determine whether there is a causal relationship between the exposure and outcome, the higher quality the study. These include exposures occurring prior to outcomes, evaluation of a dose-response gradient, accuracy of measurement of both exposure and outcome, sufficient timeframe to see an effect, and appropriate control for confounding–all concepts reflected in the tool.

Generally, when you evaluate a study, you will not see a "fatal flaw," but you will find some risk of bias. By focusing on the concepts underlying the questions in the quality assessment tool, you should ask yourself about the potential for bias in the study you are critically appraising. For any box where you check "no" you should ask, "What is the potential risk of bias resulting from this flaw in study design or execution?" That is, does this factor cause you to doubt the results that are reported in the study or doubt the ability of the study to accurately assess an association between exposure and outcome?

The best approach is to think about the questions in the tool and how each one tells you something about the potential for bias in a study. The more you familiarize yourself with the key concepts, the more comfortable you will be with critical appraisal. Examples of studies rated good, fair, and poor are useful, but each study must be assessed on its own based on the details that are reported and consideration of the concepts for minimizing bias.

Last Updated March 2014

Appendix 10. Appraisal tool for qualitative studies

Critical Appraisal Skills Programme (CASP). 2017. 10 questions to help you make sense of qualitative research [Online]. Available: http://docs.wixstatic.com/ugd/dded87_25658615020e427da194a325e7773d42.pdf [Accessed 03/08/2017]

10 questions to help you make sense of qualitative research

How to use this appraisal tool

Three broad issues need to be considered when appraising a qualitative study:

Are the results of the study valid?	(Section A)
What are the results?	(Section B)
Will the results help locally?	(Section C)

The 10 questions on the following pages are designed to help you think about these issues systematically. The first two questions are screening questions and can be answered quickly. If the answer to both is "yes", it is worth proceeding with the remaining questions.

There is some degree of overlap between the questions, you are asked to record a "yes", "no" or "can't tell" to most of the questions. A number of italicised prompts are given after each question. These are designed to remind you why the question is important. Record your reasons for your answers in the spaces provided.

These checklists were designed to be used as educational pedagogic tools, as part of a workshop setting, therefore we do not suggest a scoring system. The core CASP checklists (randomised controlled trial & systematic review) were based on JAMA 'Users' guides to the medical literature 1994 (adapted from Guyatt GH, Sackett DL, and Cook DJ), and piloted with health care practitioners.

For each new checklist a group of experts were assembled to develop and pilot the checklist and the workshop format with which it would be used. Over the years overall adjustments have been made to the format, but a recent survey of checklist users reiterated that the basic format continues to be useful and appropriate.

Referencing: we recommend using the Harvard style citation, i.e.:

Critical Appraisal Skills Programme (2017). CASP (insert name of checklist i.e. Qualitative Research) Checklist. [online] Available at: *URL*. Accessed: *Date Accessed.*

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Screening Questions

1. Was there a clear statement of the aims of the research? ☐ Yes ☐ Can't tell ☐ No

HINT: Consider
- What was the goal of the research?
- Why it was thought important?
- Its relevance

---

2. Is a qualitative methodology appropriate? ☐ Yes ☐ Can't tell ☐ No

HINT: Consider
- If the research seeks to interpret or illuminate the actions and/or subjective experiences of research participants
- Is qualitative research the right methodology for addressing the research goal?

Is it worth continuing?

Detailed questions

3. Was the research design appropriate to address the aims of the research? ☐ Yes ☐ Can't tell ☐ No

HINT: Consider
- If the researcher has justified the research design (E.g. have they discussed how they decided which method to use)?

4. Was the recruitment strategy appropriate to the aims of the research?

☐ Yes ☐ Can't tell ☐ No

HINT: Consider

- If the researcher has explained how the participants were selected
- If they explained why the participants they selected were the most appropriate to provide access to the type of knowledge sought by the study
- If there are any discussions around recruitment (e.g. why some people chose not to take part)

---

5. Was the data collected in a way that addressed the research issue?

☐ Yes ☐ Can't tell ☐ No

HINT: Consider

- If the setting for data collection was justified
- If it is clear how data were collected (e.g. focus group, semi-structured interview etc.)
- If the researcher has justified the methods chosen
- If the researcher has made the methods explicit (e.g. for interview method, is there an indication of how interviews were conducted, or did they use a topic guide)?
- If methods were modified during the study. If so, has the researcher explained how and why?
- If the form of data is clear (e.g. tape recordings, video material, notes etc)
- If the researcher has discussed saturation of data

---

6. Has the relationship between researcher and participants been adequately considered?

☐ Yes ☐ Can't tell ☐ No

HINT: Consider

- If the researcher critically examined their own role, potential bias and influence during
  (a) Formulation of the research questions
  (b) Data collection, including sample recruitment and choice of location
- How the researcher responded to events during the study and whether they considered the implications of any changes in the research design

7. Have ethical issues been taken into consideration? ❑Yes ❑Can't tell ❑No

HINT: Consider

- If there are sufficient details of how the research was explained to participants for the reader to assess whether ethical standards were maintained
- If the researcher has discussed issues raised by the study (e.g. issues around informed consent or confidentiality or how they have handled the effects of the study on the participants during and after the study)
- If approval has been sought from the ethics committee

8. Was the data analysis sufficiently rigorous? ❑Yes ❑Can't tell ❑No

HINT: Consider

- If there is an in-depth description of the analysis process
- If thematic analysis is used. If so, is it clear how the categories/themes were derived from the data?
- Whether the researcher explains how the data presented were selected from the original sample to demonstrate the analysis process
- If sufficient data are presented to support the findings
- To what extent contradictory data are taken into account
- Whether the researcher critically examined their own role, potential bias and influence during analysis and selection of data for presentation

9. Is there a clear statement of findings? ☐ Yes ☐ Can't tell ☐ No

HINT: Consider

- If the findings are explicit
- If there is adequate discussion of the evidence both for and against the researchers arguments
- If the researcher has discussed the credibility of their findings (e.g. triangulation, respondent validation, more than one analyst)
- If the findings are discussed in relation to the original research question

10. How valuable is the research?

HINT: Consider

- If the researcher discusses the contribution the study makes to existing knowledge or understanding e.g. do they consider the findings in relation to current practice or policy?, or relevant research-based literature?
- If they identify new areas where research is necessary
- If the researchers have discussed whether or how the findings can be transferred to other populations or considered other ways the research may be used

Appendix 11.

Chapter 3 Supplementary Tables S3.1 to S3.7: Descriptive statistics for health outcomes and table of variable transformations

Appendix 11 Chapter 3 Supplementary Tables: Descriptive statistics for health outcomes and table of variable transformations

Table S3.1. Child deaths per woman by country

MICS survey country or group	Number of women Original MICs	Number of women Clean data set	Valid %	Missing %	Median child deaths per woman	Minimum child deaths per woman	Maximum child deaths per woman
Afghanistan	13468	10434	77.5	22.5	.00	0	10
Belize	2735	1419	51.9	48.1	.00	0	6
Bhutan	10356	9644	93.1	6.9	.00	0	8
Bosnia Roma	1000	911	91.1	8.9	.00	0	3
Bosnia	3303	2869	86.9	13.1	.00	0	0
Ghana Accra	754	237	31.4	68.6	.00	0	2
Ghana	7688	6928	90.1	9.9	.00	0	9
Indonesia Papua	2002	1547	77.3	22.7	.00	0	6
Indonesia West Papua	1988	1841	92.6	7.4	.00	0	7
Iraq	32254	24918	77.3	22.7	.00	0	8
Kazakhstan	9490	9219	97.1	2.9	.00	0	13
Kenya Mombasa Informal Settlement	575	509	88.5	11.5	.00	0	4
Kenya Nyanza Province	4778	2255	47.2	52.8	.00	0	8
Lao PDR	16119	14162	87.9	12.1	.00	0	11
Lebanon	2764	1533	55.5	44.5	.00	0	7
Moldova	4123	3759	91.2	8.8	.00	0	3
Mongolia Khuvsgul Aimag	1311	1309	99.8	0.2	.00	0	8
Mongolia	6742	5916	87.7	12.3	.00	0	8
Montenegro	2176	2074	95.3	4.7	.00	0	2
Nigeria	22483	21987	97.8	2.2	.00	0	13

Pakistan Baluchistan	10338	9755	94.4	5.6	.00	0	13
Pakistan Punjab	73415	70364	95.8	4.2	.00	0	15
Serbia Roma	1706	1588	93.1	6.9	.00	0	3
Serbia	3577	3105	86.8	13.2	.00	0	5
Sierra Leone	10258	9752	95.1	4.9	.00	0	13
Somalia North East	3584	3366	93.9	6.1	.00	0	9
Somalia (Somaliland)	3287	2898	88.2	11.8	.00	0	9
South Sudan	7322	5252	71.7	28.3	.00	0	12
Sudan	10839	5986	55.2	44.8	.00	0	10
Swaziland	3291	2581	78.4	21.6	.00	0	5
Ukraine	6478	6188	95.5	4.5	.00	0	3
Vietnam	8179	7569	92.5	7.5	.00	0	5
Zimbabwe	10851	9470	87.3	12.7	.00	0	7
Central African Republic	9417	9175	97.4	2.6	.00	0	12
Chad	12910	11157	86.4	13.6	.00	0	10
Congo	9425	8286	87.9	12.1	.00	0	17
Madagascar	2346	2301	98.1	1.9	.00	0	10
Mauritania	8147	4554	55.9	44.1	.00	0	7
Togo	4722	3418	72.4	27.6	.00	0	7
Tunisia	4475	3461	77.3	22.7	.00	0	5
Total	350676[1]	303697[2]	86.6	13.4	.00	0	313

[1]The total number of cases reporting CDEAD derived once countries excluded which did not include CEB variable, Belarus excluded because it did not included CDEAD variable, Cuba excluded because did not have wealth index quintile variable; [2]Number of cases reporting CDEAD, once limited to cases with predictor variable responses (WS1, WS3 and WS5) to create water carry variable and with other predictor variable data for final analysis; Final analysis of CDEAD once countries/cases with remaining missing data dropped from analysis = 299084 (85.3%). A lot of CDEAD data is missing from Mauritania (44.1%), Sudan (44.8%), Lebanon (44.5), Kenya Nyanza Province (52.8), Ghana Accra (68.6%), Belize (48.1%). In most of these countries data on the type of water source was ambiguous and could have been located in the yard or elsewhere, and/or data indicating the person usually collecting water was absent. The loss of data may bias the results.

Table S3.2. Child under 5 years of age reported as having diarrhoea in past 2 weeks by country

Country	No	Yes	Missing	Total
Afghanistan	11301	3440	579	15320
	73.8 %	22.5%	3.7%	100.0%
Barbados	436	28	27	491
	88.8%	5.7%	5.5%	100.0%
Belarus	3319	124	22	3465
	95.8%	3.6%	0.6%	100.0%
Belize	1794	148	40	1982
	90.5%	7.5%	2.0%	100.0%
Bhutan	4741	1545	171	6457
	73.4%	23.9%	2.6%	100.0%
Bosnia Roma	643	104	13	760
	84.6%	13.7%	1.7%	100.0%
Bosnia	2175	120	37	2332
	93.3%	5.1%	1.6%	100.0%
Ghana Accra	404	47	21	472
	85.6%	10.0%	4.4%	100.0%
Ghana	6422	1126	78	7626
	84.2%	14.8%	1.0%	100.0%
Iraq	30982	5261	356	36599
	84.7%	14.4%	1.0%	100.0%
Jamaica	1542	95	14	1651
	93.4%	5.8%	0.8%	100.0%
Kazakhstan	5094	84	49	5227
	97.5%	1.6%	0.9%	100.0%
Kenya Mombasa	365	89	10	464
Informal Settlements	78.7%	19.2%	2.2%	100.0%
Kenya Nyanza Province	4246	792	119	5157
	82.3%	15.4%	2.3%	100.0%
Lao PDR	9894	1169	195	11258
	87.9%	10.4%	1.7%	100.0%
Lebanon	1645	271	6	1922
	85.6%	14.1%	0.3%	100.0%
Moldova	1736	133	71	1940
	89.5%	6.9%	3.7%	100.0%
Mongolia Khuvsgul	727	87	23	837
Aimag	86.9%	10.4%	2.7%	100.0%

Mongolia	3494	448	172	4114
	84.9%	10.9%	4.2%	100.0%
Montenegro	1384	35	22	1441
	96.0%	2.4%	1.6%	100.0%
Nepal Mid and far Western regions	3139	433	116	3688
	85.1%	11.7%	3.2%	100.0%
Nigeria	21198	3949	871	26018
	81.5%	15.2%	3.3%	100.0%
Pakistan Balochistan	7546	2102	784	10432
	72.3%	20.1%	7.5%	100.0%
Pakistan Punjab	56279	10354	7493	74126
	75.9%	14.0%	10.1%	100.0%
Saint Lucia	271	20	9	300
	90.3%	6.7%	3.0%	100.0%
Sierra Leone	7193	1392	213	8798
	81.8%	15.8%	2.4%	100.0%
Somalia (North East Zone)	4220	484	123	4827
	87.4%	10.0%	2.5%	100.0%
Somalia (Somaliland)	4035	626	111	4772
	84.6%	13.1%	2.3%	100.0%
South Sudan	5373	2925	1742	10040
	53.5%	29.1%	17.4%	100.0%
Sudan	9699	3577	311	13587
	71.4%	26.3%	2.3%	100.0%
Suriname	2944	344	174	3462
	85.0%	9.9%	5.0%	100.0%
Swaziland	75	9	2627	2711
	2.8%	0.3%	96.9%	100.0%
Ukraine	4256	120	26	4402
	96.7%	2.7%	0.6%	100.0%
Vietnam	3409	267	53	3729
	91.4%	7.2%	1.4%	100.0%
Zimbabwe	8313	1555	355	10223
	81.3%	15.2%	3.5%	100.0%
Central African Republic	8027	2442	435	10904
	73.6%	22.4%	4.0%	100.0%
Chad	12691	4261	761	17713
	71.6%	24.1%	4.3%	100.0%
Congo	9189	1894	162	11245

	81.7%	16.8%	1.5%	100.0%
Madagascar	2407	586	137	3130
	76.9%	18.7%	4.4%	100.0%
Mauritania	7691	1568	284	9543
	80.6%	16.4%	3.0%	100.0%
Togo	3706	1039	163	4908
	75.5%	21.2%	3.3%	100.0%
Tunisia	2690	207	41	2938
	91.6%	7.0%	1.4%	100.0%
Argentina	7998	774	158	8930
	89.6%	8.7%	1.8%	100.0%
Costa Rica	2096	174	74	2344
	89.4%	7.4%	3.2%	100.0%
Cuba	5559	462	74	6095
	91.2%	7.6%	1.2%	100.0%
Total cases: countries	292348	56710	19322	368380
reporting diarhhoea [1]	79.4%	15.4%	5.2%	100.0%

[1]Number of reported cases of diarrhoea affecting a child under five years of age in the previous 2 weeks, (Countries with no data on childhood diarrhoea: Indonesia Papua, Indonesia West Papua, Serbia, Serbia Roma); Final number of cases in analysis once cases with missing data for predictor and confounding variables removed (N=290,176; 78.8%); Swaziland had a large amount of data missing (96.9% missing) in the final analysis, which occurred in our data set. It contributes 0.7% of overall data set, and therefore may introduce some bias, but may not have much effect on results. For diarrhoea original MICs valid responses have Yes 15.5%: No 82.1%; in our data set Yes 9 (10.7%): No 75 (89.3%) so similar proportion and likely to underestimate diarrheal prevalence.

Swaziland diarrhoea MICs original✓	No	Yes	Missing	Total
	2226	420	65	2711
	(82.1%)	(15.5%)	(2.4%)	(100%)

Table S3.3. WHO Weight for age (WAZ) and height for age (HAZ) growth scores by country

Country	Z-score	Total Number	Valid Number (%)	Missing Number (%)	Minimum	Max	Mean	Std. Deviation
Barbados	WAZ	491	392 (79.8)	99 (20.2)	-3.93	3.98	.2882	1.38833
	HAZ	491	367 (74.7)	124 (25.3)	-3.98	3.89	.0087	1.32367
Belize	WAZ	1982	1809 (91.3)	173 (8.7)	-3.87	3.95	-.3338	1.16093
	HAZ	1982	1756 (88.6)	226 (11.4)	-3.98	3.44	-.8991	1.26421
Bhutan	WAZ	6457	5973 (92.5)	484 (7.5)	-3.99	3.85	-.7443	1.12161
	HAZ	6457	5439 (84.2)	1018 (15.8)	-3.99	3.86	-1.2279	1.36966
Bosnia Roma	WAZ	760	713 (93.8)	47 (6.2)	-3.82	3.65	-.2593	1.22689
	HAZ	760	662 (87.2)	98 (12.9)	-3.99	3.92	-.6011	1.57750
Bosnia	WAZ	2332	2183 (93.6)	149 (6.4)	-3.56	3.93	.7569	1.10880
	HAZ	2332	2082 (89.3)	250 (10.7)	-3.95	3.96	.2982	1.40449
Ghana Accra	WAZ	472	427 (90.5)	45 (9.5)	-3.93	3.74	-.7174	1.12988
	HAZ	472	421 (89.2)	51 (10.8)	-3.96	3.62	-.4551	1.31842
Ghana	WAZ	7626	7327 (96.1)	299 (3.9)	-3.99	3.95	-.9707	1.06810
	HAZ	7627	7136 (93.6)	490 (6.4)	-3.99	3.82	-1.1784	1.23382
Iraq	WAZ	36599	34803 (95.1)	1796 (4.9)	-3.98	3.99	-.3115	1.13942
	HAZ	36599	33519 (91.6)	3080 (8.4)	-3.99	3.98	-.7976	1.38236
Kazakhstan	WAZ	5227	4970 (95.1)	257 (4.9)	-3.99	3.94	.2228	1.13057
	HAZ	5227	4811 (92.0)	416 (8.0)	-3.97	3.99	-.3455	1.38212
Kenya Mombasa Informal	WAZ	464	443 (95.5)	21 (4.5)	-3.97	2.52	-.7859	1.15463
	HAZ	464	431 (92.9)	33 (7.1)	-3.87	2.78	-.9768	1.24608
Kenya Nyanza Province	WAZ	5157	4881 (94.6)	276 (5.4)	-3.97	3.99	-.6471	1.12946
	HAZ	5157	4632 (89.8)	525 (10.2)	-3.99	3.90	-1.2086	1.37487
Lao PDR	WAZ	11258	10624 (94.4)	634 (5.6)	-3.99	3.71	-1.3271	1.11006
	HAZ	11258	9785 (86.9)	1473 (13.1)	-3.99	3.99	-1.6560	1.28696

Lebanon	WAZ	1922	1856 (96.6)	66 (3.4)	-3.90	3.96	.0086	1.08516
	HAZ	1922	1825 (95.0)	97 (5.0)	-3.97	3.94	-.5318	1.30136
Moldova	WAZ	1940	1683 (86.8)	257 (13.2)	-3.90	3.93	.0899	1.01496
	HAZ	1940	1659 (85.5)	281 (14.5)	-3.97	3.89	-.1611	1.17282
Mongolia KA	WAZ	837	736 (87.9)	101 (12.1)	-3.73	3.73	-.0315	1.23752
	HAZ	837	715 (85.4)	122 (14.6)	-3.99	3.89	-.8418	1.39725
Mongolia	WAZ	4114	3692 (89.7)	422 (10.3)	-3.89	3.99	.0395	1.06623
	HAZ	4114	3611 (87.8)	503 (12.2)	-3.96	3.99	-.8220	1.22786
Montenegro	WAZ	1441	1384 (96.0)	57 (4.0)	-3.32	3.91	.8765	1.11429
	HAZ	1441	1317 (91.4)	124 (8.6)	-3.98	3.91	.3729	1.44999
Nigeria	WAZ	26018	23477 (90.2)	2541 (9.8)	-3.99	3.98	-1.0921	1.28251
	HAZ	26018	21475 (82.5)	4543 (17.5)	-3.99	3.99	-1.2235	1.53005
Pakistan Balochistan	WAZ	10432	4349 (41.7)	6083 (58.3)	-3.99	3.98	-.7019	1.81063
	HAZ	10432	3343 (32.0)	7089 (68.0)	-3.99	3.98	-1.2222	1.96217
Pakistan Punjab	WAZ	74126	61313 (82.7)	12813 (17.3)	-3.99	3.97	-1.4101	1.11223
	HAZ	74126	59180 (79.8)	14946 (20.2)	-3.99	3.99	-1.3104	1.33176
Saint Lucia	WAZ	300	277 (92.3)	23 (7.7)	-2.89	3.96	.1600	1.19215
	HAZ	300	278 (92.7)	22 (7.3)	-2.79	2.84	.1238	1.12544
Serbia Roma	WAZ	1556	1377 (88.5)	179 (11.5)	-3.98	3.94	-.5988	1.13238
	HAZ	1556	1348 (86.6)	208 (13.4)	-3.99	3.99	-.9593	1.25670
Serbia	WAZ	2773	2412 (87.0)	361 (13.0)	-3.40	3.96	.6241	1.13723
	HAZ	2773	2328 (84.0)	445 (16.0)	-3.98	3.95	.3364	1.37815
Sierra Leone	WAZ	8799	7872 (89.5)	927 (10.5)	-3.99	3.96	-.9106	1.27278
	HAZ	8799	6803 (77.3)	1996 (22.7)	-3.99	3.96	-1.4147	1.50046
South Sudan	WAZ	10040	5613 (55.9)	4427 (44.1)	-3.99	3.95	-1.0594	1.34647
	HAZ	10040	5201 (51.8)	4839 (48.2)	-3.99	3.99	-.8083	1.72091
Sudan	WAZ	13587	11439 (84.2)	2148 (15.8)	-3.99	3.68	-1.3574	1.15411

	HAZ	13587	10950 (80.6)	2637 (19.4)	-3.99	3.98	-1.2564	1.39963
Suriname	WAZ	3462	2803 (81.0)	659 (19.0)	-3.81	3.99	-.4056	1.08344
	HAZ	3462	2665 (77.0)	797 (23.0)	-3.98	3.91	-.5405	1.19039
Swaziland	WAZ	2711	74 (2.7)	2637 (97.3)	-2.23	3.62	-.3147	1.25722
	HAZ	2711	69 (2.5)	2642 (97.5)	-2.94	2.68	-.3886	1.25346
Vietnam	WAZ	3729	3587 (96.2)	142 (3.8)	-3.98	3.89	-.6789	1.18086
	HAZ	3729	3491 (93.6)	238 (6.4)	-3.98	3.68	-1.0385	1.26900
Zimbabwe	WAZ	10223	9540 (93.3)	683 (6.7)	-3.98	3.77	-.7586	1.03992
	HAZ	10223	9347 (91.4)	876 (8.6)	-3.99	3.99	-1.2710	1.13907
Central African Republic	WAZ	10904	10036 (92.0)	868 (8.0)	-3.99	3.97	-1.1057	1.16008
	HAZ	10904	9559 (87.7)	1345 (12.3)	-3.99	3.97	-1.4400	1.37027
Chad	WAZ	17713	12235 (69.1)	5478 (30.9)	-3.99	3.94	-1.2115	1.35433
	HAZ	17713	11226 (63.4)	6487 (36.6)	-3.99	3.99	-1.1473	1.64433
Congo	WAZ	11245	10495 (93.3)	750 (6.7)	-3.99	3.92	-1.0344	1.27931
	HAZ	11245	9456 (84.1)	1789 (15.9)	-3.99	3.99	-1.4038	1.51619
Mauritania	WAZ	9544	8319 (87.2)	1225 (12.8)	-3.99	3.99	-1.1024	1.24081
	HAZ	9544	7839 (82.1)	1705 (17.9)	-3.99	3.97	-1.0402	1.45853
Togo	WAZ	4908	4588 (93.5)	320 (6.5)	-3.98	3.54	-1.0545	1.06939
	HAZ	4908	4477 (91.2)	431 (8.8)	-3.99	3.92	-1.3828	1.18370
Tunisia	WAZ	2938	2715 (92.4)	223 (7.6)	-3.98	3.99	.3826	1.12136
	HAZ	2938	2556 (87.0)	382 (13.0)	-3.98	3.96	-.2754	1.35566
Total cases excluding countries without data[1]	WAZ	314087	266417 (84.8)	47670 (15.2)	-3.99	3.99		
	HAZ	314087	251759 (80.2)	62328 (19.8)	-3.99	3.99		

Final analysis of WHO weight for age z-scores N =230, 406, (84.8% of total children under 5 from countries reporting data, including missing cases and cases with values designated as out of possible value range, or 86.5% of cases with plausible values) and Height for age z-scores N = 217, 210 (80.2%) of total children under 5 from countries reporting data, including missing cases and cases with values designated as out of possible value range, or 86.3% of cases with a plausible value). Original data included Z-scores of -6 or above and 6 or less; scores greater than 4 or less than -4 were transformed to 3.99 and -3.99 respectively. [1]Countries with data on children under 5 but no HAZ or WAZ data: Cuba, Costa Rica, Argentina, Madagascar, Ukraine, Somalia (Somaliland), Somalia (North East), Nepal, Jamaica, Indonesia (West Papua), Indonesia (Papua), Belarus, Afghanistan. Swaziland and Pakistan Balochistan have very high number of missing cases.

Table S3.4. Women who gave birth in a health care facility by country

Country	N (%) Original MICs data set[1]		N (%) Clean data set including only cases with outcome and predictor variables						N (%) Original MICs
	No	Yes	No	Yes	Total		Missing[2]		Total
Afghanistan	3054 (61.5%)	1797 (36.2%)	2342 (62.6%)	1398 (37.4%)	3740	75.4%	1222	24.6%	4962 (100.0%)
Barbados	0 (0%)	147 (100%)	0 (0%)	141 (100.0%)	141	95.9%	6	4.1%	147 (100.0%)
Belarus	1 (0.1%)	1322 (99.8%)	1 (0.1%)	1266 (99.9%)	1267	100.0%	0	0.0%	1267 (100.0%)
Belize	47 (6.7%)	651 (92.7%)	35 (9.0%)	352 (91.0%)	387	55.1%	315	44.9%	702 (100.0%)
Bhutan	970 (39.4%)	1488 (60.4%)	874 (38.3%)	1407 (61.7%)	2281	92.5%	184	7.5%	2465 (100.0%)
Bosnia Roma	0 (0%)	264 (98.9)	0 (0.0%)	232 (100.0%)	232	86.9%	35	13.1%	267 (100.0%)
Bosnia	1 (0.1%)	715 (99.6)	1 (0.2%)	622 (99.8%)	623	86.8%	95	13.2%	718 (100.0%)
Ghana Accra	6 (3.2%)	184 (96.8%)	1 (1.8%)	55 (98.2%)	56	29.5%	134	70.5%	190 (100.0%)
Ghana	1240 (43.2%)	1600 (3.0%)	1217 (46.6%)	1396 (53.4%)	2613	91.0%	260	9.0%	2873 (100.0%)
Indonesia Papua	345 (60.4%)	223 (39.1%)	309 (68.5%)	142 (31.5%)	451	79.0%	120	21.0%	571(100.0%)
Indonesia West Papua	310 (59.7%)	192 (37.0%)	298 (63.8%)	169 (36.2%)	467	90.0%	52	10.0%	519 (100.0%)
Jamaica	7 (1.1%)	621 (3.2%)	6 (1.1%)	561 (98.9%)	567	90.0%	63	10.0%	630 (100.0%)
Kazakhstan	7 (0.3%)	2020 (99.7%)	7 (0.4%)	1968 (99.6%)	1975	97.4%	52	2.6%	2027 (100.0%)
Kenya Mombasa Informal	69 (32.5%)	138 (65.1%)	56 (32.4%)	117 (67.6%)	173	81.6%	39	18.4%	212 (100.0%)
Kenya Nyanza Province	806 (43.7%)	957 (51.9%	399 (45.5%)	478 (54.5%)	877	47.6%	967	52.4%	1844 (100.0%)
Laos PDR	2736 (61.6%)	1520 (34.2%)	2662 (69.6%)	1162 (30.4%)	3824	86.0%	620	14.0%	4444(100.0%)
Lebanon (Palestinians)	5 (0.7%)	753 (98.7%)	4 (1.0%)	397 (99.0%)	401	52.6%	362	47.4%	763 (100.0%)
Moldova	4 (0.6%)	717 (99.0%)	4 (0.6%)	643 (99.4%)	647	89.4%	77	10.6%	724 (100.0%)
Mongolia	19 (1.1%)	1665 (98.5%)	17 (1.1%)	1515 (98.9%)	1532	90.7%	158	9.3%	1690 (100.0%)
Nepal	947 (70.7%	372 (27.8%)	939 (72.0%)	365 (28.0%)	1304	97.4%	35	2.6%	1339 (100.0%)
Nigeria	5638 (56.2%)	3960 (39.5%)	5550 (59.0%)	3852 (41.0%)	9402	93.7%	635	6.3%	10037 (100.0%)
Pakistan Balochistan	1792 (76.0%)	507 (21.5%)	1701 (77.9%)	483 (22.1%)	2184	92.6%	174	7.4%	2358 (100.0%)
Pakistan Punjab	11434 (45.0%)	13798 (54.3%)	11004 (45.5%)	13179 (54.5%)	24183	95.2%	1223	4.8%	25406 (100.0%)

Saint Lucia	0 (0%)	98 (100%	0 (0.0%)	66 (100.0%)	66	67.3%	32	32.7%	98 (100%)
Serbia Roma	6 (1.1%)	556 (98.1%)	6 (1.2%)	513 (98.8%)	519	91.5%	48	8.5%	567 (100.0%)
Serbia	4 (0.4%)	949 (99.0%)	3 (0.4%)	792 (99.6%)	795	82.9%	164	17.1%	959 (100.0%)
Sierra Leone	1690 (49.5%)	1658 (48.6%)	1628 (50.6%)	1590 (49.4%)	3218	94.2%	197	5.8%	3415 (100.0%)
Somalia (North East)	1283 (84.0%)	198 (13.0%)	1198 (86.3%)	190 (13.7%)	1388	90.9%	139	9.1%	1527 (100.0%)
Somalia (Somaliland)	1030 (66.2%)	492 (31.6%)	934 (69.2%)	415 (30.8%)	1349	86.6%	208	13.4%	1557 (100.0%)
South Sudan	3505 (86.2%)	475 (11.7%)	2540 (87.8%)	352 (12.2%)	2892	71.1%	1175	28.9%	4067 (100.0%)
Sudan	4508 (78.0%	1202 (20.8%)	2285 (74.6%)	779 (25.4%)	3064	53.0%	2713	47.0%	5777 (100.0%)
Suriname	62 (4.9%)	1140 (90.1%)	57 (5.4%)	1002 (94.6%)	1059	83.7%	206	16.3%	1265 (100.0%)
Swaziland	146 (14.3)	824 (80.9%)	132 (16.7%)	658 (83.3%)	790	77.6%	228	22.4%	1018 (100.0%)
Ukraine	4 (0.3%)	1546 (98.8%	3 (0.2%)	1463 (99.8%)	1466	93.7%	98	6.3%	1564 (100.0%)
Vietnam	141 (10.3%)	1219 (89.4%)	139 (11.1%)	1113 (88.9%)	1252	91.9%	111	8.1%	1363 (100.0%)
Zimbabwe	726 (18.6%)	3115 (79.6%)	701 (20.5%)	2713 (79.5%)	3414	87.2%	499	12.8%	3913 (100.0%)
Central African Republic	2028 (43.8%	2463 (53.2%)	1989 (45.4%)	2390 (54.6%)	4379	94.6%	251	5.4%	4630 (100.0%)
Chad	4956 (80.5%)	1110 (18.0%	4384 (84.0%)	832 (16.0%)	5216	84.8%	937	15.2%	6153 (100.0%)
Congo	1010 (21.0%)	3667 (76.3%)	987 (23.9%)	3142 (76.1%)	4129	85.9%	680	14.1%	4809 (100.0%)
Madagascar	892 (74.8%)	272 (22.8%	876 (76.7%)	266 (23.3%)	1142	95.7%	51	4.3%	1193 (100.0%)
Mauritania	1243 (34.3%)	2253 (62.1%)	656 (33.4%)	1311 (66.6%)	1967	54.2%	1662	45.8%	3629 (100.0%)
Togo	753 (38.4%)	1164 (59.4%	572 (40.0%)	857 (60.0%)	1429	72.9%	532	27.1%	1961 (100.0%)
Tunisia	30 (2.6%)	1104 (97.3%)	27 (3.2%)	805 (96.8%)	832	73.3%	303	26.7%	1135 (100.0%)
Costa Rica	7 (0.8%)	839 (98.2%)	7 (0.9%)	806 (99.1%)	813	95.2%	41	4.8%	854 (100.0%)
Total	53462 (45.4%)	61955 (52.7%)	46551 (46.3%)	53955 (53.7%)	100506	85.4%	17160	14.6%	117666 (100.0%)

[1]Percentages of No + Yes for original MICs data do not add up to 100 because of missing values in original MICs data set; [2]Missing = missing data in original MICs data set + missing cases due to lack of predictor and/or confounding variables in final analysis. Number in final analysis 100505 (85.4%).

Table S3.5. Number of times a woman received antenatal care (ANC) and square root (√) of mean times received ANC by country

Country	Received ANC	Times received ANC		Clean data set times received ANC and √mean times received ANC										
	N (original MICs MN1)	N (original MICs MN3)	Don't know/ Missing	N Valid Times ANC	% Valid Times ANC	N Missing Times ANC	Mean	SD	Min	Max	√ANC	SD	Min	Max
Barbados	146	130	16	126	86.3%	20	13.92	5.36	3	30	3.66	0.71	1.73	5.48
Belarus	1323	1320	3	1264	95.5%	59	9.99	.243	5	10	3.16	0.04	2.24	3.16
Belize	687	609	78	323	47.0%	364	7.72	3.761	1	40	2.71	0.63	1.00	6.32
Bhutan	2402	2386	16	2216	92.3%	186	5.02	2.126	1	29	2.19	0.47	1.00	5.39
Bosnia Roma	209	209	0	184	88.0%	25	8.15	6.011	1	37	2.68	0.97	1.00	6.08
Bosnia	627	619	8	535	85.3%	92	9.43	4.983	1	50	2.99	0.72	1.00	7.07
Ghana Accra	186	180	6	55	29.6%	131	7.49	3.114	3	19	2.68	0.55	1.73	4.36
Ghana	2771	2753	18	2529	91.3%	242	5.94	2.408	1	33	2.39	0.50	1.00	5.74
Indo Pap	450	450	0	342	76.0%	108	5.54	2.870	1	18	2.27	0.64	1.00	4.24
Indo W Pap	449	447	2	416	92.7%	33	5.85	3.177	1	23	2.32	0.68	1.00	4.80
Iraq	10386	10060	326	7476	72.0%	2910	4.83	2.891	0	40	2.11	0.61	0.00	6.32
Jamaica	621	566	55	514	82.8%	107	8.18	3.375	1	32	2.80	0.59	1.00	5.66
Kazakhstan	2011	1790	221	1748	86.9%	263	11.91	5.322	1	40	3.36	0.77	1.00	6.32
Kenya Mombasa	198	198	0	165	83.3%	33	4.03	1.882	1	10	1.95	0.47	1.00	3.16
Kenya (Nyanza)	1702	1702	0	851	50.0%	0	3.88	1.798	0	14	1.92	0.45	0.00	3.74
Laos PDR	2358	2358	0	1968	83.5%	0	4.37	2.346	1	18	2.01	0.57	1.00	4.24
Lebanon	739	728	11	374	50.6%	365	8.36	3.286	1	27	2.83	0.58	1.00	5.20
Moldova	716	709	7	639	89.2%	77	8.52	3.733	2	36	2.86	0.57	1.41	6.00
Mongolia KA	299	290	9	289	96.7%	10	6.65	4.480	1	48	2.49	0.69	1.00	6.93
Mongolia	1677	1493	184	1363	81.3%	314	8.33	4.210	1	30	2.80	0.69	1.00	5.48

Nepal	1001	993	8	981	98.0%	20	3.55	1.513	0	15	1.84	0.40	0.00	3.87
Saint Lucia	95	90	5	59	62.1%	36	10.64	6.789	2	35	3.13	0.92	1.41	5.92
Serbia (Roma)	543	531	12	492	90.6%	51	5.99	3.049	1	30	2.37	0.62	1.00	5.48
Serbia	949	946	3	788	83.0%	161	8.83	3.842	1	30	2.91	0.62	1.00	5.48
Sierra Leone	3279	2909	370	2795	85.2%	484	6.93	4.608	0	48	2.53	0.75	0.00	6.93
Somalia (NE)	433	420	13	393	90.8%	40	2.49	1.436	1	11	1.53	0.41	1.00	3.32
South Sudan	1952	1725	227	1240	63.5%	712	3.69	3.041	0	48	1.83	0.60	0.00	6.93
Suriname	1224	901	323	797	65.1%	427	9.36	4.886	0	32	2.95	0.81	0.00	5.66
Swaziland	982	980	2	798	81.3%	184	5.01	1.941	1	15	2.19	0.44	1.00	3.87
Ukraine	1540	1452	88	1370	89.0%	170	13.44	7.427	1	65	3.53	0.98	1.00	8.06
Vietnam	1266	1261	5	1159	91.5%	107	5.08	3.242	1	40	2.16	0.66	1.00	6.32
Zimbabwe	3722	3688	34	3270	87.9%	452	5.09	2.740	1	60	2.19	0.54	1.00	7.75
CAR	3514	3390	124	3305	94.1%	209	3.79	1.851	0	24	1.89	0.46	0.00	4.90
Chad	3496	3413	83	2785	79.7%	711	3.64	1.830	0	21	1.85	0.46	0.00	4.58
Congo	4234	4163	71	3661	86.5%	573	3.77	1.750	0	30	1.89	0.43	0.00	5.48
Madagascar	935	929	6	911	97.4%	24	3.74	1.478	1	10	1.89	0.39	1.00	3.16
Mauritania	3070	2864	206	1663	54.2%	1407	4.10	1.855	1	20	1.98	0.43	1.00	4.47
Togo	1717	1680	37	1248	72.7%	469	4.09	1.868	0	20	1.97	0.45	0.00	4.47
Tunisia	1111	1104	7	806	72.5%	305	6.32	2.805	1	20	2.45	0.57	1.00	4.47
Costa Rica	837	827	10	798	95.3%	39	8.19	3.412	1	40	2.81	0.55	1.00	6.32
Total	65857	63263	2594	52696	80.0%	11920	5.78	3.993	0	65	2.29	0.73	0.00	8.06

Number in final analysis 52696 (80%)

Table S3.6. Child left home alone for 1 or more hours, 1 or more days per week by country

Country	No	Yes	Missing	Total
Afghanistan	10341	4174	889	15404
	67.1%	27.1%	5.8%	100.0%
Barbados	458	4	29	491
	93.3%	0.8%	5.9%	100.0%
Belarus	3424	19	22	3465
	98.8%	0.5%	0.6%	100.0%
Belize	1923	20	39	1982
	97.0%	1.0%	2.0%	100.0%
Bhutan	5854	408	195	6457
	90.7%	6.3%	3.0%	100.0%
Bosnia and Herzegovina Roma	714	32	14	760
	93.9%	4.2%	1.8%	100.0%
Bosnia and Herzegovina	2283	13	36	2332
	97.9%	0.6%	1.5%	100.0%
Ghana Accra	394	58	20	472
	83.5%	12.3%	4.2%	100.0%
Ghana	6280	1247	99	7626
	82.3%	16.4%	1.3%	100.0%
Iraq	34634	1642	323	36599
	94.6%	4.5%	0.9%	100.0%
Jamaica	1614	23	14	1651
	97.8%	1.4%	0.8%	100.0%
Kazakhstan	5058	121	48	5227
	96.8%	2.3%	0.9%	100.0%
Kenya Mombasa Informal	395	58	11	464
	85.1%	12.5%	2.4%	100.0%
Kenya Nyanza Province	2502	2527	128	5157
	48.5%	49.0%	2.5%	100.0%
Lao PDR	10360	621	277	11258
	92.0%	5.5%	2.5%	100.0%
Lebanon	1799	112	11	1922
	93.6%	5.8%	0.6%	100.0%
Moldova	1844	25	71	1940
	95.1%	1.3%	3.7%	100.0%
Mongolia KA	789	25	23	837
	94.3%	3.0%	2.7%	100.0%
Mongolia	3836	111	167	4114

	93.2%	2.7%	4.1%	100.0%
Montenegro	1406	13	22	1441
	97.6%	0.9%	1.5%	100.0%
Nepal	2362	1158	168	3688
	64.0%	31.4%	4.6%	100.0%
Nigeria	19101	5910	1007	26018
	73.4%	22.7%	3.9%	100.0%
Pakistan Balochistan	7054	2071	1307	10432
	67.6%	19.9%	12.5%	100.0%
Saint Lucia	284	7	9	300
	94.7%	2.3%	3.0%	100.0%
Serbia Roma	1500	11	45	1556
	96.4%	0.7%	2.9%	100.0%
Serbia	2712	3	58	2773
	97.8%	0.1%	2.1%	100.0%
Sierra Leone	6577	1779	442	8798
	74.7%	20.2%	5.0%	100.0%
Somalia (North East)	4062	609	156	4827
	84.2%	12.6%	3.2%	100.0%
Somalia (Somaliland)	4089	531	152	4772
	85.7%	11.1%	3.2%	100.0%
Suriname	3213	70	179	3462
	92.8%	2.0%	5.2%	100.0%
Swaziland[1]	85	0	2626	2711
	3.1%	0.0%	96.9%	100.0%
Ukraine	4309	68	25	4402
	97.9%	1.5%	0.6%	100.0%
Vietnam	3539	137	53	3729
	94.9%	3.7%	1.4%	100.0%
Zimbabwe	9428	442	353	10223
	92.2%	4.3%	3.5%	100.0%
Central African Republic	7968	2295	641	10904
	73.1%	21.0%	5.9%	100.0%
Chad	11450	4586	1677	17713
	64.6%	25.9%	9.5%	100.0%
Congo	8361	2671	213	11245
	74.4%	23.8%	1.9%	100.0%
Madagascar	2482	511	137	3130
	79.3%	16.3%	4.4%	100.0%

Mauritania	7933	1031	579	9543
	83.1%	10.8%	6.1%	100.0%
Togo	3918	816	174	4908
	79.8%	16.6%	3.5%	100.0%
Tunisia	2728	168	42	2938
	92.9%	5.7%	1.4%	100.0%
Argentina	8253	468	209	8930
	92.4%	5.2%	2.3%	100.0%
Costa Rica	2228	43	73	2344
	95.1%	1.8%	3.1%	100.0%
Total	219544	36638	12766	268948
	81.6%	13.6%	4.7%	100.0%

Swaziland has large amount of missing data compared to original MICs. It contributes 0.7% of overall data set, and therefore may introduce some bias, but may not have much effect on results. For child left alone original MICs valid responses have Yes 4.2%: No 95.7%; in our data set Yes 0 (0%): No 85 (100.0%) so likely to underestimate child left alone prevalence.

Swaziland original MICs	2532	109	70	2711
	93.4%	4.0%	2.6%	100.0%

Number in final analysis once cases missing predictor or confounding variables deleted 228307 (84.9%)

Table S3.7. Variable transformations

Original MICs variable	Transformation	New variable
Main source of drinking water (WS1) and location of the water source (WS3: only asked of survey respondents reporting that their main drinking water was obtained from non-piped sources; specified the location of the water source as in the dwelling, yard or elsewhere) WS5: categorised as adult woman aged 15+, adult man aged 15+, female child <15, male child <15.	WS1 and WS3 combined to capture the location (in own dwelling, in own yard/plot or elsewhere) of all reported water source types for all households. Respondents who had not indicated the location of their water source, but who did provide the water source type, were transformed into the following response categories; • 'piped into dwelling', 'piped into compound or yard' and 'rainwater collection' were assumed to be located in the home or yard; • 'piped to neighbour', 'public standpipe or tap', 'filter plant', 'water yard/hand pump', 'tanker truck', 'cart with small tank/drum', 'surface water', bottled water' and 'sachet water' were assumed to be located elsewhere; 'tube well/borehole', 'hand pump', 'motorised pump', 'protected/unprotected well', 'protected/unprotected spring', 'reverse osmosis', 'other' and 'missing' were designated as missing because these sources could possibly be located in the respondents own yard or elsewhere. • respondents with their main drinking water located in their own dwelling or yard were assumed to not be a water fetching household, whilst those obtaining water from elsewhere were assumed to be a water fetching household (variable 'Water fetching household' Yes/No) The new 'Water fetching household' variable was combined with Person collecting water (WS5) to create new water carrying variable	Water carrying categorised as no one, adult woman aged 15+, adult man aged 15+, female child <15, male child <15.

Main source of drinking water (WS1)	Original response categories transformed into 2015 JMP definitions of improved and unimproved water sources	Improved water supply yes/no
Type of toilet facility (WS8) with 20 categories	Transformed to 4 response options, flush toilet, other improved, unimproved, open defecation	Toilet facility category
Type of toilet facility (WS8) with 20 categories	Calculated percentage of households within unique cluster using flush toilets or improved toilet and transformed into percentage coverage quintiles, with 80-100% category further divided in to 80-90% and 90-100% coverage	Improved sanitation usage (% within cluster)
Highest level of education of household head (helevel)	Transformed to two response categories, no education or primary level, and secondary school or higher.	Highest level of education of household head
Place of delivery (MN18) with 20 response categories (96 = 'other', 99 = 'missing')	Dichotomised to birth in health care facility (public or private) yes/no (96, 99 excluded from analyses)	Birth in a health care facility yes/no
Times received antenatal care as continuous variable (MN3) (98 = 'don't know', 99 = 'missing')	Square root of number of times received antenatal care	Square root antenatal care
Number of days per week child left alone for more than one hour (8 = 'don't know, 9 = 'missing')	Dichotomised into child left alone for more than one hour, on one or more days per week yes/no (excluding 8 & 9)	Child left alone >1hour, one or more days per week yes/no

WHO Weight for age z-score (99.97 = 'measurement out of range; 99.98 = 'z-score out of range'; 99.99 = 'missing')	Scores equal to or less than -4 transformed to -3.99; scores equal to or greater than 4 transformed to 3.99 (99.97, 99.98, 99.99 excluded from analyses)	WHO Weight for age z-score corrected
WHO Height for age z-score (99.97 = 'measurement out of range; 99.98 = 'z-score out of range'; 99.99 = 'missing')	Scores equal to or less than -4 transformed to -3.99; scores equal to or greater than 4 transformed to 3.99 (99.97, 99.98, 99.99 excluded from analyses)	WHO Height for age z-score corrected

Appendix 12. DfID Household survey questionnaire

PART I: Water Use

Public health and social benefits of at-house versus shared water supply

Section 1 – Demographic / Economic

Section 2 – Inputs (Water source)

Section 3 – Outputs (Water use / Time Spent / Storage / Hygiene / Sanitation)

Obtain written / oral consent to participate in the study from the household participant(s) before proceeding with the interview: NOW ATTACH THE CONSENT FORM TO THE BACK OF THIS QUESTIONNAIRE.

SUMMARY INFORMATION

Date	
Country	
Community	
Household ID	
Household GPS Waypoint	

Team details:

Interviewer 1: ____**(Print & Sign Name)**

(Print name – to identify the person who conducted the interview

Sign name – to verify interviewer has performed self check of completed HHQ prior to conducting the next interview)

Quality controller ____**(Print & Sign Name)**

(Print name – to identify the reviewer who checks the completed HHQ for completeness and sense

Sign name – to verify the review has been carried out and any queries have been resolved)

Supporting Notes to complete the Questionnaire:

- *Questions are to be directed to an adult within the household unless otherwise stated*
- *Questions applicable to another person should be directed to that person where possible. Where this is not possible, the interviewer should ask the main respondent to respond on the other's behalf.*
- *Where question is not applicable, please enter code 333*
- *Where the respondent did not wish to answer, please enter code 444*
- *Where respondent did not know the answer, please enter code 555*
- *Ensure that all questions are marked up by the interviewer as any empty questions will be considered accidental omissions.*
- *Please specify that all questions are about typical use patterns in the current season*
- *Where answers are coded, record the participants code with the codes number. Do not simply tick.*
- *Text in Italics is provided as notes to the interviewers and are not to be read out to the participant(s).*

(Section 1) Household Demographics

Can you tell me who lives here? *(Give the main respondent ID #1)*

1. How many people normally live in your household (*number*)						
2. Is the head of your household male (0) or female (1) *(Gender)*?						
3. Person ID #	4. First and middle name	5. Gender *0 – male* *1 – female* *(Gender)*	6. Relationship to head of household *(relHH)* *0 - Head of household* *1 - wife/husband* *2 - son/daughter* *3 - son/daughter in-law* *4 - grandchild* *5 - parent of HH* *6 - brother/sister* *7 - nice/nephew by blood* *8 - niece/nephew by marriage* *9 - adopted/foster/stepchild* *10 - other*	7. Age (years)	8. Level of education current or achieved *0 – never attended school* *1 – primary* *2 – second* *3 – lower second* *4 – higher second* *5 – higher* *6 – other* *(edulevel)*	9. In the last month did you stay in this house most days? *0 – No* *1 - Yes*
(main respondent) 1						
2						
3						
4						
5						
6						
7						
8						

Employment

	10. In the last 12 months did your household receive any of the following funds: 0 – No 1 – Yes	11. Amount
0 - Wage		*wkly*
1 - Land revenue		*wkly*
2 - Property rent		*wkly*
3 - Remittances		*yearly*
4 - Social Benefits		*wkly*
5 -Other		

12. Does your family own this house?

0. No *ownhouse* |__|__|

1. Yes |__|__|

13. Which of these statements best describes your household?

0. Single family: single story house *residenttype* |__|__|Go to next question)

1. Single family, multi-story house |__|__|Go to next question)

2. Multiple families, single story house |__|__|Go to next question)

3. Multiple families, multi-story house |__|__|Go to next question)

4. Single family apartment/tenement |__|__|(Go to question 16)

14. What material is your roof made from? (*requires in-country check)*

0. Concrete or tile *roofmaterial* |__|__|

1. Metal (including corrugated iron) |__|__|

2. Wood/straw/plastic |__|__|

3. Other |__|__|

15. What material is used on the floor of your house? (*requires in-country check)*

0. Concrete slabs/bricks/tiles *floormaterial* |__|__|

1. Wooden tile |__|__|

2. Earth floor / soil |__|__|

3. Other |__|__|

16. How many rooms do the household use for sleeping when everyone you identified in the first table s in the house? *(kitchen included but not counting the bathrooms, toilets, balconies, hallways, and terraces, don't include visitors)*
Numerical Response ....

17. Does your house have electricity?

0. No *electric* |__|__|

1. Yes |__|__|

18. In the house, what is the total number of_______ that you have – that are currently working? *(numerical response):*

0.	Radio/Radio Cassette	how many: ....
1.	Television	how many: ....
2.	Telephone mobile	how many: ....
3.	Refrigerator	how many: ....
4.	Washing Machine	how many: ....
5.	Car	how many: ....
6.	Bicycle	how many: ....
7.	Motorbike	how many: ....
8.	Stove (gas/electric/kerosene)	how many: ....

333=Not applicable | 444=Answer declined | 555=Don't know

19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.
Which of these best describes your main water supply in the current season? *(what does the user see?)* *Interviewers should take a photo of the water system for verification after the study.* ***Tick here if photograph has been taken [ ]***	On a normal day, what number of people will take water from this source? *(Numerical Response)*	On a normal day, what number of people do you think use water from this source? (0) <250px /50 HH (1) ~250px/ ~50 HH (2) >250px/ >50 HH	Is the pressure of the supply: 0. bad 1. satisfactory 2. good	Over the last 2 weeks, how many days was there no water? *(Numerical Response)*	During the days when water was available, on average, how many hours of supply do you receive a day? *(Numerical Response)*	When it broke down the last time, how many days did it take for your main water supply system to become operable again? *(Numerical Response)*	Do you have a water meter that records your monthly household water usage? 0. No 1. Yes	If you can't read a water meter can you estimate the total amount of water your household uses a day in the current season? *(litres)* *(you may have to work with the participant to estimate this)*	If you have a water meter according to your water meter, how much water did your household use last month? *(water bill)*	How much did you pay for your water last month? *(local currency cost)*
	numuse	*propuse*	*pressure*	*nowater*	*hrswater*	*dayswater*	*waterm*	*estmwater*	*billwater*	*costw*
Piped supply to in-house taps (inside compound)										
Piped supply HH tap (1) (i.e. coming from outside HH)		-								
Piped Supply to yard (2) A tap in yard/garden –could be stored in overground tank		-								
Well(motorised pump)(3) A tap in yard/garden from your own well with motor pump		-	-				-		-	
Well (manual lifting pump) (4)		-	-		-		-		-	
Rainwater collection(5)		-	-		-	-	-		-	
Shared supply (outside compound)										
Piped supply with tap(7)	-						-	-	-	
Covered well with Manual Pump(8)	-						-	-	-	
Open well with manual lifting (9)	-		-		-		-	-	-	
Surface water (river, pond, stream (10)	-		-		-	-	-	-	-	-
Rainwater collection(11)										

Seasonal water availability

Months of the Year	30. Are there typically any months in the year where water from your main source is not available? 0 – No 1 - Yes *nowater*	*31.* Reason for no water *(write reason in English)* *whynowater*
Jan		
Feb		
Mar		
Apr		
May		
June		
July		
Aug		
Sept		
Oct		
Nov		
Dec		

(SECTION 3) OUTPUTs

Domestic Use *(defined as activities that relate to the home including subsistence gardening and animal keeping)*
Productive Use *(defined as any activity that uses water (collected or from a water system) that results in a monetary return or non-monetary gain)*

	Domestic Use							***Productive Use***					
32. Thinking about each use – which water sources do you mostly use? *(Complete for all that apply)* *(Interviewers to circle code relating to relevant level of services)* 0=No 1=Yes 333=if they do not do this activity	Drinking	Preparing food	Bathing	Cleaning House	Washing clothes	Washing dishes	Home Garden /Animals	Agriculture / Farming / Crops	Aquaculture (fish / prawns etc)	Raising of animals, or animal produce	Laundry for others	Preparing food /drink	Washing vehicles for others
0 – Main source													
1- Alternative Source													
2- Main and Alternative sources													
33. Taking all sources together where do you mostly do you do these activities: 0-at home 1-at source 2-elsewhere 3-multiple locations *(where)*								*(Farming uses)*			*(Commercial services)*		
34. When did you last do this activity? *(number of days ago)*								*(Farming uses)*			*(Commercial services)*		

What is/are your alternative water source(s)? *(Use codes in question19)*

35. Alternative Source A________________ / |__|__|__|

36. Alternative Source B_______________ / |__|__|__|

_

37. Alternative Source C________________ / |__|__|__|

38. Would you say you are able to access enough water to meet your water needs to undertake your **domestic** activities *(within the house/compound)?*

0. No	*supply*	|__|__|
1. Less than half of the time		|__|__|
2. About half of the time		|__|__|
3. More than half of the time		|__|__|
4. Yes		|__|__|
Not applicable		|__|__|__|

39. Would you say are able to access enough water to meet your water needs to undertake commercial or **productive** activities? *(defined as any activity that uses water that results in a monetary return or non-monetary gain)*

0. No	*Supply*	|__|__|
1. Less than half of the time		|__|__|
2. About half of the time		|__|__|
3. More than half of the time		|__|__|
4. Yes		|__|__|
Not applicable		|__|__|__|

40. *If* you said no for either domestic or productive water uses please state the reasons why you don't have enough access to the water you require.

0. Storage problems	*storageprob*	|__|__|
1. Number of water collectors		|__|__|
2. Number of water collection containers that can be used		|__|__|
3. Temporal (absolute) availability of water source		|__|__|
4. Seasonal (absolute) availability of water		|__|__|
5. Power to extract water from source of water		|__|__|
6. Reliability or predictability of source of water		|__|__|
7. Price		|__|__|
8. Water pressure		|__|__|
9. Accessibility (location) to supply		|__|__|
Not applicable		|__|__|__|

Current water carriers

41. Does anyone in your household ever carry water from a source outside of your home or yard?

0.	No	waterout	|__|__|*(Go to question 56)*
1.	Yes		|__|__|*(Go to next question)*
Not applicable			|__|__|__|

42. If yes which of these sources is it?

Piped supply to in-house taps (inside compound)

1.	Piped supply HH tap (i.e. coming from outside HH)	|__|__|
2.	Piped Supply to yard (i.e. A tap in yard/garden –could be stored in over ground tank)	|__|__|
3.	Well (motorised pump) (i.e. A tap in yard/garden from your own well with motor pump)	|__|__|
4.	Well (manual lifting pump)	|__|__|
5.	Rainwater collection system	|__|__|

Shared supply (outside compound)

6.	Piped supply with tap	|__|__|
7.	Covered well with Manual Pump	|__|__|
8.	Open well with manual lifting	|__|__|
9.	Surface water (river, pond, stream)	|__|__|
10.	Rainwater collection system	

43. How many months of the year do you collect water from a source (which is outside the home)?

1.	One	|__|	2.	Two	|__|
3.	Three	|__|	4.	Four	|__|
5.	Five	|__|	6.	Six	|__|
7.	Seven	|__|	8.	Eight	|__|
9.	Nine	|__|	10.	Ten	|__|__|
11.	Eleven	|__|__|	12.	Twelve	|__|__|

Ask these questions of each person who carries water:

	wateryears	*waterdays*	*watertripsday*	*watercarry*	*waterout*	*queue*	*waterrtn*	*contain*	*containhold*	*containfill*	*safety*
44. Person ID	45. How many years have you been collecting water for? (years)	46. How many days in a week do you normally collect water? *(days)*	47. How many trips to the water point do you usually make per day, on days that you collect water? *(1 trip = going to the water source AND back again)*	48. How do you normally carry or move your water containers back to your house? *0 – motor vehicle* *1- animal driven cart* *2 – human driven cart* *3 – wheelbarrow* *4 – manually rolling container along ground* *5 – hippo roller/Q-drum* *6 – balanced on head* *7 – basket with head straps* *8 – carried not on head* *9 – yoke across shoulders with buckets* *10 – other*	49. How long does it take you to get to your usual water point? (Estimated time to water source) *(minutes)*	50. How long do you normally have to queue for water? *(minutes)*	51. How long does it take you to get to your usual water point and back home with filled containers? (Estimated round trip collection time) *(minutes)*	52. How many containers do you normally carry per trip? *(number)*	53. How much water does each water container hold? *(list volume in litres for each)*	54. Do you fill the water containers? 0 - 100% full 1- 75% full 2- 50% full	55. Have you ever felt at risk whilst collecting water? 0-No 1-Yes
									|		
									|		
									|		
									|		

Past water carriers

Ask only of participants who used to carry water but no longer do.

	wateragesrt	*wateragestp*	*freqcarry*	*whystop*
56. Person ID	57. How old were you when you started carrying water? *(years)*	58. How old were you when you stopped collecting water *(years)*	59. How often did you carry water? 0. Daily 1. Weekly 2. Monthly 3. Rarely	60. What was the main reason you stopped? 0. Changed to a private supply 1. Physically unable to 2. Someone else started to collect water for me / my household 3. Other

Current and Past Water Carriers - Manual or Physical Work

	worktype	*workhead*	*workhours*	*workyears*
61. Person ID	62. Does the work you undertake involve? 0. Sedentary work 1. Manual work 2. Both sedentary and manual work	63. Does this work involve you carrying heavy loads on your head (separate from carrying water)? 0-No 1-Yes	64. How many hours a day would you usually do this work? *(hours)*	65. How many years have you been performing this work? *(years)*

Opportunity cost of time spent

Target the following question at an adult (ideally at person ID #1) (Persons ID if not #1___________)

66. Can you tell me what you did during the day yesterday from 5am in the morning till 5am this morning?

	Diary		*SCHEDULE CODES*
5 – 5:30		*1*	*Sleep*
5:30 - 6		*2*	*Drink and Eat*
6 - 6:30		*3*	*Resting*
6:30 - 7		*4*	*Washing (dishes and / or clothes)*
7 - 7:30		*5*	*Dressing, getting ready*
7:30 - 8		*6*	*Going to get water*
8 - 8:30		*7*	*Preparing to eat*
8:30 - 9		*8*	*Other domestic activities*
9 - 9:30		*9*	*Purchases (at the market, etc.)*
9:30 - 10		*10*	*Taking care of other members of the household*
10 - 10:30		*11*	*Work and activities related to work (going to work, finding a job …)*
10:30 - 11		*12*	*Professional training*
11 - 11:30		*13*	*Religious and spiritual activities*
11:30 - 12		*14*	*Spending time with other people*
12 - 12:30		*15*	*Watching television*
12:30 - 13		*16*	*Going to school, doing homework*
13 - 13:30		*17*	*Phone calls, letters, emails, internet, video games*
13:30 - 14		*18*	*Walking*
14 - 14:30		*19*	*Playing*
14:30 - 15		*20*	*Playing sports*
15 - 15:30		*21*	*Visits / meeting*
15:30 - 16		*22*	*Bathing*
16 - 16:30		*23*	*Going to the toilet*
16:30 - 17		*24*	*Other*

	Diary		*SCHEDULE CODES*
17 - 17:30		*1*	*Sleep*
17:30 - 18		*2*	*Drink and Eat*
18 - 18:30		*3*	*Resting*
18:30 - 19		*4*	*Washing (dishes and / or clothes)*
19 - 19:30		*5*	*Dressing, getting ready*
19:30 - 20		*6*	*Going to get water*
20 - 20:30		*7*	*Preparing to eat*
20:30 - 21		*8*	*Other domestic activities*
21 - 21:30		*9*	*Purchases (at the market, etc.)*
21:30 - 22		*10*	*Taking care of other members of the household*
22 - 22:30		*11*	*Work and activities related to work (going to work, finding a job …)*
22:30 - 23		*12*	*Professional training*
23 - 23:30		*13*	*Religious and spiritual activities*
23:30 - 24		*14*	*Spending time with other people*
24 - 0:30		*15*	*Watching television*
0:30 - 1		*16*	*Going to school, doing homework*
1 - 1:30		*17*	*Phone calls, letters, emails, internet, video games*
1:30 - 2		*18*	*Walking*
2 - 2:30		*19*	*Playing*
2:30 - 3		*20*	*Playing sports*
3 - 3:30		*21*	*Visits / meeting*
3:30 - 4		*22*	*Bathing*
4 - 4:30		*23*	*Going to the toilet*
4:30 - 5		*24*	*Other*

Water storage and treatment

67. Are you storing water right now?

0. No *waterstore* |__|__| *(go to question 67)*
1. Yes |__|__| (go to next question)

68. In how many containers are you currently storing water in and how much do they hold?

	Type 1	Type 2	Type 3	Type 4
Number of containers of this type				
Volume container (max) *(litres)*				

Try to look at the containers to verify their volume capacity - (If you don't know the volume – take photo and ask the team later)

69. Do you have any additional containers for water storage that aren't being used?

0. No *storeother* |__|__|
1. Yes |__|__|

Hygiene Practices

*Interviewers **Observation***

Can you please show me where you usually wash your hands?

70. Is soap present?

0. No *handssoap* |__|__|
1. Yes |__|__|

Household Sanitation

Water for Toilet Use

71. Do you have a toilet in the house and **if so may I see it**? (*Interviewer observes if in use or used for something else e.g. storage*)

0. Toilet not present *observetoilet* |__|__|
1. Toilet present and signs of use |__|__|
2. Toilet present and not used |__|__|

Answer declined |__|__|__|

72. Are there any other points that I haven't asked about that you think may be helpful for me to know?

---

73. Additional notes made by interviewer

FINAL STEPS

A) Organise Date of 2nd Interview

Thank you for going through that questionnaire with me.

My colleague will visit soon visit you to complete the last bit of the study.

This will involve:

1. Some questions about your households health
2. If you use a shared water source we may also ask to measure the height and weight of the usual water carrier and follow them on their normal trip to collect water and take a sample of the water collected.

Can you tell me a convenient time and day for the other interviewer to visit you?

The interviewer and the main respondent have agreed that my colleague will return to this house on:

DATE ___________________________

TIME ___________________________

B) Agreement to partake in group-meetings

Would you like to be involved in future opportunities to discuss this topic? If you are could you provide me with your details on how best to contact you. We can then invite you to any future group discussions. You can then decide nearer the time if you would like to attend.

Tick this box if you have invited them [.....] *(do not indicate whether they have agreed to be invited or not)*

Collect their contact details on a separate form along with a signed copy of their consent for the team to use their details 'to be invited to a group meeting'. Store this separately from the HHQ consent form that you attach to this HHQ.

C) Please could someone show me where your shared water source is? *(Do not do this if this household has been selected for Part IIb (i.e. if this house is one of the 10% sample)*

(If main source is a shared source – record this. If they have more than one shared alternative source they use equally, record last source they are happy to take you to)

Prepare GPS to track route, elevation and distance.

Waypoint at water source ___________________________

Water source code ___________________________

Photo taken No / Yes *(circle whether a photo of the water supply system has been taken)*

Thank you again.

Survey Close

(DON'T FORGET TO ATTACH THE CONSENT FORM FOR THE STUDY TO THE BACK OF THIS QUESTIONNAIRE)

COPY OUT DETAILS RECORDED EARLIER IN TABLE BELOW AND GIVE TO 2ND INTERVIEWER TO CONDUCT PART 2

Household GPS Waypoint				
Person ID #	First and middle name	Gender *0 – male* *1 - female*	Age (years)	Water Carrier *0 – No* *1 - Yes*
1 *(main respondent)*				
2				
3				
4				
5				
6				

PART II: HEALTH & SOCIAL

Public health and social benefits of at-house versus shared water supply

Household Questionnaire

Part IIa – Health and Water Carriers (200 households)

Part IIb – Anthropometric measurements / trip with water carrier / water quality measurements (20 households only)

Date	
Country	
Community	
Household ID	
Household GPS Waypoint	

Team details:

Interviewer 1: ____**(Print & Sign Name)**

(Print name – to identify the person who conducted the interview

Sign name – to verify interviewer has performed self check of completed HHQ prior to conducting the next interview)

Quality controller ____**(Print & Sign Name)**

(Print name – to identify the reviewer who checks the completed HHQ for completeness and sense

Sign name – to verify the review has been carried out and any queries have been resolved)

Supporting Notes to complete the Questionnaire:

- *Questions are to be directed to an adult within the household unless otherwise stated (useful to ask a female adult if available)*
- *Questions applicable to another person should be directed to that person where possible. Where this is not possible, the interviewer should ask the main respondent to respond on the other's behalf.*
- *Where question is not applicable, please enter code 333*
- *Where the respondent did not wish to answer, please enter code 444*
- *Where respondent did not know the answer, please enter code 555*
- *Please specify that all questions are about typical use patterns in the current season*
- *Where answers are coded, record the participants code with the codes number. Do not simply tick.*
- *Ensure you have both the hand out cards – 1. Borg Scale and 2. Likert Scales.*

IMPORTANT

- *Ensure you have a copy of the person ID sheet copied over from HHQ Part 1*
- *Check with interviewer 1 if a parent/guardian signed the consent form presented in Part 1 – to enable participation of children in the study.*
- *If children under 5 years are present and consent has been obtained please proceed with question 11.*
- *If children under 5 years are present but consent has not been obtained DO NOT proceed with question 11 and enter code: 444.*
- *If no children are present the enter code: 333.*

Part IIa: Health

(Unless stated otherwise, applicable to all household participants)

Health; Diarrhoea, Skin, Eye problems

Please ask the following questions to all persons in the household (or direct them to the main household respondent on behalf of everyone in the household where HH members are not present).

	Skin	*skintime*	*eye*	*eyetime*	*diarrhoea*	*miss*
Person ID *(Obtain copy of ID sheet from HQ Part 1)*	1. Has any person in the household reported any skin symptoms in the last 2 weeks (e.g. itchy, dry, scaly skin)? 0. No 1. Yes	2. How long have they had these symptoms for? (days)	3. Has any person in the household reported any eye infections over the last 2 weeks (e.g. redness, itching, swelling – not injury) 0. No 1. Yes	4. How long have they had these symptoms for? *(days)*	5. Do you know of anyone in the household who has had diarrhoea (*passage of 3 or more loose or liquid stools within 24-hour period*) in the last 2 weeks? 0. No 1. Yes	6. Did any of these this result in you missing work or school? 0. No 1. Yes 333. N/A 444. A/D 555. D/K

Peri-natal history and health

Potentially sensitive questions - try to speak to all women in the household of child bearing age (13years – 50 years)

Can I ask about the birth history of the household over the last 3 years?

womenid	*numberchild*	*childborn*	*Pregout*	*pregstat*
ID number of all Women *(refer to copy of ID sheet from HQ Part 1 and enter women between ages 13-50 years)*	7. Has this women given birth to a child (born alive or still-born) in the last 3 years? (*NB: this does not include miscarriages)* *0. No (go to next woman)* *1. Yes*	8. How many children born alive and still alive *(numerical)*	9. How many children born alive but no longer alive *(numerical)*	*10.* How many children born dead *(numerical)*
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|
	|__|__|__|	|__|__|__|	|__|__|__|	|__|__|__|

Mid-Upper Arm Circumference

I'd like to measure the circle around the mid-upper arm of your children who are under 5 years old. I would do it using this tape.

*Do this for **all children under 5** present in the household at the time of survey.*

Consent must have been provided already by the parent/guardian to include child's participation measurement.

Person ID (children <5years)	Can I measure the width of their mid-upper arm? . *(centimetres up to 1 decimal point e.g. 13.4cm)* muac		
	[Notes: Measure length between the bony protrusion on the shoulder and the point of the elbow]	*[Notes: Divide length by 2]*	11. Circumference of upper arm at the mid-point
			Measurement 1
			Measurement 2

Instructions on obtaining the Mid-Upper-Arm-Circumference:

1. *The subject's left arm should be bent at the elbow at a 90 degree angle, with the upper arm held parallel to the side of the body.*
2. *Measure the distance between the bony protrusion on the shoulder (acromion) and the point of the elbow (olecranon process).*
3. *Mark the mid-point with soluble pen/pencil.*
4. *Ask the subject to let arm hang loose and measure around the upper arm at the mid-point, making sure that the tape measure is snug but not tight.*
5. *Repeat process.*
6. *Acceptable error of measurement in boys is 3.1mm whereas it is 3.0mm for girls. HOWEVER, if measurements are greater than the allowable measurement error, no additional measurement should be undertaken.*

Disability

12. Does anyone in your family ever have any difficulty in doing day-to-day activity because of a health condition, which has lasted or is expected to last for 6 months or more?

00. No disabilityhealth |__|__|

01. Yes |__|__|

13. Person ID with disability |__|__| OR N/A |__|__|__|

General Functioning and Disability questions

Provide participant with coded health card (Likert scale).

	Female adult with private water supply or female adult (or child) who is a known water carrier 14. Person ID ________	Child (>5years and <16years) with a private water supply or a child who is a known water carrier 15. Person ID ________
Disability		
Do you have difficulty in doing the following activities: *0. No difficulty* *1. Some difficulty* *2. A lot of difficulty* *3. Cannot do it at all*		
16. Seeing, even if wearing glasses?		
17. Breathing?		
18. Hearing, even if using a hearing aid?		
19. Walking or climbing steps?		
20. Remembering or concentrating?		
21. With self-care, such as washing all over or dressing?		
22. Communicating, such as understanding or being understood by others?		
Health Today		
23. In general, how would you rate your health **today**? *1. Very good* *2. Good* *3. Moderate* *4. Bad* *5. Very Bad*		
Pain		
24. In the past week (7 days) have you had any physical pain? 0. No *(Go to question 28)* 1. Yes *(Go to next question)*		
25. If yes, was that pain: 0. Mild 1. Moderate 2. Severe		

26. How long has your pain lasted for? 0. Less than one month 1. One month or more but less than 3 months 2. Three months or more		
27. Is your pain 0. Always present 1. It comes and goes		
28. Where do you mainly feel that pain? *Participants may indicate one or more area.* 0. Head 1. Neck 2. Shoulders/arms 3. Hands 4. Lower back 5. Upper back 6. Chest/ribs 7. Abdomen/stomach 8. Hips/pelvis or legs 9. Feet		
Impairment of function screening questions		
Do you: *0. No* *1. Yes (lasted less than 1 month)* *2. Yes (lasted more than one month/permanent)*		
29. have any difficulty using your arms?		
30. have any difficulty using your legs?		
31. have any difficulty using any other part of your body such as your back and neck?		
32. ever have 'fits' or 'epilepsy', or loss of consciousness?		
Perceived cause of functional impairment		
33. 'So that I can be clear, would you say that the difficulty was caused by any of the following'? 0. Illness 1. Injury 2. You were born with it 3. Something else happened ('please explain') 4. You don't know what caused it 333. N/A		

PART IIb:

Height & Weight Measurement / Route Monitoring / Water Sampling

The following section is applicable to **10%** of participating households only (Part IIb for 20 HH only)
This section should target the 'usual' or last water carrier only.

Anthropometric Survey *(At the participants house)*

Measurements of person who mainly does the water fetching/carrying (or last person who collected water if main water carrier unavailable).

May I measure your height and weight?

Person ID	1. 1st Height (cm – to the nearest mm e.g. 126.2cm)	2. Weight (kg)	3. 2nd Height (*again*) (cm – to the nearest mm e.g. 126.2cm)	4. Average height =(1st height + 2nd height)/2 (cm – to the nearest mm e.g. 126.2cm)
	Wcheight1	*Wcweight*	*Wcheight2*	*Wcheight3*

Interviewer notes:
Height measurements require pockets to be emptied and shoes off.
Participant breaths in.
Headpiece brought down onto the head.
Participant breathes out.
Height measurement is taken.
If 1st height and 2nd height are greater than 2cm apart, start measurements again.
If 3rd height and 4th height are greater than 2cm apart, abandon attempts to measure height in this person.
Interviewer 2 may take the measurements and interact with the household participants. An assisting interviewer may record the measurements taken by interviewer 2 on this sheet. The assisting interviewer must not interact or support the Part2 of the interview in any other way.

Observed Water Collection

Step 1: Describe the water walk

1. Observed Water Collection

I would now like to accompany you on your route to collect water. We can leave whenever you are ready. Please don't attempt to do anything differently from that which you usually would do to collect water.

During the trip I'll also make a note of the distance you travel and how much water you take home.

2. Water Sampling

I would also like to take two water samples along your trip:

(a) one at your water collection point source

(b) one from the storage container in which you put the collected water

3. Questions?

1. Do you have any questions about this at all? Y/N

- Do not proceed until all questions have been answered to the satisfaction of the participant

2.May I accompany you and observe while you collect water as you usually would? Y/N

– If the answer is Yes to this question, please proceed. If the answer is no please re-visit the consent form and either seek agreement, or find an alternative water carrier from the household who is happy for the water trip to be observed, or thank them for their time and end the questionnaire

Interviewer Checklist:

Check that the GPS is receiving satellite
Stopwatch
Water testing kit
Camera

Step 2: Prepare to Leave the House: Make Waypoint (HH #ID)

1. Participant ID		
2. GPS waypoint of house Waypoint Ref: _____________		

Information about water carrying containers: at the home

3. Container ID#	4. Estimated volume of this type of container (litres)	5. Number of this type of container	6. Weight of empty container (kg)
Container type 1			
Container type 2			
Container type 3			

7. Mode of transport

0	*motor vehicle*	
1	*animal driven cart*	
2	*human driven cart*	
3	*Wheelbarrow*	
4	*manually rolling container along ground*	
5	*hippo roller/Q-drum*	
6	*balanced on head*	
7	*basket with head straps*	
8	*carried not on head*	
9	*yoke across shoulders with buckets*	
10	*Other*	

8. Time leaving the house (24hour clock)	

Prepare GPS to track route, elevation and distance.

Step 3: Clear Current Track

Step 4: Turn Track ON

Step 5: Walk to the Water Source

Observation Points along the Terrain *(make these relevant for the majority of the route taken)*

9. What is the path made of? (Composition)		
0	Sand/grass	
1	Gravel	
2	Pavement (concrete or slabs	
3	Bitumen	
4	Mixed	

10. Is the path sloping or flat? (Incline)		
0	Flat or gentle	
1	Moderate slope	
2	Steep slope	

11. What condition is the path in? (Path Condition)		
0	Poor (a lot of bumps, cracks, holes, rocks or weeds)	
1	Moderate (some bumps cracks, holes, rocks or weeds)	
2	Good (very few bumps, cracks, holes rocks or weeds)	

Step 6: At the source: Make Way Point (HH #ID WS #ID)

Arriving at the Water Source (data collected using GPS, stopwatch, observation and water testing kit)

12. Time arriving at the water source (24hour clock)	
13. GPS reading at water source	

14. Photo taken of water source *(HH ID# and Coded Water Source)*	
15. Water source type 0. Piped supply with tap (standpipe/capped well with mechanical pump/protected spring with tap) 1. Sealed / covered well with Manual Pump 2. Open well with manual lifting] 3. Surface water (river, pond, stream) 4. Rainwater collection point 5. Other (specify)	
16. Is this your normal water source for drinking? 0. No 1. Yes	
17. Water sample taken at water source 0. No 1. Yes	(coded 'V_HH#ID_S')
18. Activities observed whilst at the water source (that lasted over 2minutes): 0. queuing 1. chatting 2. washing laundry 3. dishes 4. other	

Step 7: Filling

19. Container ID#	20. Time taken to fill 1 container *(00:00 min:sec)*	21. Estimated percentage that the container is filled to (%)	22. Weight of each full container (kg)
Container type 1			
Container type 2			

* *(if more than 1 container at a given volume just measure the first container of that size)*

Step 8: Explain the Borg Scale

Explain to the participant that after carrying water, you will ask them to rate how hard it feels. Read the following phrase, and show them the scale, and explain that you will show them this again when they are home, and will ask them then to rate how it felt carrying water.

INTERVIEWERS TO SAY THIS:

"While you are carrying water, try to estimate how hard you feel the work is. Rate the degree of perceived exertion you feel. Include the total amount of exertion and physical fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath or how hard the work is. Try to concentrate on your total, inner feeling of exertion. Estimate your exertion as honestly and neutrally as possible. Rate your perception of the exertion using the Borg Scale – see the table below.'

Step 9: Return Home

Upon returning to the home

23. Time arriving back at the home (24hour clock)	

Show the participant the scale and ask the participant to rate how much they felt they exerted themselves collecting water using the Borg scale. (Please circle value communicated by participant)

24. Using this scale can you tell me how much you felt you exerted yourselves whilst you collected water?

Code	Borg	Rating Perceived Exertion Scale
00	0	Nothing at all
01	0.5	Very, very weak (just noticeable)
02	1	Very weak
03	2	Weak (light)
04	3	Moderate
05	4	Somewhat strong
06	5	Strong (heavy)
07	6	-
08	7	Very Strong
09	8	-
10	9	-
11	10	Maximal

25. May I now take a sample of water from a container where you store your drinking water?

Water sample taken from drinking water container
(note label to following – (Country__HH#ID__"H")

Please check if collected and labeled _______________

Step 10: SAVE Current Track

GPS Unit ID: ____

Track ID (HH ID# WT or Automatic GPS Name): ____

26. Round-Trip Distance to Source (m) ____

Thank the participant for their time and for participating in the study.

Ask them if they have any questions for you.

Thank you.

Survey Close

Appendix 13. South African enumerator training timetable

Appendix 13 ENUMERATOR TRAINING 2012

Day 1 Ethics and conduct				
Time	**Topic**	**Activity**	**Learning Outcome**	**Resources**
9.00 – 10.30	Informed, voluntary consent, Declaration of Helsinki	• Introduce day • Time to read summary of declaration	Has knowledge of the content of the declaration	DoH hand-out
	'Informed': what information do participants need to make a choice & decide whether to participate in the study?	• Group discussion in response to JG reading out the survey information inviting study participation • List on flipchart 'what you would want to know before making a decision' • Go through each point and have participants write down/share a sensible answer; phrase a response	Will be able to provide sufficient information about the study for participants to make an informed decision on participation	Flipchart and stand Flipchart pens Enumerator folder with training information, copies of survey and other data collection tools, spare paper for note writing, pens, plastic sleeves, SA child protection act and declaration of Helsinki
10.30 – 10.45	**Break**			
10.45 – 11.45	'Voluntary'	• Group define 'voluntary'; e.g. is truly free to make choice about participation; understands is free to withdraw at any time; is assured and believes there will be no adverse consequence of withdrawing from study • Round Robin discussion about communication/behaviours which might be perceived as coercive/bullying • Discussion of who might do this (researcher, parent, husband/wife) • Plan of what to do if someone is coercing someone else to participate	Will be able to facilitate behaviour and manage environment so that all participants decisions to participate are voluntary	Participant information and consent forms Flip chart, pens etc

11.45 – 12.15	'Consent'	Agreement to participate; discuss • Verbal • Written • Non-verbal • Child v adult • Record of consent: discuss form	Will be able to recognise and record consent appropriately	Participant information and consent forms Flip chart, pens etc
12.15-1.15	**Lunch**			
1.15 – 2.15	Child protection act	• Participants read hand-out of relevant sections of the act, highlight unfamiliar terms and key issues with highlighter pen • Discussion of key points, summary on flip chart	Will be able to identify indicators of child abuse in accordance with the South African Child Protection Act	Paper copy of the relevant sections of the act
2.15 – 2.45	Vignette	• Discussion in response to vignette and question 'What should enumerator do?' • Summarise on flip chart of potential actions	Will be able to respond to indicators of child abuse in accordance with the South African Child Protection Act	Vignette case study, flipchart
2.45 – 3.15	Summary	• Read key points summary of Child protection Act, clarify any questions		Key points summary of the Act
3.15 – 3.30	**Break**			
3.30 – 5.30	Researcher conduct	• Round Robin of behaviour/qualities enumerators should demonstrate • List key points on flip chart, categorise into pairs • In pairs, provide example of situation/scenario which might challenge that behaviour : pairs to suggest 3 possible responses to the situation and write them up on flip chart • Individuals to indicate with red, amber, green dots, which is preferred response • Group discussion about behaviour	Will be able to identify and prioritise appropriate conduct for researchers during field and project work	Flip chart, RAG sticker dots
Day 2 Survey tools				

9.00m – 9.30	Intro to parts of survey	Read and discuss introductory session	Will be able to complete the introductory section of the survey	Survey Introductory section
9.30-10.30	Role play Part 1	• Role play in pairs • Highlight questions on form	Will be able to conduct and record Part 1 of Survey	Part 1 of Survey
10.30-10.45	**Break**			
10.45 – 12.00	Role play part 1	• Swap over pairs to role play • Highlight questions on form • Clarify questions	Will be able to conduct and record Part 1 of Survey	Part 1 of Survey
12.00- 1.00	**Lunch**			
1.00 – 2.00	Role play Part 2	• Role play in pairs • Highlight questions on form	Will be able to conduct and record Part 2 of Survey	Part 2 of Survey
2.00 – 3.00	Role play part 2	• Swap over pairs to role play • Highlight questions on form		Part 2 of Survey
3.00 – 3.15	**Break and clarify questions**			
3.15 – 5.15	Community Observation	• Discuss • Do in pairs with walk through community • Compare findings and clarify questions	Will be able to conduct and record community observation	Community Observation Checklist
Day 3 Anthropometric Measures and Risk Assessment				
9.00 – 10.45	Anthropometric measures techniques	• Practice measurement techniques of height, weight, waist circumference, MUAC	Will be able to conduct anthropometric measurement techniques	Anthropometric training manual
11.00 – 11.15	**Break**			
11.15 – 12.00	Anthropometric measures process	• Run through process in 3's	Will be able to conduct and record anthropometric measurement process	Anthropometric training manual
12.00 - 12.45	Anthropometric measures process	• Run through process in 3's, swapped roles		Anthropometric training manual

12.45 – 1.45	**Lunch and clarify questions**			
1.45 – 2.45	Walk with Garmin watch	• Practice placement and operation of watch • Walk to agreed point and return	Will be able to position and operate Garmin forerunner 210	Anthropometric training manual Garmin watches
2.45 – 3.00	**Break and clarify questions**			
3.00 – 4.30	Risk assessment	• Round Robin and list risks and hazards considering safety and security • Discuss actions to remove/reduce /mitigate risk and how to manage hazard if occurs • Discuss log books and daily checks to do	Will be able to analyse potential risks related to data collection and field work Will be able to formulate strategies to manage risk	Risk assessment form Log books Flip chart, pens etc
4.30- 5.00	Summary and close	• Opportunity for questions and clarification • Give out certificates of attendance		

Appendix 14. Chapter 4 Supplementary tables and figures

Appendix 14 Chapter 4 supplementary tables and figures

Table S4.1 History of water carriage

Personal history of water carriage	Frequency	Percent (%)	Valid (%)	Cumulative (%)
Currently	967	28.7	28.7	28.7
Previously	412	12.2	12.2	41.0
No history	1986	59.0	59.0	100.0
Total	3365	100.0	100.0	

Table S4.2 History of water carriage by country

Country		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Ghana	Currently	444	33.5	33.5	33.5
	Previously	98	7.4	7.4	40.9
	No history	784	59.1	59.1	100.0
	Total	1326	100.0	100.0	
South Africa	Currently	374	30.4	30.4	30.4
	Previously	206	16.7	16.7	47.2
	No history	650	52.8	52.8	100.0
	Total	1230	100.0	100.0	
Vietnam	Currently	149	18.4	18.4	18.4
	Previously	108	13.3	13.3	31.8
	No history	552	68.2	68.2	100.0
	Total	809	100.0	100.0	

Table S4.3 Past water carriers (Q56 ID) SA n = 207; GH n = 104; V n = 110

Variable	Country	N (%)	Mean (SD)	Median (Range)
Age when started carrying water	SA	144 (69.6%)	10.8 (8.4)	9 (5 – 65)
	GH	80 (76.9%)	12.5 (7.3)	10 (5 – 52)
	V	85 (77.3%)	26.0 (11.5)	25 (5 – 54)
Age when stopped carrying water	SA	162 (78.3%)	37.2 (19.4)	33.5 (5 – 87)
	GH	82 (78.8%)	32.7 (12.6)	30 (14 – 70)
	V	101 (91.8%)	34.5 (12.9)	34 (6 - 79)
Years water carrying	SA	130 (62.8%)	25.4 (19.4)	20 (0 – 81)
	GH	77 (74.0%)	19.7 (14.5)	18 (1 – 60)
	V	83 (75.5%)	7.1 (10.2)	4 (0 – 66)

Table S4.4 Physical pain in previous 7 days[1]

Pain previous 7 days		Frequency	Percent	Valid Percent	Cumulative Percent
Adult	No	309	9.2	50.6	50.6
	Yes	302	9.0	49.4	100.0
	Total	611	18.2	100.0	
Missing	System	2754	81.8		
Child	No	327	9.7	84.7	84.7
	Yes	59	1.8	15.3	100.0
	Total	386	11.5	100.0	
Missing	System	2979	88.5		
Total		3365	100.0		

[1]Pain and disability questions asked of 1 adult and 1 child per household, therefore the large number of missing participants is appropriate.

Table S4.5 Self-reported pain in previous 7 days

Adult n 611	**Response category**	**GH n225 Frequency (%)**		**SA n202 Frequency (%)**		**V n184 Frequency (%)**	
		At-home	Shared	At-home	Shared	At-home	Shared
Pain in past 7 days (Q24)	No	40 (41.2)	56 (43.8)	69 (67.0)	60 (60.6)	67 (47.2)	17 (39.0)
	Yes	57 (58.8)	72 (56.3)	34 (33.0)	39 (39.4)	75 (52.8)	25 (58.5)
	Total	97 (100.0)	128 (100.0)	103 (100.0)	99 (100.0)	142 (100.0)	42 (97.6)
Child n380	**Response category**	**GH n167 Frequency (%)**		**SA n131 Frequency (%)**		**V n82 Frequency (%)**	
		At-home	Shared	At-home	Shared	At-home	Shared
Pain in past 7 days (Q24)	No	58 (76.3)	79 (86.8)	70 (95.9)	55 (94.8)	46 (80.7)	19 (76.0)
	Yes	18 (23.7)	12 (13.2)	3 (4.1)	3 (5.2)	11 (19.3)	6 (24.0)
	Total	76 (100.0)	91 (100.0)	73 (100.0)	58 (100.0)	57 (100.0)	25 (100.0)

*Refers only to severity of pain experienced in last 7 days;

Table S4.6 Location of pain

Pain location		Frequency	Percent	Valid Percent	Cumulative Percent
Abdomen/ stomach	No	899	26.7	90.2	90.2
	Yes	98	2.9	9.8	100.0
	Total	997	29.6	100.0	
Chest/ ribs	No	929	27.6	93.2	93.2
	Yes	68	2.0	6.8	100.0
	Total	997	29.6	100.0	
Feet	No	943	28.0	94.6	94.6
	Yes	54	1.6	5.4	100.0
	Total	997	29.6	100.0	
Hands	No	952	28.3	95.5	95.5
	Yes	45	1.3	4.5	100.0
	Total	997	29.6	100.0	
Head	No	860	25.6	86.3	86.3
	Yes	137	4.1	13.7	100.0
	Total	997	29.6	100.0	
Hips/ pelvis or legs	No	853	25.3	85.6	85.6
	Yes	144	4.3	14.4	100.0
	Total	997	29.6	100.0	
Lower back	No	863	25.6	86.6	86.6
	Yes	134	4.0	13.4	100.0
	Total	997	29.6	100.0	
Neck	No	897	26.7	90.0	90.0
	Yes	100	3.0	10.0	100.0
	Total	997	29.6	100.0	
Shoulder/ arms	No	913	27.1	91.6	91.6
	Yes	84	2.5	8.4	100.0
	Total	997	29.6	100.0	
Upper back	No	908	27.0	91.1	91.1
	Yes	89	2.6	8.9	100.0
	Total	997	29.6	100.0	
Missing	System	2368	70.4		
Total		3365	100.0		

Table S4.7 Pain location by country and water supply

Adult	Response category (yes)	GH n225 Frequency (%)		SA n202 Frequency (%)		V n184 Frequency (%)	
		At-home n97	Shared n128	At-home n103	Shared n99	At-home n142	Shared n42
Pain location (Q28)*	Head	37 (38.1)	49 (38.3)	5 (4.9)	3 (3.0)	16 (11.3)	2 (4.8)
	Neck	21 (21.6)	28 (21.9)	2 (1.9)	2 (2.0)	35 (24.6)	5 (11.9)
	Shoulder/arms	14 (14.4)	21 (16.4)	3 (2.9)	3 (3.0)	35 (24.6)	7 (16.7)
	Hands	18 (18.6)	17 (13.3)	3 (2.9)	2 (2.0)	1 (0.7)	1 (2.4)
	Lower back	27 (27.8)	31 (24.2)	3 (2.9)	8 (8.1)	47 (33.1)	16 (38.1)
	Upper back	33 (34.0)	37 (28.9)	5 (4.9)	5 (5.1)	5 (3.5)	1 (2.4)
	Chest/ribs	19 (19.6)	26 (20.3)	3 (2.9)	8 (8.1)	3 (2.1)	2 (4.8)
	Abdomen/stomach	22 (22.7)	37 (28.9)	4 (3.9)	5 (5.1)	11 (7.7)	2 (4.8)
	Hips/pelvis or legs	25 (25.8)	34 (26.6)	7 (6.8)	9 (9.1)	44 (31.0)	17 (40.5)
	Feet	13 (13.4)	20 (15.6)	4 (3.9)	5 (5.1)	7 (4.9)	0 (0.0)
Children	**Response category (yes)**	**GH n167 Frequency (%)**		**SA n131 Frequency (%)**		**V n82 Frequency (%)**	
		At-home n76	Shared n91	At-home n73	Shared n58	At-home n25	Shared n57
Pain location (Q28)*	Head	13 (17.1)	9 (9.9)	0 (0.0)	1 (1.7)	2 (3.5)	0 (0.0)
	Neck	5 (6.6)	1 (1.1)	0 (0.0)	0 (0.0)	1 (1.8)	0 (0.0)
	Shoulder/arms	2 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Hands	2 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.8)	0 (0.0)
	Lower back	2 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (8.0)
	Upper back	2 (2.6)	0 (0.0)	1 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)
	Chest/ribs	3 (3.9)	1 (1.1)	1 (1.4)	0 (0.0)	1 (1.8)	1 (4.0)
	Abdomen/stomach	8 (10.5)	4 (4.4)	0 (0.0)	1 (1.7)	2 (3.5)	3 (12.0)
	Hips/pelvis or legs	3 (3.9)	1 (1.1)	0 (0.0)	0 (0.0)	4 (7.0)	0 (0.0)
	Feet	4 (5.3)	0 (0.0)	1 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)

Table S4.8 Pain severity

Pain severity		Frequency	Percent	Valid Percent	Cumulative Percent
Adult	Mild	70	2.1	23.2	23.2
	Moderate	126	3.7	41.7	64.9
	Severe	106	3.2	35.1	100.0
	Total	302	9.0	100.0	
Missing	System	3063	91.0		
Child	Mild	23	.7	39.0	39.0
	Moderate	21	.6	35.6	74.6
	Severe	15	.4	25.4	100.0
	Total	59	1.8	100.0	
Missing	System	3306	98.2		
Total		3365	100.0		

Table S4.9 Self-reported pain severity by water supply location

Adult n 611	Response category	GH n225 Frequency (%)		SA n202 Frequency (%)		V n184 Frequency (%)	
		At-home	Shared	At-home	Shared	At-home	Shared
Pain intensity (Q25)*	Mild	15 (15.5)	19 (14.8)	3 (2.9)	1 (1.0)	25 (17.6)	7 (16.7)
	Moderate	23 (23.7)	27 (21.1)	14 (13.6)	16 (16.2)	33 (23.2)	13 (31.0)
	Severe	19 (19.6)	26 (20.3)	17 (16.5)	22 (22.2)	17 (12.0)	5 (11.9)
	Total responses	57 (58.8)	72 (56.3)	34 (33.0)	39 (39.4)	75 (52.8)	25 (59.5)
	N/A	40 (41.2)	56 (43.8)	69 (67.0)	60 (60.6)	67 (47.2)	17 (40.5)
Child n380	**Response category**	**GH n167 Frequency (%)**		**SA n131 Frequency (%)**		**V n82 Frequency (%)**	
		At-home	Shared	At-home	Shared	At-home	Shared
Pain intensity (Q25)*	Mild	4 (5.3)	4 (4.4)	0 (0.0)	0 (0.0)	7 (12.3)	3 (12.0)
	Moderate	7 (9.2)	4 (4.4)	1 (1.4)	3 (5.2)	4 (7.0)	1 (4.0)
	Severe	7 (9.2)	4 (4.4)	2 (2.7)	0 (0.0)	0 (0.0)	2 (8.0)
	Total responses	18 (23.7)	12 (13.2)	3 (4.1)	3 (5.2)	11 (19.3)	6 (24.0)
	N/A	58 (76.3)	79 (86.8)	70 (95.9)	55 (94.8)	46 (80.7)	19 (76.0)

*Refers only to severity of pain experienced in last 7 days;

N/A = not applicable, participant had not experienced pain in last 7 days

Table S4.10 Pain Duration

Pain duration		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Adult	<1 month	143	4.2	48.5	48.5
	≥1 month <3months	40	1.2	13.6	62.0
	≥3 months	112	3.3	38.0	100.0
	Total	295	8.8	100.0	
Missing	System	3070	91.2		
Child	<1 month	40	1.2	75.5	75.5
	≥1 month <3months	6	.2	11.3	86.8
	≥3 months	7	.2	13.2	100.0
	Total	53	1.6	100.0	
Missing	System	3312	98.4		
Total		3365	100.0		

Table S4.11 Pain consistency

Pain consistency		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Adult	Always present	110	3.3	36.5	36.5
	Comes and goes	191	5.7	63.5	100.0
	Total	301	8.9	100.0	
Missing	System	3064	91.1		
Children	Always present	10	.3	19.2	19.2
	Comes and goes	42	1.2	80.8	100.0
	Total	52	1.5	100.0	
Missing	System	3313	98.5		
Total		3365	100.0		

Table S4.12 Pain duration and consistency by country and water supply location

Adult n611	**Response category**	**GH n225 Frequency (%)**		**SA n202 Frequency (%)**		**V n184 Frequency (%)**	
		At-home n97	Shared n128	At-home n103	Shared n99	At-home n142	Shared n42
Pain duration (Q26)	<1 month	32 (33.0)	52 (40.6)	16 (15.5)	23 (23.2)	12 (8.5)	8 (19.0)
	≥1 month <3 months	13 (13.4)	8 (6.3)	6 (5.8)	7 (7.1)	4 (2.8)	2 (4.8)
	≥3 months	10 (10.3)	12 (9.4)	9 (8.7)	8 (8.1)	58 (40.8)	15 (35.7)
	Total responses	55 (56.7)	72 (56.3)	31 (30.1)	38 (38.4)	74 (52.1)	25 (59.5)
	N/A	42 (43.3)	56 (43.8)	72 (69.9)	61 (61.6)	68 (47.9)	17 (40.5)
Constant pain (Q27)	always present	19 (19.6)	19 (14.8)	11 (10.7)	11 (11.1)	35 (24.6)	15 (35.7)
	comes and goes	38 (39.2)	53 (41.4)	23 (22.3)	27 (27.3)	40 (28.2)	10 (23.8)
	Total responses	57 (58.8)	72 (56.3)	34 (33.0)	38 (38.4)	75 (52.8)	25 (59.5)
	N/A	40 (41.2)	56 (43.7)	69 (67.0)	61 (61.6)	67 (47.2)	17 (40.5)
Children n380	**Response category**	**Ghana n167 Frequency (%)**		**SA n131 Frequency (%)**		**V n82 Frequency (%)**	
		At-home n76	Shared n91	At-home n73	Shared n58	At-home n25	Shared n57
Pain duration (Q26)	<1 month	15 (19.7)	10 (11.0)	3 (4.1)	2 (3.4)	6 (10.5)	3 (12.0)
	≥1 month <3 months	2 (2.6)	1 (1.1)	0 (0.0)	1 (1.7)	0 (0.0)	2 (8.0)
	≥3 months	0 (0.0)	1 (1.1)	0 (0.0)	0 (0.0)	5 (8.8)	1 (4.0)
	Total responses	17 (22.4)	12 (13.2)	3 (4.1)	3 (5.2)	11 (19.3)	6 (24.0)
	N/A	59 (77.6)	79 (86.8)	70 (95.9)	55 (94.8)	46 (80.7)	19 (76.0)
Constant pain (Q27)	always present	3 (3.9)	4 (4.4)	0 (0.0)	0 (0.0)	1 (1.8)	2 (8.0)
	comes and goes	14 (18.4)	8 (8.8)	3 (4.1)	2 (3.4)	10 (17.5)	4 (16.0)
	Total responses	17 (22.4)	12 (13.2)	3 (4.1)	2 (3.4)	11 (19.3)	6 (24.0)
	N/A	59 (77.6)	79 (86.8)	70 (95.9)	56 (96.6)	46 (80.7)	19 (76.0)

N/A = not applicable, participant had not experienced pain in last 7 days

Table S4.13 Difficulty with physical functioning

Adult n606		Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using arms	No	454	13.5	74.9	74.9
	Yes (lasted less than 1 month)	85	2.5	14.0	88.9
	Yes (lasted more than one month/permanent)	67	2.0	11.1	100.0
	Total	606	18.0	100.0	
Missing	System	2759	82.0		
Total		3365	100.0		

Adult n606		Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using legs	No	395	11.7	65.2	65.2
	Yes (lasted less than 1 month)	96	2.9	15.8	81.0
	Yes (lasted more than one month/permanent)	115	3.4	19.0	100.0
	Total	606	18.0	100.0	
Missing	System	2759	82.0		
Total		3365	100.0		

Adult n603		Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using body	No	387	11.5	64.2	64.2
	Yes (lasted less than 1 month)	104	3.1	17.2	81.4
	Yes (lasted more than one month/permanent)	112	3.3	18.6	100.0
	Total	603	17.9	100.0	
Missing	System	2762	82.1		
Total		3365	100.0		

Children 374		Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using arms	No	358	10.6	95.7	95.7
	Yes (lasted less than 1 month)	14	.4	3.7	99.5
	Yes (lasted more than one month/permanent)	2	.1	.5	100.0

	Total	374	11.1	100.0	
Missing	System	2991	88.9		
Total		3365	100.0		

	Children 374	Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using legs	No	354	10.5	94.7	94.7
	Yes (lasted less than 1 month)	14	.4	3.7	98.4
	Yes (lasted more than one month/permanent)	6	.2	1.6	100.0
	Total	374	11.1	100.0	
Missing	System	2991	88.9		
Total		3365	100.0		

	Children 374	Frequency	Percent (%)	Valid %	Cumulative %
Difficulty using body	No	356	10.6	95.2	95.2
	Yes (lasted less than 1 month)	16	.5	4.3	99.5
	Yes (lasted more than one month/permanent)	2	.1	.5	100.0
	Total	374	11.1	100.0	
Missing	System	2991	88.9		
Total		3365	100.0		

Table S4.14 Body region physical functioning by country and water supply

Adults n611	Response Category	GH n225 Frequency (%)		SA n202 Frequency (%)		V n184 Frequency (%)	
		At house	Shared	At house	Shared	At house	Shared
Difficulty using arms	No	65 (67.0)	87 (68.0)	86 (83.5)	79 (79.8)	101 (71.1)	36 (85.7)
	Yes (lasted < 1 month)	27 (27.8)	32 (25.0)	12 (11.7)	13 (13.1)	1 (0.7)	0 (0.0)
	Yes (lasted >1month/permanent)	5 (5.2)	7 (5.5)	4 (3.9)	5 (5.1)	40 (28.0)	6 (14.3)
	Total	97 (100.0)	126 (98.4)	102 (99.0)	97 (98.0)	142 (100.0)	42 (100.0)
Difficulty using legs	No	59 (60.8)	89 (69.5)	81 (78.6)	68 (68.7)	75 (52.8)	23 (54.8)
	Yes (lasted < 1 month)	28 (28.9)	31 (24.2)	12 (11.7)	18 (18.2)	2 (1.4)	5 (11.9)
	Yes (lasted >1month/permanent)	10 (10.3)	6 (4.7)	8 (7.8)	12 (12.1)	65 (45.8)	14 (33.3)
	Total	97 (100.0)	126 (98.4)	101 (98.1)	98 (99.0)	142 (100.0)	42 (100.0)
Difficulty using body: back/ neck	No	51 (52.6)	72 (56.3)	92 (89.3)	82 (82.8)	66 (46.5)	24 (57.1)
	Yes (lasted < 1 month)	34 (35.1)	43 (33.6)	7 (6.8)	11 (11.1)	4 (2.8)	5 (11.9)
	Yes (lasted >1month/permanent)	11 (11.3)	11 (8.6)	1 (1.0)	5 (5.1)	71 (50.0)	13 (31.0)
	Total	96 (99.0)	126 (98.4)	100 (97.1)	98 (99.0)	141 (99.3)	42 (100.0)
Children n359	**Response Category**	**GH n156 Frequency (%)**		**SA n121 Frequency (%)**		**V n82 Frequency (%)**	
		At house	**Shared**	**At house**	**Shared**	**At house**	**Shared**
Difficulty using arms	No	71 (93.4)	77 (84.6)	68 (93.2)	55 (94.8)	57 (100.0)	24 (96.0)
	Yes (lasted < 1 month)	4 (5.3)	9 (9.9)	1 (1.4)	0 (0.0)	0 (0.0)	0 (0.0)
	Yes (lasted >1month/permanent)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	Total	76 (100.0)	86 (94.5)	69 (94.5)	56 (96.6)	57 (100.0)	24 (96.0)
Difficulty using legs	No	66 (86.8)	81 (89.0)	68 (93.2)	55 (94.8)	53 (93.0)	25 (100.0)
	Yes (lasted < 1 month)	8 (10.5)	5 (5.5)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	Yes (lasted >1month/permanent)	2 (2.6)	0 (0.0)	0 (0.0)	0 (0.0)	4 (7.0)	0 (0.0)
	Total	76 (100.0)	86 (94.5)	68 (93.2)	56 (96.6)	57 (100.0)	25 (100.0)

Difficulty using body: back/ neck	No	70 (92.1)	76 (83.5)	68 (93.2)	55 (94.8)	57 (100.0)	24 (96.0)
	Yes (lasted < 1 month)	6 (7.9)	9 (9.9)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	Yes (lasted >1month/permanent)	0 (0.0)	1 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (4.0)
	Total	76 (100.0)	86 (94.5)	68 (93.2)	56 (96.6)	57 (100.0)	25 (100.0)

Table S4.15 Self-reported functional disability adults

Adult		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Seeing	No difficulty	455	13.5	74.5	74.5
	Some difficulty	118	3.5	19.3	93.8
	A lot of difficulty	36	1.1	5.9	99.7
	Cannot do it at all	2	.1	.3	100.0
	Total	611	18.2	100.0	
Breathing	No difficulty	532	15.8	87.1	87.1
	Some difficulty	62	1.8	10.1	97.2
	A lot of difficulty	16	.5	2.6	99.8
	Cannot do it at all	1	.0	.2	100.0
	Total	611	18.2	100.0	
Hearing	No difficulty	571	17.0	93.5	93.5
	Some difficulty	33	1.0	5.4	98.9
	A lot of difficulty	7	.2	1.1	100.0
	Total	611	18.2	100.0	
Walking	No difficulty	386	11.5	63.2	63.2
	Some difficulty	166	4.9	27.2	90.3
	A lot of difficulty	56	1.7	9.2	99.5
	Cannot do it at all	3	.1	.5	100.0
	Total	611	18.2	100.0	
Remembering	No difficulty	518	15.4	84.8	84.8
	Some difficulty	76	2.3	12.4	97.2
	A lot of difficulty	16	.5	2.6	99.8
	Cannot do it at all	1	.0	.2	100.0
	Total	611	18.2	100.0	

Self-care	No difficulty	533	15.8	87.2	87.2
	Some difficulty	66	2.0	10.8	98.0
	A lot of difficulty	11	.3	1.8	99.8
	Cannot do it at all	1	.0	.2	100.0
	Total	611	18.2	100.0	
Communicating	No difficulty	591	17.6	96.7	96.7
	Some difficulty	17	.5	2.8	99.5
	A lot of difficulty	3	.1	.5	100.0
	Total	611	18.2	100.0	
Missing	System	2754	81.8		
Total		3365	100.0		

Table S4.16 Self-reporting functional disability children

Child		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Seeing	No difficulty	356	10.6	93.4	93.4
	Some difficulty	21	.6	5.5	99.0
	A lot of difficulty	4	.1	1.0	100.0
	Total	381	11.3	100.0	
Breathing	No difficulty	368	10.9	96.6	96.6
	Some difficulty	10	.3	2.6	99.2
	A lot of difficulty	2	.1	.5	99.7
	Cannot do it at all	1	.0	.3	100.0
	Total	381	11.3	100.0	
Hearing	No difficulty	372	11.1	97.6	97.6
	Some difficulty	7	.2	1.8	99.5
	A lot of difficulty	2	.1	.5	100.0
	Total	381	11.3	100.0	
Walking	No difficulty	375	11.1	98.4	98.4
	Some difficulty	4	.1	1.0	99.5
	A lot of difficulty	1	.0	.3	99.7
	Cannot do it at all	1	.0	.3	100.0
	Total	381	11.3	100.0	
Remembering	No difficulty	368	10.9	96.1	96.1
	Some difficulty	11	.3	2.9	99.0
	A lot of difficulty	3	.1	.8	99.7
	Cannot do it at all	1	.0	.3	100.0
	Total	383	11.4	100.0	
Self-care	No difficulty	376	11.2	98.7	98.7

	Some difficulty	4	.1	1.0	99.7
	Cannot do it at all	1	.0	.3	100.0
	Total	381	11.3	100.0	
Communication	No difficulty	374	11.1	98.2	98.2
	Some difficulty	4	.1	1.0	99.2
	A lot of difficulty	2	.1	.5	99.7
	Cannot do it at all	1	.0	.3	100.0
	Total	381	11.3	100.0	
Missing	System	2984	88.7		
Total		3365	100.0		

Table S4.17 Functional disability (difficulty walking and with self-care) by country and water supply location

Variable	Response	GH n225 Frequency (%)		SA n202 Frequency (%)		V n184 Frequency (%)	
		Home n97	Shared n128	Home n103	Shared n99	Home n142	Shared n42
Adult Difficulty walking or climbing stairs	No difficulty	48 (49.5)	66 (51.6)	80 (77.7)	73 (73.7)	79 (55.6)	27 (64.3)
	Some difficulty	35 (36.1)	37 (28.9)	17 (16.5)	18 (18.2)	49 (34.5)	10 (23.8)
	A lot of difficulty	10 (10.3)	15 (11.7)	6 (5.8)	7 (7.1)	13 (9.2)	5 (11.9)
	Cannot do at all	1 (1.0)	0 (0.0)	0 (0.0)	1 (1.0)	1 (0.7)	0 (0.0)
	Total	94 (96.9)	118 (92.2)	103 (100.0)	99 (100.0)	142 (100.0)	42 (100.0)
Adult Difficulty with self-care	No difficulty	76 (78.4)	105 (82.0)	99 (96.1)	96 (97.0)	109 (76.8)	36 (85.7)
	Some difficulty	15 (15.5)	11 (8.6)	2 (1.9)	1 (1.0)	31 (21.8)	6 (14.3)
	A lot of difficulty	3 (3.1)	3 (2.3)	2 (1.9)	1 (1.0)	2 (1.4)	0 (0.0)
	Cannot do at all	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.0)	0 (0.0)	0 (0.0)
	Total	94 (96.9)	119 (93.0)	103 (100.0)	99 (100.0)	142 (100.0)	42 (100.0)
Variable	**Response**	**GH n156 Frequency (%)**		**SA n121 Frequency (%)**		**V n82 Frequency (%)**	
		Home n70	Shared n86	Home n67	Shared n54	Home n57	Shared n25
Child Difficulty walking or climbing stairs	No difficulty	75 (98.7)	90 (98.9)	73 (100.0)	56 (96.6)	57 (100.0)	25 (100.0)
	Some difficulty	1 (1.3)	1 (1.1)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	A lot of difficulty	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Cannot do at all	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	Total	76 (100.0)	91 (100.0)	73 (100.0)	58 (100.0)	57 (100.0)	25 (100.0)
Child Difficulty with self-care	No difficulty	75 (98.7)	90 (98.9)	73 (100.0)	56 (96.6)	56 (98.2)	25 (100.0)
	Some difficulty	1 (1.3)	1 (1.1)	0 (0.0)	1 (1.7)	1 (1.8)	0 (0.0)
	A lot of difficulty	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Cannot do at all	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)
	Total	76 (100.0)	91 (100.0)	73 (100.0)	58 (100.0)	57 (100.0)	25 (100.0)

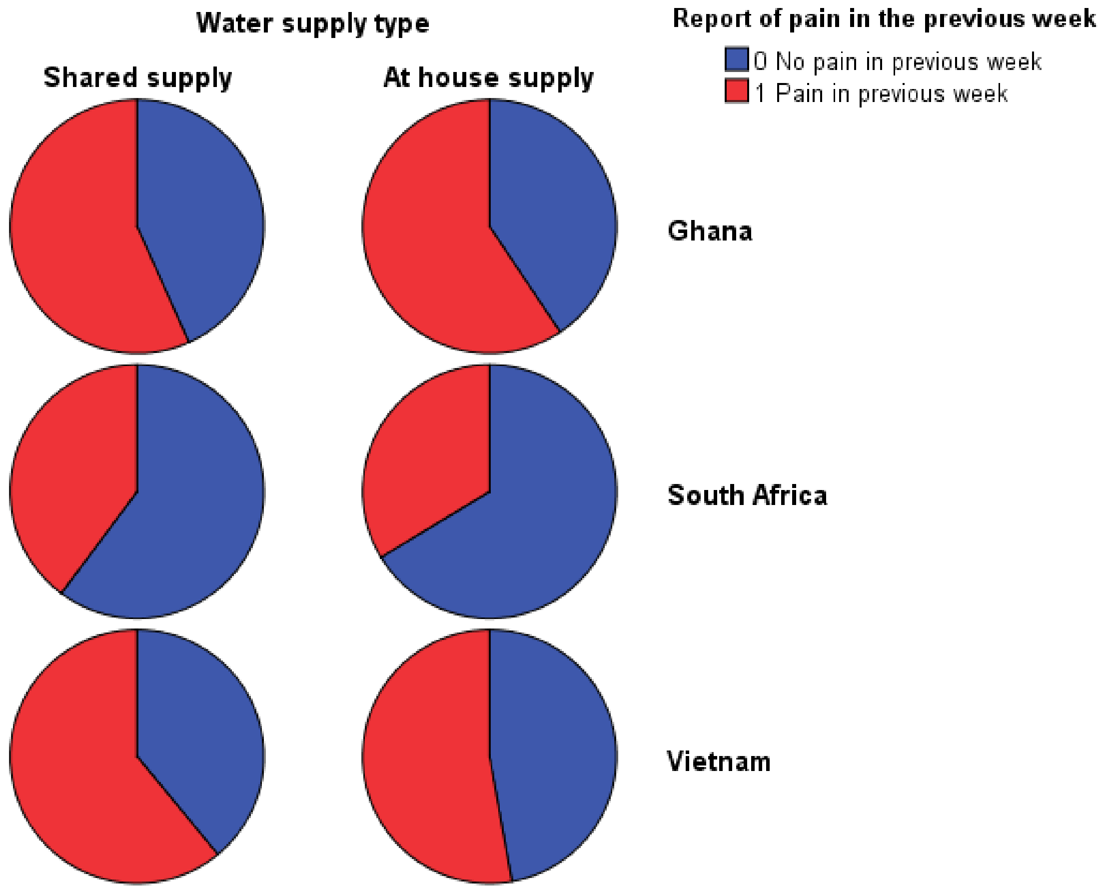
Table S4.18 Self-reported rating of general health today

General Health		Frequency	Percent (%)	Valid (%)	Cumulative (%)
Adults	Very good	182	5.4	30.8	30.8
	Good	189	5.6	32.0	62.8
	Moderate	149	4.4	25.2	88.0
	Bad	65	1.9	11.0	99.0
	Very bad	6	.2	1.0	100.0
	Total	591	17.6	100.0	
Missing	System	2774	82.4		
Children	Very good	183	5.4	53.5	53.5
	Good	113	3.4	33.0	86.5
	Moderate	32	1.0	9.4	95.9
	Bad	14	.4	4.1	100.0
	Total	342	10.2	100.0	
Missing	System	3023	89.8		
Total		3365	100.0		

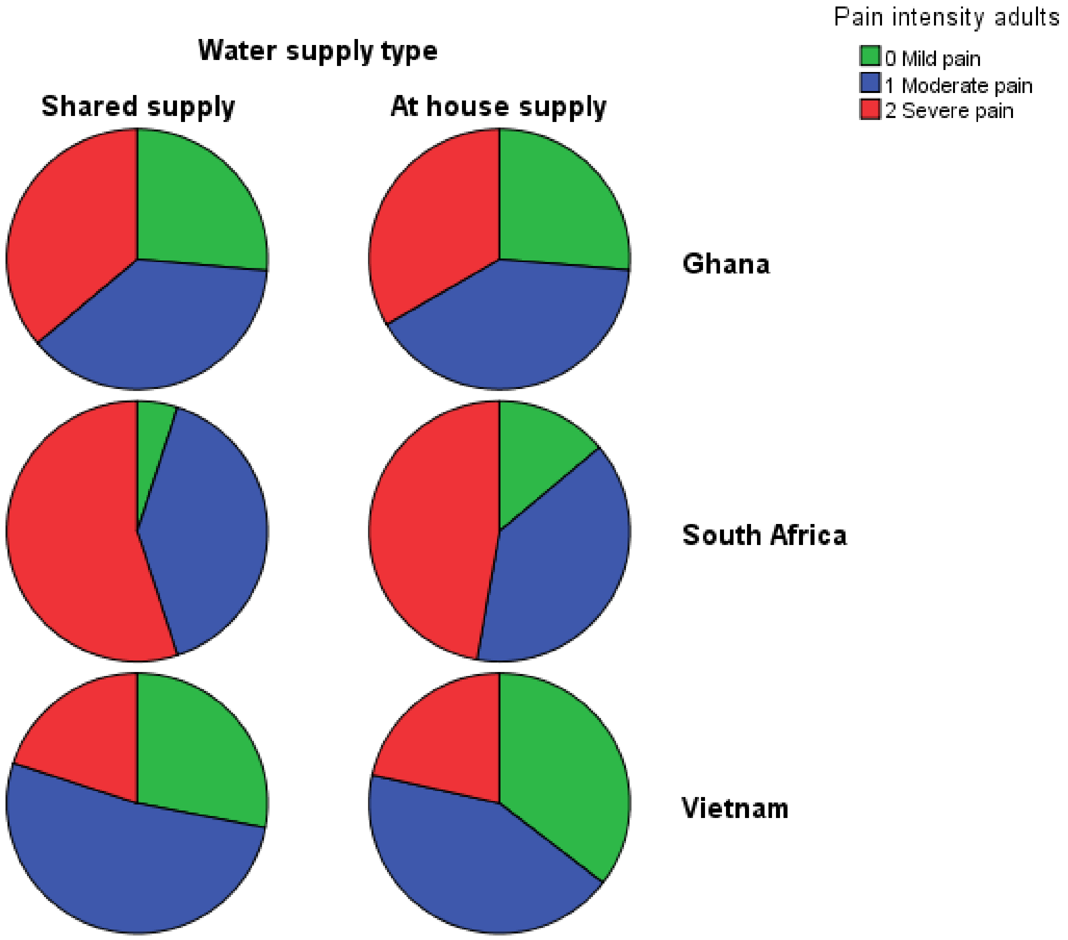
Table S4.19 General Health by country and water supply

Adults n611	**Response**	**GH n225 Frequency (%)**		**SA n202 Frequency (%)**		**V n184 Frequency (%)**	
		Home n97	Shared n128	Home n103	Shared n99	Home n142	Shared n42
Rating of general health	Very good	42 (43.3)	53 (41.4)	43 (41.7)	44 (44.4)	0 (0.0)	0 (0.0)
	Good	33 (34.0)	45 (35.2)	47 (45.6)	40 (40.4)	17 (12.0)	7 (16.7)
	Moderate	10 (10.3)	16 (12.5)	11 (10.7)	8 (8.1)	89 (62.7)	15 (35.7)
	Bad	9 (9.3)	12 (9.4)	2 (1.9)	6 (6.1)	23 (16.2)	13 (31.0)
	Very bad	2 (2.1)	1 (0.8)	0 (0.0)	1 (1.0)	1 (0.7)	1 (2.4)
	Total	96 (99.0)	127 (99.2)	103 (100)	99 (100.0)	130 (91.5)	36 (85.7)
Children n359	**Category**	**GH n156 Frequency (%)**		**SA n121 Frequency (%)**		**V n82 Frequency (%)**	
		Home n70	Shared n86	Home n67	Shared n54	Home n57	Shared n25
Rating of general health	Very good	49 (64.5)	61 (67.0)	39 (58.2)	27 (46.6)	0 (0.0)	1 (4.0)
	Good	20 (26.3)	20 (22.0)	20 (29.9)	21 (36.2)	21 (36.8)	7 (28.0)
	Moderate	3 (3.9)	3 (3.3)	4 (6.0)	1 (1.7)	14 (24.6)	5 (20.0)
	Bad	0 (0.0)	3 (3.3)	1 (1.5)	4 (6.9)	3 (5.3)	3 (12.0)
	Very bad	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
	Total	72 (94.7)	87 (95.6)	64 (95.5)	53 (91.4)	38 (66.7)	16 (64.0)

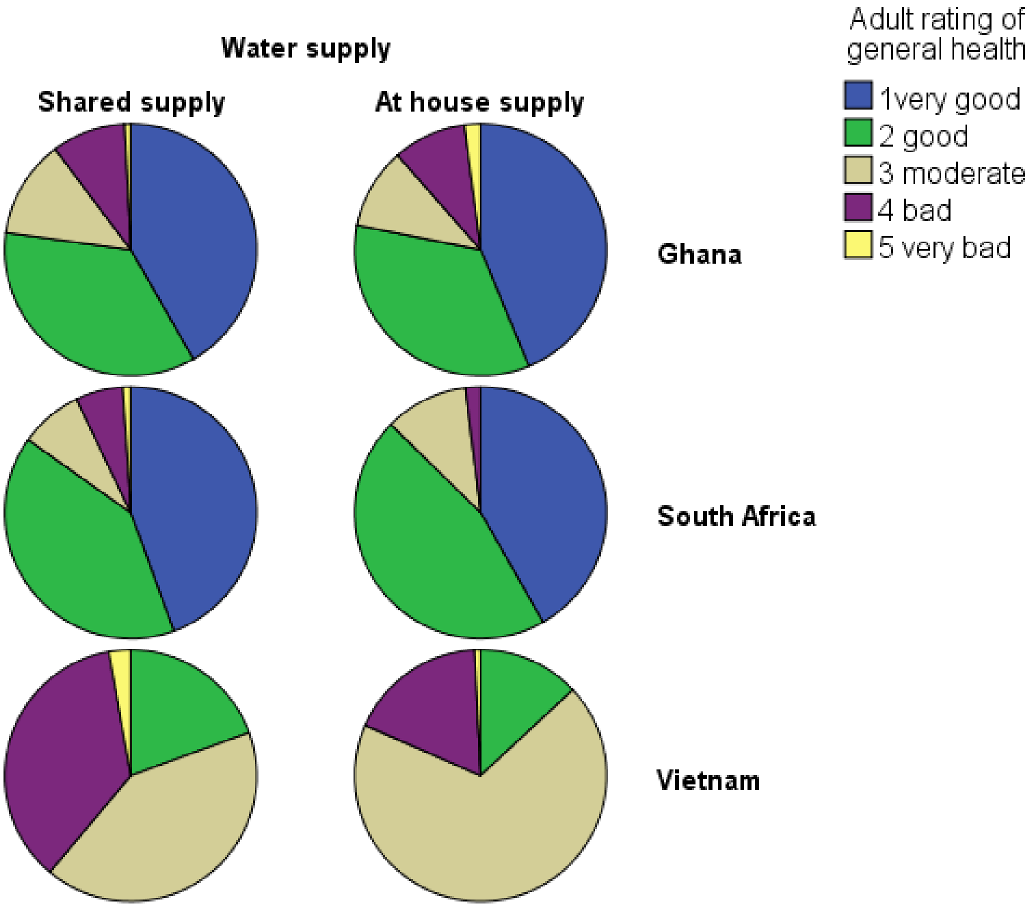
Figures comparing at-house versus shared supply in each country.



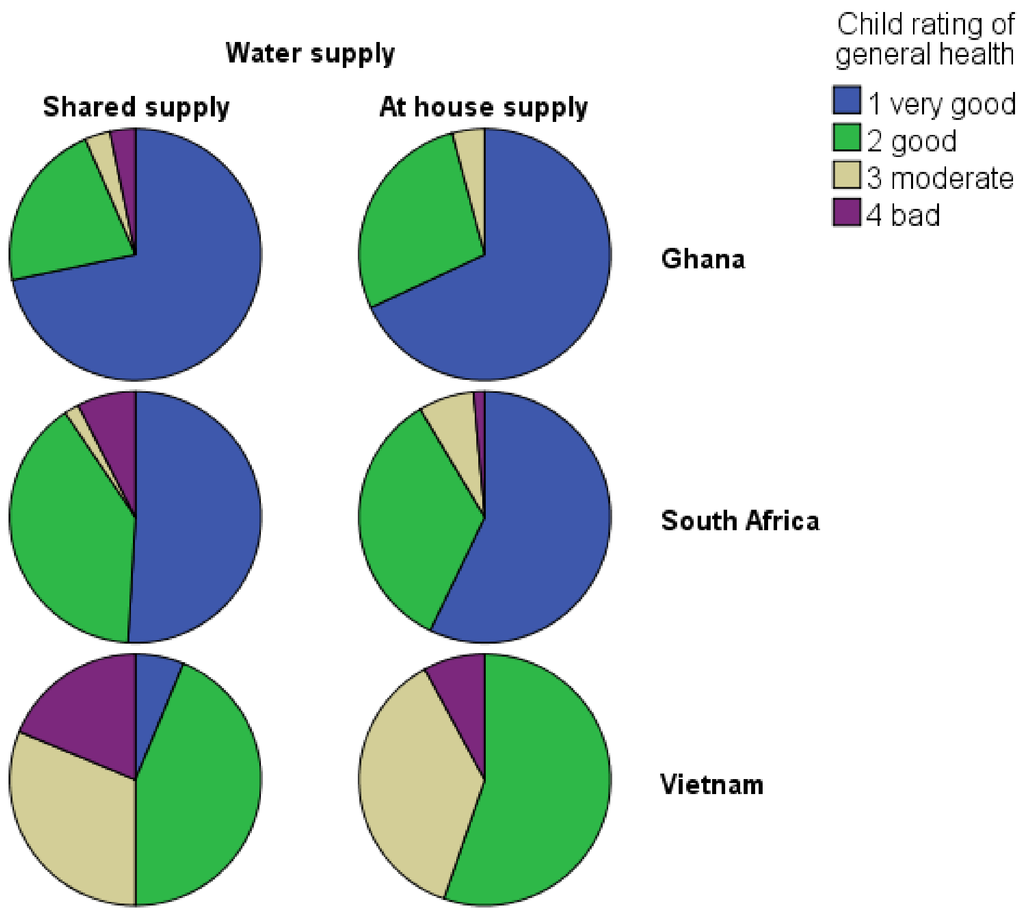
Supplementary Figure 4.1: Report of pain in previous 7 days by water supply type and country



Supplementary Figure 4.2: Reported pain intensity for adults according to water supply type and country



Supplementary Figure 4.3: Comparison of adult rating of general health according to type of supply and country



Supplementary Figure 4.4: Comparison of child rating of general health according to type of supply and country

Appendix 15. Ethics application University of Leeds

I signIUNIVERSITY OF LEEDS RESEARCH ETHICS COMMITTEE APPLICATION FORM [1]

UNIVERSITY OF LEEDS

Please read each question carefully, taking note of instructions and completing all parts. If a question is not applicable please indicate so. The superscripted numbers refer to sections of the guidance notes, available at www.leeds.ac.uk/ethics. Where a question asks for information which you have previously provided in answer to another question, please just refer to your earlier answer rather than repeating information.

To help us process your application enter the following reference numbers, if known and if applicable:

Ethics reference number:	
Grant reference and/ or student number:	DFID Project Reference No: RGM 483272

PART A: Summary

A.1 Which Faculty Research Ethics Committee would you like to consider this application? [2]

☑ MaPS and Engineering (MEEC)

A.2 Title of the research [3]

Health and Social Benefits of At-house Water Supplies in Developing Countries in Vietnam, South Africa and Ghana.

NB: The following application comprises a formal request on behalf of the University of Leeds and the University of East Anglia for ethical approval to undertake the following research in Vietnam and South Africa respectively. Ethical approval to undertake the following research in Ghana is being requested separately through the University of North Carolina in the US.

A.3 Principal investigator's contact details [4]	
Name *(Title, first name, surname)*	Ms Barbara Evans
Position	Senior Lecturer and Principle Investigator. Barbara is the Principal Investigator for this project and has over twenty years of experience in water and sanitation practice in countries of the global south.
Department/ School/ Institute	Civil Engineering
Faculty	Engineering
Work address *(including postcode)*	University of Leeds, Leeds, LS2 9JT
Telephone number	+44(0)113 343 1990
University of Leeds email address	b.e.evans@leeds.ac.uk

A.4 Purpose of the research: [5] (Tick as appropriate)

- [x] Research
- [ ] Educational qualification: ***Please specify:*** ________________________
- [ ] Educational Research & Evaluation [6]
- [ ] Medical Audit or Health Service Evaluation [7]
- [ ] Other

A.5 Select from the list below to describe your research: (You may select more than one)

- [x] Research on or with human participants
- [ ] Research with has potential significant environmental impact.[8] If yes, please give details:

  ____

- [x] Research working with data of human participants
  - [x] New data collected by questionnaires/interviews
  - [x] New data collected by qualitative methods
  - [x] New data collected from observing individuals or populations
  - [x] Research working with aggregated or population data
  - [x] Research using already published data or data in the public domain
- [ ] Research working with human tissue samples [9]

A.6 Will the research involve any of the following: [10] (You may select more than one)

If your research involves any of the following an application must be made to the National Research Ethics Service (NRES) via IRAS www.myresearchproject.org.uk as NHS ethical approval will be required. There is no need to complete any more of this form. Contact governance-ethics@leeds.ac.uk for advice.

- ☐ Patients and users of the NHS (including NHS patients treated in the private sector) [11]
- ☐ Individuals identified as potential participants because of their status as relatives or carers of patients and users of the NHS
- ☐ Research involving adults in Scotland, Wales or England who lack the capacity to consent for themselves [12]
- ☐ A prison or a young offender institution in England and Wales (and is health related) [14]
- ☐ Clinical trial of a medicinal product or medical device [15]
- ☐ Access to data, organs or other bodily material of past and present NHS patients [9]
- ☐ Use of human tissue (including non-NHS sources) where the collection is not covered by a Human Tissue Authority licence [9]
- ☐ Foetal material and IVF involving NHS patients
- ☐ The recently deceased under NHS care
- ☑ None of the above

You must inform the Research Ethics Administrator of your NRES number and approval date once approval has been obtained.

If the University of Leeds is not the Lead Institution, or approval has been granted elsewhere (e.g. NHS) then you should contact the local Research Ethics Committee for guidance. The UoL Ethics Committee need to be assured that any relevant local ethical issues have been addressed.

A.7 Will the research involve NHS staff recruited as potential research participants (by virtue of their professional role) or NHS premises/ facilities?

☐ Yes ☑ No

If yes, ethical approval must be sought from the University of Leeds. Please note that NHS R&D approval is needed in addition, and can be applied for concurrently: www.myresearchproject.org.uk. Contact governance-ethics@leeds.ac.uk for advice.

A.8 Will the participants be from any of the following groups? (Tick as appropriate)

- ☑ Children under 16 [16]
- ☑ Adults with learning disabilities [12]
- ☐ Adults with other forms of mental incapacity or mental illness
- ☐ Adults in emergency situations
- ☐ Prisoners or young offenders [14]
- ☐ Those who could be considered to have a particularly dependent relationship with the investigator, e.g. members of staff, students [17]
- ☑ Other vulnerable groups

☐ No participants from any of the above groups

Please justify the inclusion of the above groups, explaining why the research cannot be conducted on non vulnerable groups.

Background and Definition of Vulnerable Groups
The research will target households in communities that have varying levels of access to water supply and sanitation. These households may or may not contain vulnerable groups.

Vulnerable groups include: children, elderly, people with disabilities, people with low literacy levels, the poorest members of the community, and immune-compromised persons.

Both vulnerable and non-vulnerable groups of people have equal rights to, and reliance on, water for consumption and use. Therefore our research neither targets nor discriminates between vulnerable and non-vulnerable groups of people.

However, it is important to include these groups as there is strong evidence that vulnerable subgroups, especially young children suffer disproportionately from the adverse health impacts of inadequate water supply and also take a major burden of the responsibility for carrying water. As such we seek to have a representative sample of the study population, that includes vulnerable groups who will likely be most adversely affected by any problems in water supply and sanitation

Non-vulnerable groups speaking on behalf of vulnerable groups
Non-vulnerable participants will be asked questions about their own health and, where necessary, that of vulnerable individuals in their household who are unable to respond themselves.

Vulnerable groups invitation to be interviewed
Some questions however within the structured household interview will be relevant to individuals assuming a specific role within the household, namely those responsible for the collection of water from outside the home.

The research teams' working and learned knowledge on water collecting practices in developing countries indicate that children under the age of 16 years often adopt responsibility for household water collection (i.e. individuals are likely to include children (both male and female) less than 16 years old (some of whom may have a physical disability)). Adults and young persons over 16 years who collect water but have a physical disability may also be classed as a vulnerable group and would be invited to participate to appropriate consent procedures.

The research team acknowledges equal right to water and more specifically aim to secure improved access to water within disadvantaged groups. As a result we feel it pertinent to invite such individuals (subject to appropriate consent procedures) to participate in the survey subject to appropriate consent procedures.

Questions about water collecting practices that may involve may be asked of vulnerable groups relate to the identification of their household water sources outside the home, as well as the social (e.g. time away from school to collect water), and health outcomes associated with the collection of water. For individuals who collect water, we will measure their weight and height to calculate Body Mass Index (BMI), with the aim of determining whether weight of water carried compared to BMI is a risk factor for pain or movement disorders.

Safeguarding vulnerable groups through consent
Written agreement for the research team to work in selected communities will be requested from community leaders of selected villages and urban areas prior to undertaking any field survey work. Consent will be sought from all participating household members invited to partake in the survey through face-to-face meetings, communicated through a native speaking interviewer and a written information sheet about the project. Consent will be indicated by either a written signature, or in the case of participants with limited literacy, a mark witnessed by another household member.

Both oral consent from children under 16 years with or without physical disability, and written consent from an accompanying adult relative or guardian living within the household, would be required prior to inclusion of children under 16 years in the study.

Adults and young persons over 16 years who have a physical disability would be asked to provide written consent to participate (subject to their level of disability). If their disability meant they were unable to provide written consent, oral consent would be required.

A Criminal Record Bureau (CRB) check will be needed for researchers working with children or vulnerable adults (see www.crb.gov.uk)

A.9 Give a short summary of the research [18]

*This section must be completed in **language comprehensible to the lay person**. Do not simply reproduce or refer to the protocol, although the protocol can also be submitted to provide any technical information that you think the ethics committee may require. This section should cover the main parts of the proposal.*

A protocol has not been provided so that the research is communicated in lay terms.

Project Team

A project team, comprising experts and researchers in water and health specialist groups from world-class research institutions, have joined forces to deliver an international study on the 'Public Health and Social Benefits of At-house Water Supplies' for the UK Department for International Development.

The institutions include, 1. the water@leeds team at the University of Leeds, 2. the University of East Anglia, 3. the Water Institute at the University of North Carolina, 4. the London School of Hygiene and Tropical Medicine and 5. The University College London.

The following application comprises a formal request for ethical approval on behalf of the University of Leeds and the University of East Anglia only.

All other University partners will either request ethical approval independently from their governing institution (e.g. the University of North Carolina) or do not require ethical approval and constitute as advisory members (London School of Hygiene and Tropical Medicine and The University College London) to the project only (with regards to method and data interpretation).

Research Aim

This research project aims to "test the hypothesis that increased access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply."

The method draws on three research components to facilitate this understanding: a review of both scientific and grey literature; analysis of existing global data to explore associations between levels of water service, quality of service and health and social outcomes; and field studies located within three developing countries utilising qualitative and quantitative fieldwork data collection and analysis.

This application constitutes a request on behalf of the University of Leeds and the University of East Anglia for ethical approval for the research team to proceed with the proposed field research in Vietnam and South Africa.

Research Content

Detailed field studies will entail mixed methods research project staggered over 6 month period in rural and urban areas of mixed density. Methods proposed to collect data at each community and household include (i) face to face interviews coupled with (ii) structured observations and (iii) natural group meetings.

Appendix A provides details of the types of data collected either through the detailed survey questions, structured observation, or exploratory discussion groups. This Appendix is not offered as an exemplar field questionnaire, but provides the ethical review committee with detail of our proposed data collection points. All survey questions will be made culturally relevant and effective through a review by in-country collaborators and piloting prior to the main survey.

These questions and methods aim to secure detailed information pertaining to three areas of water security agenda (i) the level of service of water supply and the patterns of water consumption, (ii) the health impacts of at-house drinking water (such as the prevalence of diarrhoea, eye and dermatological ailments, musculoskeletal pain and personal injury) and (iii) the social and economic impacts of at-house drinking water.

Partnership with Select Institutions in Respective Developing Countries

The proposed field research for which we are requesting approval from the ethics review committee will take place in two countries; Vietnam and South Africa. The University of Leeds seek to collect data from rural and urban communities in Vietnam where the Project Investigator (Ms Barbara Evans) and her team currently have on-going projects. Efforts are currently underway to form memorandum of understanding with the Hanoi School of Public Health so as to obtain within country ethical clearance as well as identify the most appropriate study sites and suitable in-country Vietnamese field researchers.

The University of East Anglia will undertake field research in South Africa within Limpopo Province. The University anticipates it will collaborate with Tshwane University of Technology on this project, having worked in successful partnership over the last 5 years. Collaboration with Tshwane University of Technology in refining data collection tools is underway.

Data Collection and Analysis – Household Questionnaires

Household interviews will be undertaken by trained community fieldworkers fluent in the participants' preferred languages. Data collection methods will be trialled in South Africa during a 2 week pilot study. All selection procedures, data collection methods, and enumerators will be tested during this pilot phase to determine their feasibility, reliability and validity for use across various densities of housing in Vietnam and South Africa. The pilot phase will aim to engage approximately 100 people from around 20 households per country.

Subsequent to analysis of data collected in the pilot study, the survey method will then be refined and rolled out on both new and a larger cohort of households involving approximately 900 respondents per country (assuming 4 to 5 people per household) from around 200 households.

Data Collection and Analysis – Observational Studies

Structured observations are proposed around the communities participating within the study. Observational studies by their nature do not interfere with the existing services people currently receive. Researchers will carry information sheets in the local language, which can be provided to community members requesting information relating to the study and will answer questions relating to the study where practically possible. If necessary community leaders will be requested to assist in informing community members about the study. The observational methods will involve both national and UK field researchers observing the extent, status and usage patterns of community facilities for household sanitation, solid waste, drainage, water supply and hygiene. Observations will also be made on, the terrain to water source and operational arrangements at the water source. We propose to undertake structured observations that meet high ethical standards. For any issues that are raised during the course of the country the lead field investigators will assume overall responsibility for the ethics of the activity.

The observational studies are vitally important to triangulate information obtained through household interviews and to obtain information on relevant community-level contextual variables.

Data Collection and Analysis – Natural Group Meetings

A number of group discussions work is proposed to elucidate any areas of concern or interest that arise during the fieldwork. Group discussions are anticipated to focus on community opinions relating to existing water sources, perceptions about the distance to source, reliability of source, taste of water, social activities centred on water collection and the nature and extent of water use for productive purposes such as household food production.

A series of natural-group discussions and semi-structured focused groups with individuals and selected groups of participants will include opportunistic group discussions with, people who naturally gather together, plus groups that may be less accessible in public environments. Access to less accessible groups will require local knowledge and / or community members to support their invitation into the project and ensure the study does not discriminate against more disparate or private groups of people.

With permission from all participants, the discussions will be recorded using audio equipment. Where permission is not granted to record the discussions, flip chart paper will be used to record statements and points of view in the local dialect. At least two group discussions will be carried in each country to capture responses from groups with a private water supply (i.e. from a tap in their house or yard) and those who have a more public or community water supply (i.e. from a shared tap in the yard or community).

Lead Field Researchers

Lead field researchers from the University of Leeds and the University of East Anglia will be based in country during the fieldwork to oversee the project. Their roles will include the facilitation of relationships with local institution partners, selection of possible households for inclusion in the pilot study and final study separately, securing mechanisms within respective countries to obtain consents to proceed from local institution partners, community leaders and interviewees. They will also be responsible for the training, validation and support of enumerators, data management, oversee the process of transcription and translation into English of qualitative interview data by an in-country researches. The lead researchers will then use the development of emergent themes for exploration within on-going focus groups. They will also manage adherence to the research protocol and data protection rights.

Analysis

Data analysis will involve the data entry onto a purpose built Microsoft Access database and transferred for analysis onto a statistical program (i.e. STATA) to perform analysis. Statistical analysis will be directed by Professor Paul Hunter from the University of East Anglia and Dr Wolf-Peter Schmidt from the London School of Hygiene and Tropical Medicine and supported by the larger research team. It is anticipated that analysis will involve modelling of data using multi-linear regression. Qualitative data generated during natural group meetings and structured observation methods will be cross-checked and interpreted using emergent theme analysis facilitated by Nvivo software.

Reporting

In-country contributions to the method, data collection, analysis, reporting and/or reviewing process will receive acknowledgement and/or authorship of publications prepared for submission to peer-reviewed journals. No interviewees will be made directly or indirectly identifiable in any of the publications.

Findings from field studies will be made available to participating communities through open public meetings (to confirm interpretation of group discussion data) and a nationally-appropriate mechanism (likely to include a summary presentation to communities and/or participation of key community representatives in national workshops).

The aim of our dissemination plan is for relevant national and international policy makers, NGOs and other agencies to reassess the value of promoting community versus in home/in yard taps. Our specific objective is to ensure that key players within the target organizations are aware of the research, its conclusions and the implications for their policy areas. We consider the key stakeholders to include DFID, World Health Organization, World Bank, UNICEF, NGOs such as Water Aid and Oxfam, the wider scientific/public health community and interested members of the general community.

Our dissemination strategy to reach these stakeholders will focus on three main channels of communication:

1. Direct communication to national and international policy-makers and practitioners;
2. Direct into the international monitoring processes; and
3. To academia and professional practice.

A.10 What are the main ethical issues with the research and how will these be addressed? [19]

The project team has identified a number of potential ethical issues but has sought to mitigate them by the following means:

Ethical Approval within the UK and within In-Country locations

University of Leeds

The study is being submitted for Ethical Review in the University of Leeds on behalf of both the project team located within the School of Civil Engineering at the University of Leeds and the Norwich Medical School at the University of East Anglia. It will also be submitted for Ethical Review within country institutions in Vietnam and South Africa. The research team recognises that both the UK and in-country institutions expect high ethical standards of all its researchers and research projects. We consider obtaining ethical approval from the University of Leeds (as well as the institutions within Vietnam and South Africa) as a step towards fostering cultural sensitivity and safeguarding of rights around vulnerable subjects (e.g. non-competent participants such as those with health problems and children).

In country institutions

The University of Leeds will seek to gain project approval from the ethical review committee located within the School of Public Health in Hanoi (SPHH). The Principle Investigator of this current project, Barbara Evans, is located within the Faculty of Civil Engineering (FCE) at the University of Leeds. The SPHH have worked closely with the University of Leeds on health projects run previously by the Nuffield Institute in Public Health (NIPH). Ms. Evans not only has a long standing working relationship with the NIPH but is well suited to lead the proposed project given an extensive career history undertaking research on water and sanitation in developing countries, with a focus on South East Asia (including Vietnam). The NIPH have facilitated an introduction between SPHH and FCE, and the SPHH have demonstrated interest in Ms. B. Evans's proposed project, which may provide an opportunity to widen their working relationship with the University of Leeds.

Similarly the University of East Anglia (UEA) will seek to gain ethical approval from Tshwane University of Technology (TUT) with who they were joint partners on previous research. Both parties have enjoyed previous collaboration projects relating to water access and health. Most recently was a project run in 2010 from which two publications were released. The research for these projects required ethical review and approval by UEA and TUT. As a result both parties are familiar with their ethical requirements and have working respect for the ethical requirements to conduct research on human participants within South Africa.

Both the UL and the UEA believe obtaining ethical approval for research involving human participants is the first step, but not the only step, in delivering a project that adheres to the principles of academic excellence, community, integrity, inclusiveness and professionalism and have identified the following additional areas.

Appreciation for Local Culture

The proposed study will involve collaboration and ethical appraisal and clearance as appropriate with in-country institutions. This partnership with local institutions will provide independent and culturally relevant detailed advice on the development of our method. We will request advice on the relevance and phrasing of each question, identification of competent interviewers either fluent in the native language or from the study region, the translation of our structured survey into local dialect, the review of proposed information sheets, support during the write up and reporting phase and ultimately within country information dissemination. This process of method sharing has already begun between the in-country and UK institutions. Prior agreement of intellectual property between all research partners and collaborators will also be sought and agreed in a contract or memorandum of understanding. Participant information sheets will be developed from ones already in use in other settings by the researchers.

Identification of Participants

Communities will be identified from appropriate in-country data sources and knowledge to identify communities with a range of contexts to be included, namely:

- Levels of access to water relative to distance from home and that these water source points can be or have been readily mapped (i.e. households with a private water supply in the home or yard vs. households who share a water supply with a defined group of people vs. Households who share a communal water supply);
- Density of housing in a given area (density ranges within Vietnam range from 1 person per squared kilometre to 1000 persons per squared kilometre and so areas that exhibit both high and low density in a given province would be selected)

Additional factors that determine the identification of communities within the study relate to the communities willingness to participate. Households will then be selected from such communities through stratified random sampling and invited to participate in the study.

These criteria for inclusion of households into the project do not discriminate in the selection and recruitment of participants by including or excluding them on the grounds of race, age, sex, disability, or religious or spiritual beliefs. They are also considered to be fair given the wide spectrum of characteristics included within each level of stratification. The process of random selection also supports a fair chance of inclusion and exclusion of participants in the study.

Similarly a series of natural-group discussions and semi-structured focused groups with individuals and selected groups of participants will include opportunistic group discussions with, people who naturally gather together, plus groups that may be less accessible in public environments. Access to less accessible groups will require local knowledge and / or community members to support their invitation into the project and ensure the study does not discriminate against more disparate or private groups of people. These discussions aim to elaborate on participant's beliefs, understandings and feelings towards their current water supply and service systems.

The study hopes to recruit participants with varying levels of physical disability. The study design however does not place an unfair burden of participation in the research on vulnerable members from which other members of the community are intended to benefit.

Introducing the project to the community

For communities in which collective decision-making is customary, as is the case in Vietnam and South Africa, community leaders able to express the collective will, will be the field teams first point of contact in our approach to recruit households into the study. A community leader may express agreement or refusal on behalf of a community and this agreement or refusal to participate in the study will be respected.

Identified households would be invited to participate only upon agreement to proceed by these community/area leaders. Household members in areas randomly selected, and agreed to for study by community leaders, would be personally invited to participate in the survey by enumerators fluent in the local dialect. Should an individual make themselves known to the study group to volunteer in the study community leaders had declined, individuals would be given information on the project and reasons why community leaders have declined to take part and inform them therefore that members of the community will no longer be invited to volunteer in the study.

Consent from community leaders will be a required prerequisite before the field research team both invite household participants to the study and undertake observation works around the community and public facilities (e.g. communal sanitation provision, school sanitation provision, communal water supplies).

Recruitment of Participants and Informed Consent

Every participant will receive relevant information relating to the study including: notification of any proposed participation, what the research requires and if it has received in-country and community approval. Every participant has the right to honest and accurate answers to questions relating to the research and the researchers. Interviewers will be properly trained and culturally sensitive and will carry identification.

The local enumerators will provide each household with an information sheet translated into the local language informing them about the project. The enumerators will then discuss the project with all members belonging to households selected for invitation to the study. Discussions will involve talking through the aims and method of the study and the roles and rights of participating households.

The information sheet is explicit in informing participants that they may withdraw from the study at any time during the survey or after the survey without any consequences to themselves or their households. The enumerators will inform participants of this. The information sheet also comprises the consent form and an example of which has been provided for review by the ethics committee at the University of Leeds. This approach supports the informed consent process i.e. it will provide adequate information in a form and manner that enables it to be understood and an informed judgement made and any consent is voluntary in nature.

Further more neither the information sheet nor the enumerators will avoid raising expectations amongst communities about specific outcomes, which are not within the scope of the project. For example, communities without piped supply are not lead to expect the project will provide improved level of service to water. This would be achieved through clear communication of the project's objectives and processes and adequate training of enumerators.

Consent from vulnerable groups

As introduced in the study overview, some structured questions will be directed to members of the household responsible for a given role. In particular the role of interest involves water collection. It is envisaged that children under 16 years may be tasked with this role and therefore the research considers the inclusion of 'vulnerable groups' as recognised by ethical review process and research practice. Questions would only be directed to such individuals providing they were able to understand the project, were old enough to respond, provided verbal agreement to be asked some questions regarding their role as a water collector, a parent or adult guardian residing within the same household agreed to the child's participation in the survey and provided an additional signature to permit the interviewee to proceed with the structured questions or in the case of participants with limited literacy, a mark witnessed by another household member. The project will not induce participants to participate in the research and will offer no financial or material reward for their involvement.

Nature of the Questions

The information sheet outlines the content of the survey questions thereby obtaining the participant's prior consent by forewarning him or her of the nature of participation. The majority of the survey questions are not considered to be intrusive and or cause distress given they relate to household demographics, household health (eye, skin, diarrhoea and musculoskeletal pain), household assets and income, and level of service of water supply.

However some questions may be potentially distressing and intrusive. These questions pertain to miscarriage, child death or perceptions around disability. Additional steps are proposed in an effort to acknowledge the potentially distressing nature of these questions. These include the field research team making provisions for the in-country enumerators to be properly trained to deliver each question in a professional, discrete and respectful manner. Whilst they will not be trained to counsel distressed participants they will be trained in ways to offer supportive information such as details of appropriate points of contact (e.g. counsellors offering support in grievance, loss or depression),

Furthermore the questions are to be asked within the private environment of the participant's home so to reduce any potential embarrassment associated with health or wealth questions.

Lead field researchers shall remain in situ during the fieldwork to monitor and audit the research, the research conduct and respond to any unforeseen adverse circumstances.

Study Design

The research teams commitment to the advancement of knowledge implies a duty to conduct honest and thoughtful inquiry and rigorous analysis, and to be accountable for our activities.

Scientific inadequacies in a study proposal have ethical implications. As such the research team comprises established academics and consultants with research, publication and advisory experience in the field of water and sanitation provisions and health. The scientific quality of our proposal is believed to be such that its objectives are achievable and will not waste resources nor needlessly use participants' donated time.

The field and advisory team comprises of investigators with the necessary skills and resources to conduct the study and deal with any contingencies that may affect participants. Necessary skills include competence in understanding different cultural understandings of knowledge and of how such understandings might impact on the analysis and results of a study.

Parameters of confidentiality

The parameters of confidentiality will be discussed and agreed with partner institutions in Vietnam and South Africa as well as community leaders in selected areas of study. The project team will adhere to data protection of confidential records and in particular be responsible for safeguarding completed survey forms and consent forms from loss or disrepair. Methods to support this include the photocopying of all questionnaires so that two sets are stored in two places at any one time, the storage of transcribed data from hard copy to electronic copy on a password controlled internet filing site, and encrypted or pass word protected storage of files that ensures the information can only be reviewed by the project team only (e.g. password protected pen drives and lap tops, lock secured filing of hard copied forms). Any published or analysed data will be anonymised prior to analysis, write up and reporting.

Collection of confidential information from structured interviews and observational measurements

A key issue concerning health information is whether the individual concerned is "identifiable" from the information. The structured interviews will collect details such as address, community area, and level of service of water supply from which personal identifiers can be inferred.

The observational component will predominantly collect anonymous data, defined as data that is collected without personal identifiers and from which no personal identifier can be inferred. However some observational data will be linked to the participant involved e.g. a measurement related to water carrying performed by a particular individual. Such data would involve the collection of identifiable data such as the individual's name, date of birth or address.

Matters of confidentiality identified and discussed above will remain particularly relevant to both structured interview and observational methods of data collection. Personal identifiers however will be removed during the aggregation of the data and prior to export form the country of data collection . Again, any published or analysed data will be made anonymous prior to analysis, write up and reporting.

Collection of information from records

The research team may propose to collect information from a third party such as aggregate health records for an area or water operators regarding hours of operation and water quality at source. Access to medical records for purposes of the study would be restricted to appropriately qualified investigators and study associates. A named investigator to whom the records are disclosed will provide a written undertaking to ensure the confidentiality of the records. The data would also be requested without personal identifiers such as prevalence of recorded diarrhoea episodes, eye and skin complaints and musculoskeletal conditions in a given area. Where medical records are provided by a third party that contain personal identifiers, the investigators will make arrangements for protecting the confidentiality of such data by omitting information that might lead to the identification of individual participants, or limiting access to the data, or by other means. Ethical approval for access to the health records would be obtained from the relevant health authorities in the respective sites prior to accessing such records.

Investigators will ensure the adequate physical and electronic security of data. All electronic files of health records obtained would be stored by the qualified investigator (ie. the lead field investigators and principle investigators of the project) on a password protected flash drive and/or computer. All paper copies of health records will be stored, by our qualified investigators, in a key-secured container, to ensure the safeguarding of confidential health data.

Communication of the Results

The research team will communicate the results in a timely, understandable and responsible manner. We will communicate the results to other scientists with appropriate peer review and communicate the results to other interested parties such as national sponsors (UK Government Department for International Development), international water and sanitation community (the Joint Monitoring Program for Water Supply and Sanitation) and within study country conferences. We will submit our methods and results to peer review (for example, review for publication) as the peer review process plays an important role in improving study protocols and scientific reports. We will strive to ensure that, at a minimum, both positive and negative study results are interpreted and reported on accurately. Results of the study will not be published in a form that permits the identification of individual participants, and will be published in a form that gives due regard to cultural and other sensitivities.

Respect for participants and their rights

Recruitment and engagement of participants throughout the project will be mindful of at least two fundamental principles of people’s rights; autonomy and justice.

Autonomy, which requires that people who are capable of deliberation about their personal goals, will be treated with respect for their capacity for self-determination. It also involves the protection of people with impaired or diminished autonomy, which requires that people who are dependent or vulnerable be afforded security against harm.

Justice requires that, within a population, there is a fair distribution of the benefits and burdens of participation in a study and, for any participant, a balance of burdens and benefits. In general, our proposed engagement with selected communities during the conduct of the study aims to bring long-term benefit to the communities at large within the country of study and internationally.

PART B: About the research team

B.1 To be completed by students only [20]	
Qualification working towards (eg	PhD

Masters, PhD)	
Students name and background	Jo-Anne Geere. Jo-Anne currently works at the University of East Anglia. With over 15 years experience in clinical physiotherapy, Jo is now a Lecturer in Physiotherapy. She has particular interest and expertise on the musculoskeletal system and is leading the designing and deployment of instruments for the assessment of spinal pain and other musculoskeletal disorders. Jo previously conducted a study in South Africa and has recently published a number of papers documenting her work on physical disability in developing countries. Jo.Geere@uea.ac.uk
Supervisor's name *(Title, first name, surname)*	Paul Hunter
Department/ School/ Institute	University of East Anglia
Faculty	Medicine and Health Sciences
Work address *(including postcode)*	Queens Building 2.10 Norwich NR4 7TJ
Supervisor's telephone number	+ 44 1603 591004
Supervisor's email address	paul.hunter@uea.ac.uk
Module name and number *(if applicable)*	N/A
Qualification working towards (eg Masters, PhD)	PhD
Students name and background	Batsirai Majuru Batsi is an Environmental Health Scientist and doctoral student at the University of East Anglia. She has lived in South Africa where she has experience of research on Water and Health and on Water Policy issues in South Africa. B.Majuru@uea.ac.uk
Supervisor's name *(Title, first name, surname)*	Paul Hunter
Department/ School/ Institute	University of East Anglia
Faculty	Medicine and Health Sciences
Work address *(including postcode)*	Queens Building 2.10 Norwich NR4 7TJ
Supervisor's telephone number	+ 44 1603 591004
Supervisor's email address	paul.hunter@uea.ac.uk
Module name and number *(if applicable)*	N/A
Qualification working towards (eg Masters, PhD)	PhD
Students name and background	Kristen Downs

	Kristen Downs, MS (UNC) is a doctoral student in Environmental Engineering with the Water Institute at the University of North Carolina at Chapel Hill with research experience in monitoring and the sustainability of rural water supply systems in Mozambique. Kristen will be both contributing and participating to the pilot study in South Africa. kristen.downs@unc.edu
Supervisor's name *(Title, first name, surname)*	Jamie Bartram
Department/ School/ Institute	University of North Carolina at Chapel Hill
Faculty	Environmental Sciences and Engineering
Work address *(including postcode)*	Rosenau 144 135 Dauer Drive Campus Box 7431 Chapel Hill 27599-7431 USA
Supervisor's telephone number	(US) T: 919-966-3934
Supervisor's email address	jbartram@email.unc.edu
Module name and number *(if applicable)*	N/A
Qualification working towards (eg Masters, PhD)	Masters Candidate
Students name and background	Ashley Rhoderick Ashley is a Masters MSEE Candidate 2013. She is currently preparing a field research project based in Ghana. Some of her time will support the project and as such will be both contributing and participating to the pilot study in South Africa. alrhode@live.unc.edu
Supervisor's name *(Title, first name, surname)*	Jamie Bartram
Department/ School/ Institute	University of North Carolina at Chapel Hill
Faculty	Environmental Sciences and Engineering
Work address *(including postcode)*	Rosenau 144 135 Dauer Drive Campus Box 7431 Chapel Hill 27599-7431 USA
Supervisor's telephone number	(US) T: 919-966-3934
Supervisor's email address	jbartram@email.unc.edu
Module name and number *(if applicable)*	N/A

B.2 Other members of the research team (eg co-investigators, co-supervisors) [21]

Name *(Title, first name, surname)*	Ms Laura Bates
Position	Laura is a Post Doctoral Research Assistant whose role is to assist the Principle Investigator from the University of Leeds (Ms. Barbara Evans) on this project. Laura will act as the lead field researcher in Vietnam. She has a Masters in International Public Health and a Masters of Science in Environmental Science. She lived for over 5 years in Arabian Gulf and worked in the greater Middle East, as well as the Maldives, Yemen, and Australia and therefore has a wealth of experience of working in different counties with different cultures.
Department/ School/ Institute	Civil Engineering
Faculty	Water Engineering and Environment
Work address *(including postcode)*	University of Leeds, Leeds, LS2 9JT
Telephone number	+44(0)113 343 2294
Email address	l.a.bates@leeds.ac.uk

Name *(Title, first name, surname)*	Professor Paul Hunter
Position	Paul is Professor of Health Protection and an honorary consultant in medical microbiology at the Norfolk and Norwich University Hospital. He is a registered medical practitioner with a licence to practice and is on the specialist register in medical microbiology and virology. He has extensive experience of conducting epidemiological studies in Europe and in low income countries.
Department/ School/ Institute	University of East Anglia
Faculty	Norwich Medical School
Work address *(including postcode)*	Norwich NR4 7TJ England
Telephone number	+ 44 1603 591004
Email address	paul.hunter@uea.ac.uk

Name *(Title, first name, surname)*	Nora Groce
Position	Professor Groce is a medical anthropologist, working in the area of global health and international development with particular emphasis on cross-cultural systems of health care and health as a human rights issue. Her research interests include issues of disability in international health and development, violence as a global public health problem, equity in access to health care in ethnic, minority and rural communities and the integration of western and traditional health care systems.
Department/ School/ Institute	University College London
Faculty	Leonard Cheshire Chair of Disability and Inclusive Development Epidemiology & Public Health Institute of Epidemiology & Health Faculty of Population Health Sciences
Work address *(including postcode)*	Taviton Street London WC1H 0BT

Telephone number	+44 (0)20 3108 3177
Email address	nora.groce@ucl.ac.uk

Name *(Title, first name, surname)*	Prof. Jamie Bartrum
Position	**Jamie Bartram**, PhD (UNC) is a Professor at the University of North Carolina at Chapel Hill and the Director of the 'Water Institute at UNC'. Dr. Bartram has over 20 years experience of international policy, research and advisory work in public health and disease prevention, especially in relation to environment and health and water supply and sanitation; and in more than 30 developing and developed countries worldwide.
Department/ School/ Institute	University of North Carolina at Chapel Hill
Faculty	Environmental Sciences and Engineering
Work address *(including postcode)*	Rosenau 144 135 Dauer Drive Campus Box 7431 Chapel Hill 27599-7431 USA
Telephone number	(US) T: 919-966-3934
Email address	jbartram@email.unc.edu

Part C: The Research

C.1 What are the aims of the study? [22] (Must be in language comprehensible to a lay person.)

This research project aims to "*test the hypothesis that increase access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply*."

Three overarching research questions drive the research to test the hypothesis that greater health, social and economic benefits are realized as a result of an at-house water supply as compared to a public water supply.

They are:
1. What are the patterns of water usage (including quantities used and purposes) in the context of distance to source, levels of sharing, reliability and water quality (at source)?
2. What health outcomes are associated with the different quantity of water consumed, and the different levels of service of water supply?
3. What are the socio-economic benefits derived from different levels of service of water supply?

C.2 Describe the design of the research. Qualitative methods as well as quantitative methods should be included. (Must be in language comprehensible to a lay person.)

Overview

The research will develop our understanding of the social and economic benefits of in-home or private in-yard water connections compared to shared or public water supplies and also the social and economic drivers of and barriers to the uptake of such connections. To do this the project proposes to collect both community level context data and house hold detailed data.

The study will combine both quantitative and qualitative elements so as to provide information on the strength of association between potential risk factors and health and social outcomes. As detailed in section A9 the proposed mixed method study will collect data at community and household levels through (i) face to face interviews coupled with (ii) structured observations and (iii) natural group meetings:

(i) Household Face To Face Interviews

This will involve the use of face-to-face interview coupled with structured observations.

(ii) Structured Observation

This will involve the use of the following tools: structured observation, GPS-based mapping of infrastructure, collection of at source water quality data (where available) through the assemblage of existing utility data, community mapping, transect walks, interviews with local service providers, interviews with community leaders.

(iii) Triangulation through natural-group discussions and semi-structured interviews

Additional qualitative data on the household and community experience of water supply and related outcomes will be collected through a series of natural-group discussions and semi-structured focused groups with individuals and selected groups of participants (such as groups of people who naturally gather together plus the facilitated gathering of groups that are less accessible to ensure discussions do not discriminate against more disparate or private groups of people). These will provide additional information on how current water supply and service systems impact on people and communities.

C.3 What will participants be asked to do in the study? [23] *(e.g. number of visits, time, travel required, interviews etc)*

Structured interviews

Household participants recruited to the study will be asked to volunteer their time to complete a face to face structured interview about their level of service of water, their health and their social behaviours relating to water. Enumerators fluent in the local dialect will conduct the face to face interviews. One enumerator will ask questions pertaining to level of service of water supply and household economics. This enumerator will arrange a meeting for a second enumerator to conduct an interview on their health and social experiences relating to water supply. The second interview will be arranged this way so to maximise the number of respondents available to participate in the health and social questionnaire. In total both interviews are not expected to take more than 2 hours of the participant's time.

Observations
Community participants recruited to the study will not be asked to do anything other than carry on their daily business so that the researchers' structured observations can be made. Approval to observe the community will first be obtained by community leaders. Anthropometric observations will also be made including height and weight. Measurements of waist circumference may be trialled during the pilot study to test the time taken to undertake this measurement and the reliability of the measurement.

Natural Group Meetings
A subset of the interviewed participants and other community members will be invited to attend natural group discussions or facilitated grouped discussions that will explore in greater detail the themes identified in the structured interview and observations. Participants would be asked to volunteer their time to contribute to a single group session. Light refreshments will likely be provided. No travel costs will be offered as it is hoped that the event would take place in a local venue. Participants from studied communities will be invited to an open community meeting where the study team will communicate the range of themes derived from group discussions back to the community. This will not only inform the contributing communities of the communities beliefs, concerns and issues relating to water supply but will also serve as to verify or amend our interpretation if necessary.

C.4 Does the research involve an international collaborator or research conducted overseas: [24]
(Tick as appropriate)

☑ Yes ☐ No

If yes, describe any ethical review procedures that you will need to comply with in that country:

The University of Leeds will collaborate with the School of Public Health in Hanoi (SPHH). The school has its own code of ethics procedures and application for ethical review and clearance will be made to the Scientific Ethical Committee in Health Research and the Ethical Committee of the Health System Research Project at the University of Hanoi upon ethical clearance by the University of Leeds. Further, any national ethical clearance procedures will be adhered to on the advice of SPHH.

Similarly the University of East Anglia will seek to gain ethical approval from Tshwane University of Technology (TUT) in South Africa who were joint partners on previous related research. Both parties have enjoyed previous collaboration projects relating to water access and health. Both parties are familiar the ethical requirements for research in human health. UEA has a working respect for TUTs ethical requirements to conduct research on human participants within South Africa which is in line with national requirements. Should additional health data be required e.g. health records from clinics, ethical approval will also be obtained the provincial Department of Health

Describe the measures you have taken to comply with these:

The University of Leeds have contacted Dr Anh the Dean of the School of Public Health in Hanoi who has agreed to collaborate with the University of Leeds on this project. We are currently agreeing a terms of reference of the works, part of which includes a request for details of their ethical review requirements so we may meet their ethical criteria.

Similarly the University of East Anglia have contacted Dr Stanley Mukhola of Tshwane University of Technology in South Africa to determine the meeting schedule of their ethics committee. Both universities are reviewing the core method to ensure that the questions proposed are relevant and acceptable to residents of South Africa. The committee meet every month and have agreed to receive the project protocol as soon as it is ready.

Include copies of any ethical approval letters/ certificates with your application.

C.5 Proposed study dates and duration

Research start date (DD/MM/YY): 01/01/2012 Research end date (DD/MM/YY): 31/12/2012

Fieldwork start date (DD/MM/YY): June 2012	Fieldwork end date (DD/MM/YY): November 2012

C.6. Where will the research be undertaken? (i.e. in the street, on UoL premises, in schools) [25]

Study sites within Vietnam

Interviews will be undertaken in the home, observational studies in the streets and areas surrounding the community, and focus group discussion in an appropriate community location which may be a public building or communal open space.

Study sites within South Africa
Interviews will be undertaken in the home, observational studies in the streets and areas surrounding the community, and focus group discussion in an appropriate community location which may be a public building or communal open space.

RECRUITMENT & CONSENT PROCESSES

How participants are recruited is important to ensure that they are not induced or coerced into participation. The way participants are identified may have a bearing on whether the results can be generalised. Explain each point and give details for subgroups separately if appropriate.

C.7 How will potential participants in the study be:

(i) identified?

Communities will be identified from national housing databases and screened to ensure a range of contexts are included in the study. Relevant factors will include:

- Levels of access to water relative to distance from home and that these water source points can be or have been readily mapped (i.e. households with a private water supply in the home or yard vs. households who share a water supply with a defined group of people vs. Households who share a communal water supply);
- Density of housing in a given area (density ranges within Vietnam range from 1 person per squared kilometre to 1000 persons per squared kilometre and so areas that exhibit both high and low density in a given province would be selected)

Additional factors that determine the identification of communities within the study relate to the communities willingness to participate. Households will then be selected from such communities through stratified random sampling and invited to participate in the study. Up to 300 households will be identified with a view to engaging 200 in the study.

It is anticipated that the random stratification will result in sufficient numbers of participants with a disability for analysis. If however the random sample results in too few participants with disability for analysis, purposive sampling will be carried out to ensure recruitment of a representative sample of people with physical disability (both adults and children), which is a particular health outcome of interest.

(ii) approached?

Community leaders will be approached by the field researchers in the project seeking their agreement that the study be conducted in their area. Their permission will be sought not only demonstrate respect for local leadership mechanisms but will also help to identify informed representatives of a community who could act as an additional communication pathways and provide information to other community members about the project and/or the researchers' presence.

Both local enumerators and lead field researchers will meet with local authorities and community leaders and discuss the project by providing them with a presentation and / or round table discussion to introduce the project. Key points that will be provided include the key drivers behind the project, the health and social concerns of focus related to water supply and sanitation, the UKs contribution to international development and the proposed method of data gathering and participant engagement. The researchers will invite local authorities and community leaders to raise any questions and concerns so to talk through them directly.

The field team will explore the preferred etiquette of the local authorities or community leaders to enter and walk around the village so to map the points of water source as well as identify households that may agree to participate in the project. Where community leaders are in support of our work it may be appropriate to receive an orientation to the area and introduction to some of the households within the research area. This would serve as a reconnaissance of the area, opportunistic introduction to members of the community, and community acceptance of our temporary presence within their home area.

(iii) recruited? [26]

Each household randomly identified using stratified sampling will be invited to participate in the project. Personal invitations to each household will entail a visit by a field team member, namely a local enumerator who will hold a valid identification card, explain the background to the project and invite the household to participate. Willing participants will be asked to sign a consent form to confirm they understand the purpose of the project, that the project will involve the collection of data for analysis, that their personal data will remain confidential, and that they are able to freely withdraw from the project at any time in which case their personal data will be removed from future analysis but data that has been analysed in aggregate will remain in the project data set.

C.8 Will you be excluding any groups of people, and if so what is the rationale for that? [27]

Excluding certain groups of people, intentionally or unintentionally may be unethical in some circumstances. It may be wholly appropriate to exclude groups of people in other cases.

No – the structured interview will gather information about all residents within a household. All adults at the house at the time of interview will be invited to participate, in particular questions regarding household demographics, self-reported health status and water access and collection. Persons unable to speak for themselves may be represented by another resident adult subject to appropriate consent, thereby not excluding individuals or groups of people.

C.9 How many participants will be recruited and how was the number decided upon? [28]

It is important to ensure that enough participants are recruited to be able to answer the aims of the research.

The power calculation is based on the following parameters of a 95% significance level (Two-sided α=0.05) at a power of 80% and a desired Odds Ratio of 0.7 or less (i.e. about a 30% reduction or more). The required sample population has been calculated, assuming an outcome affecting 10% of the population (at the mean of the normal covariate and a squared correlation of x with other included covariates) at 1069 cases as shown in the calculation below.

Logistic regression, test that $\beta = 0$ for one normal covariate, x, adjusting for prior covariates

Column	1
Test significance level, α	0.050
1 or 2 sided test?	2
Proportion, p_μ, at mean μ of covariate x	0.100
At $x_T = \mu + \sigma$, Proportion, p_T	0.072
Odds ratio = $p_T(1 - p_\mu) / [p_\mu(1 - p_T)]$	0.700
Coefficient, B = ln(odds ratio)	-0.357
ρ^2 = squared corr. of x with included covariates	0.300
Power (%)	80
n	1069

REFERENCES for ROT1-1:

Hsieh, F.Y. "Sample size tables for logistic regression" Statistics in Medicine 8(1989) pp. 795-802

This sample size would be highly effective for multiple linear regression, a sample size of 1000 would give a power of 99% to detect a R^2 of 0.1 in a multiple linear regression with 10 predictor variables. To account for the fact that the study will be household cluster sampled we shall assume a design effect of 2 and so we will require a total sample size of 2 x 1069 ≈ 2200 plus another 10% for contingency ≈2500 respondents. This corresponds to 900 respondents per country and assuming 4 to 5 people per household about 200 households.

C.10 Will the research involve any element of deception? [29] If yes, please describe why this is necessary and whether participants will be informed at the end of the study.

No

C.11 Will informed consent be obtained from the research participants?[30]

☑ Yes ☐ No

f yes, <u>give details</u> of how it will be done. Give details of any particular steps to provide information (in addition to a written information sheet) e.g. videos, interactive material. If you are not going to be obtaining informed consent you will need to justify this.

Every participant will receive information about the project including information concerning who the enumerators are, the proposed research, whether it has received in-country and community approval and the fact that it is seeking voluntary involvement of household participants in the area. All enumerators will be honest, accurate and consistent in providing information relating to the research and properly trained and culturally sensitive enumerators who will carry identification will carry out the researchers and interviewers.

The local enumerators will provide each household with a locally transcribed information sheet informing them about the project. The enumerators will then discuss the project with all adults available at household at the time of survey. Discussions will involve talking through the aims and method of the study and the roles and rights of participating households. The information sheet outlines the content of the survey questions thereby forewarning him or her of the nature of participation. The information sheet will also inform participants that they may withdraw from the study at any time during the survey or after the survey and the enumerators will support potential participants understanding of this.

The sheet will contain an area to certify consent to participate and an example of which has been provided for review by the ethics committee at the University of Leeds. This approach supports the informed consent process i.e. it will provide adequate information in a form and manner that enables it to be understood and an informed judgement made and any consent is voluntary in nature.

Should oral agreement to participate in the study be given by participants living with the household, written signatures will be collected for each participant, or on behalf of each participant (where literacy is limited or the participant involves an individual from a vulnerable group) to confirm this agreement and documented on two copies of the participant information sheet (one to be held by the participant and the other to be held by the study team). Written agreement to participate will be a prerequisite to proceeding with the questionnaire survey.

The project will not induce participants to participate in the research and will offer no financial or material reward for their involvement.

Lead field researchers shall remain in situ during the fieldwork to monitor and audit the research, the research conduct and respond to any unforeseen adverse circumstances.

If participants are to be recruited from any of potentially vulnerable groups, <u>give details of extra steps</u> taken to assure their protection. Describe any arrangements to be made for obtaining consent from a legal representative.

Some structured household questions will be directed to residents responsible for a given role. Where the individual undertaking that role is a child (less than 16 years) additional consent from both the child (oral) and adult (written consent on behalf of the child) will be required. Questions would only be directed to a child providing they were able to understand the project, were old enough to respond, provided verbal agreement to be asked some questions regarding their role (e.g. as a water collector), and that a parent or adult guardian residing within the same household agreed to the child’s participation in the survey and provided an additional consent to permit the interviewee to proceed with the structured questions. Where children or vulnerable individuals are recruited to the study, enumerators and researchers will also be trained to be sensitive to any signs of distress or indications that the participant no longer wishes to continue with the study. Should this occur, such individuals would be offered the opportunity to withdraw from the study.

Copies of any written consent form, written information and all other explanatory material should accompany this application*. The information sheet should make explicit that participants can withdrawn from the research at any time, if the research design permits.*
Sample information sheets and consent forms are available from the University ethical review webpage at http://researchsupport.leeds.ac.uk/index.php/academic_staff/good_practice/ethical_review_process/university_ethical_review-1.

C.12 Describe whether participants will be able to withdraw from the study, and up to what point (eg if data is to be anonymised). If withdrawal is not possible, explain why not.

Participants will be able to withdraw from participation in the study at any time by the simple expedient of requesting to terminate a household interview or by withdrawing from a focus group. This will be made clear to all participants by the enumerators at the start of each interaction.

Completed structured interviews will collect details such as address, community area, and level of service of water supply from which personal identifiers can be inferred. A key issue concerning health information is whether the individual concerned is "identifiable" from the information. Matters of confidentiality identified and discussed above (section A.10) will remain particularly relevant to this section of the method. Personal identifiers will be removed during the entry of the data and prior to transfer from the country of data collection. Again, any published or analysed data will be made anonymous prior to analysis, write up and reporting.

C.13 How long will the participant have to decide whether to take part in the research? [31]
It may be appropriate to recruit participants on the spot for low risk research; however consideration is usually necessary for riskier projects.

The enumerators will make separate enquiries at each household as to whether they would like to voluntarily participate in the project. The enumerators will be able to conduct the interview immediately or return on an agreed day/date if an adult participant in the household agrees.

Alternatively, if an adult participant in the household is unsure if they will participate the enumerator will offer to leave the information sheet with the household for them to consider, and will offer to return the following day(s) to answer any questions they may have and re-invite participation within the project. Given time constraints the enumerator may have enough time to visit each household up to two times to answer any queries and conduct the structured questionnaire.

For any households not wanting to be involved, the enumerator will thank them for their time, apologise for the interruption and leave the household premises immediately.

C.14 What arrangements have been made for participants who might not adequately understand verbal explanations or written information given in English, or who have special communication needs? [32]*(e.g. translation, use of interpreters etc. It is important that groups of people are not excluded due to language barriers or disabilities, where assistance can be given.)*

Arrangements will be made to recruit enumerators who have excellent verbal and written skills in both English and the local dialect. They will be required to verbally explain the project and talk through the written information sheet (that has been translated from English into the local dialect and back translated for cross checking) to support the participants understanding of the project.

C.15 Will individual or group interviews/ questionnaires discuss any topics or issues that might be sensitive, embarrassing or upsetting, or is it possible that criminal or other disclosures requiring action could take place during the study (e.g. during interviews/group discussions, or use of screening tests for drugs)? [33]

☑ Yes ☐ No

If Yes, give details of procedures in place to deal with these issues

The information sheet outlines the content of the survey questions thereby obtaining the participant's prior consent by forewarning him or her of the nature of participation. The majority of the survey questions are not considered to be intrusive and or cause distress given they relate to household demographics, household health (eye, skin, diarrhoea and musculoskeletal pain), household assets and income, and level of service of water supply.

However some questions may be potentially distressing and intrusive. These questions pertain to miscarriage, child death or perceptions around disability. Additional steps are proposed in an effort to acknowledge the potentially distressing nature of these questions. These include the field research team making provisions for the in-country enumerators to be properly trained to deliver each question in a professional, discrete and respectful manner. Whilst they will not be trained to counsel distressed participants they will be trained in ways to offer supportive information such as details of appropriate points of contact (e.g. counsellors offering support in grievance, loss or depression),

The information sheet outlines the content of the survey questions thereby forewarning the participant's prior consent by forewarning him or her of the nature of participation. Furthermore the questions are to be asked within the private environment of the participant's home so to reduce any potential embarrassment associated with health or wealth questions.

Lead field researchers shall remain in situ during the fieldwork to monitor and audit the research, the research conduct and respond to any unforeseen adverse circumstances.

The information sheet should explain under what circumstances action may be taken

C.16 Will individual research participants receive any payments, fees, reimbursement of expenses or any other incentives or benefits for taking part in this research? [34]

☐ Yes ☑ No

If Yes, please describe the amount, number and size of incentives and on what basis this was decided.

The project will not induce participants to participate in the research and will offer no financial or material reward for their involvement.

RISKS OF THE STUDY

C.17 What are the potential benefits and/ or risks for research participants? [35]

Risks are minimal as the study does not involve the administration of an intervention with the potential to influence the status of participants. It is a data collection process.

The purpose of the study is to investigate the health effects of carrying water, which has potentially negative health impacts such as injury or strain of the musculoskeletal system (which may for example manifest as neck or back pain). Therefore, participants will not be asked to do any tasks other than what they would normally do and care will be taken to avoid or minimise repetition of tasks during observation. Participants will be informed that they should perform tasks in the usual manner that they would be performed and asked not to perform tasks which they believe may hurt or harm them.

Taking part in the study will take up the participant's time, during observation, interview and/or during group discussion work. Observation and assessment will be pre-arranged at a time agreeable and convenient to the participant, to minimise any disruption to usual activities as much as possible.

Risks to participant confidentiality (during data transfer between in-country project sites and UK project sites) will be mitigated through the removal of personal identifiers to all project data prior to leaving the country of data collection. Participants will be assigned a number referent upon recruitment to the study thereby preserving participant anonymity. All data will be stored under lock and key with access permissions granted to members of the research team only. All communications between the two sites will employ the use of number referents for participants.

The findings will be used to inform the development of future community workshops that highlight health outcomes relevant to the community, and suggest interventions linked to these outcomes, which are acceptable and desirable to the community. The findings will therefore lead to the development and use of health outcome measures, which are meaningful and relevant to individual and community needs and can be used to monitor the impact of water and sanitation interventions. Appropriate outcome measures are important to monitor the effects of water supply systems on health and evaluate changes to water supply systems. This may lead to improvement of the services provided to the community in the future.

C.18 Does the research involve any risks to the researchers themselves, or people not directly involved in the research? *Eg lone working* [36]

☑ Yes ☐ No

If yes, please describe:

Potential risks relate to the researchers operating within a country that is not their normal place of residence or work. All researchers have previously visited the proposed country of fieldwork on matters separate to this project and are therefore familiar with the cultural and environmental context of their country of focus. They will however undertake a detailed risk assessment to ameliorate identified risks specific to this project.

Health and safety risks during fieldwork include working in peoples' homes, observing water and sanitation infrastructure, adhering to a field protocol so not to endanger ones self or others working on the project, communicating one's location and travel plans and having an operable communication device. Control measures relating to visits to villages and homes conducted by the researchers include:

- Planned visits only through contact with the local community;
- Recruitment of enumerators familiar with the region and local languages;
- Consideration of safety of travel to each location prior to visiting;
- Communication with the lead field researcher of each field visit to be logged in a log book recording details of time of departure, destination and anticipated time of return;
- Possession of a fully charged and operable mobile phone and first aid box about them self at all times during field visits;
- Commitment to vigilance on the maintenance and securing of vehicles and equipment to prevent theft or damage to property and minimise the risk of vehicle breakdown;
- Communication with the lead field researcher of the end of each field visit to be logged in terms of return time and adverse events.

Other health hazard mitigation measures include that from considered ingestion of food and water, awareness of available medical services, provision of health insurance and administration of to date and relevant vaccinations.

Such risks and others are being identified and reduced or mitigated though the completion of a risk assessment.

Is a risk assessment necessary for this research?

☑ Yes ☐ No If yes, please include a copy of your risk assessment form with your application.

A risk assessment is currently under preparation for this project. Telephone conversations with Ms Blaikie (30 April 2012) indicated that we may submit our request for ethical approval from the committee in advance of the completion of the risk assessment.

Further information on fieldwork risk assessments is available at http://www.leeds.ac.uk/safety/fieldwork/index.htm.

DATA ISSUES

C.19 Will the research involve any of the following activities at any stage (including identification of potential research participants)? (Tick as appropriate)

☑ Examination of personal records by those who would not normally have access

☐ Access to research data on individuals by people from outside the research team

- [x] Electronic transfer of data
- [x] Sharing data with other organisations
- [x] Exporting data outside the European Union
- [ ] Use of personal addresses, postcodes, faxes, e-mails or telephone numbers
- [x] Publication of direct quotations from respondents
- [x] Publication of data that might allow identification of individuals to be identified
- [x] Use of audio/visual recording devices
- [x] FLASH memory or other portable storage devices

Storage of personal data on or including any of the following:

- [x] Manual files
- [ ] Home or other personal computers
- [ ] Private company computers
- [x] Laptop computers

C.20. How will the research team ensure confidentiality and security of personal data? E.g. anonymisation procedures, secure storage and coding of data. [37] You may wish to refer to the data protection and research webpage.

One of the teams research members Ms. L. Bates has met with and received training from Adrian Slator, the University's Legal Advisor. As such the following is proposed:

The research team will adhere to University of Leeds policy and guidelines on data security, and specifically must ensure that personal data belonging to each participant is kept securely by the research team and that this personal information is not disclosed either orally or in writing, or in any other way, intentionally or otherwise to any unauthorised third party and that doing so could considered gross misconduct in certain cases.

The research team does not intend to use a person external to the team to process the data on the team's behalf but should circumstances change, the Principal Investigator will ensure a written contract is created between the parties, which specifies that the processor agrees to act on the University's instructions and to abide by the provisions of the Data Protection Act in connection with data security.

The research team will make reasonable efforts to ensure that all personal information is kept securely and will pay particular attention to the security of sensitive data. All personal data will be accessible only by those who need to use it and sensitive data will be either be kept in a lockable room with controlled access, or kept in a locked filing cabinet, or kept in a locked drawer, or protected by password if held on a computer, or kept only on disks which are themselves kept securely.

Off-University site use of personal data presents a potentially risk of loss, theft or damage and the institutional and personal liability that may accrue from the off-site use of personal data is similarly increased. For these reasons, authorised research team members will anonymise all personal data upon collection and prior to leaving the country of data collection. The research team will take appropriate security precautions in respect of day-to-day PC usage in-country for data that has not yet been anonymised. This will include care to ensure that data on the screens of PCs and terminals are not visible except to unauthorised research team members and that computer passwords are kept confidential. Screens will not be left unattended when personal data is being processed and manual records will not be left where they can be accessed by unauthorised research team members. When manual records containing personal identifiers are no longer required, they will be shredded or bagged and disposed of securely. Participants will be assigned a number referent upon recruitment to the study thereby preserving participant anonymity. All communications between the two sites will employ the use of number referents for participants.

C.21 For how long will data from the study be stored? Please explain why this length of time has been chosen.[38]

10years, ________ months

We will adhere to RCUK guidance and store data for a period of ten years for the purpose of review, cross checking and follow-up analysis.

NB: [RCUK guidance] states that data should normally be preserved and accessible for ten years, but for some projects it may be 20 years or longer.

Students: It would be reasonable to retain data for at least 2 years after publication or three years after the end of data collection, whichever is longer

CONFLICTS OF INTEREST

C.22 Will any of the researchers or their institutions receive any other benefits or incentives for taking part in this research over and above normal salary or the costs of undertaking the research? [39]

☐ Yes ☑ No

If yes, indicate how much and on what basis this has been decided

____

C.23 Is there scope for any other conflict of interest? [40] *For example will the research funder have control of publication of research findings?*

☐ Yes ☑ No ***If yes, please explain*** ____

C.24 Does the research involve external funding? (Tick as appropriate)

☑ Yes ☐ No ***If yes, what is the source of this funding****?*

Funding is provided by the UK Governments Department for International Development

PART D: Declarations

Declaration by Chief Investigators

1. The information in this form is accurate to the best of my knowledge and belief and I take full responsibility for it.
2. I undertake to abide by the University's ethical and health & safety guidelines, and the ethical principles underlying good practice guidelines appropriate to my discipline.
3. If the research is approved I undertake to adhere to the study protocol, the terms of this application and any conditions set out by the Research Ethics Committee.
4. I undertake to seek an ethical opinion from the REC before implementing substantial amendments to the protocol.
5. I undertake to submit progress reports if required.
6. I am aware of my responsibility to be up to date and comply with the requirements of the law and relevant guidelines relating to security and confidentiality of patient or other personal data, including the need to register when necessary with the appropriate Data Protection Officer.
7. I understand that research records/ data may be subject to inspection for audit purposes if required in future.
8. I understand that personal data about me as a researcher in this application will be held by the relevant RECs and that this will be managed according to the principles established in the Data Protection Act.
9. I understand that the Ethics Committee may choose to audit this project at any point after approval.

Sharing information for training purposes

Optional – please tick as appropriate:

☑ I would be content for members of other Research Ethics Committees to have access to the information in the application in confidence for training purposes. All personal identifiers and references to researchers, funders and research units would be removed.

Principal Investigator

Signature of Principal Investigator: ...Babarely...................... (This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: Ms Barbara Evans

Date: (dd/mm/yyyy): ...15-5-12.....................................

Supervisor of student research

I have read, edited and agree with the form above.

Supervisor's signature: .... (This needs to be an actual signature rather than just typed. Electronic signatures are acceptable)

Print name: ....

Date: (dd/mm/yyyy) ....

Please submit your form **by email** to J.M.Blaikie@leeds.ac.uk or if you are in the Faculty of Medicine and Health FMHUniEthics@leeds.ac.uk. **Remember to include any supporting material** such as your participant information sheet, consent form, interview questions and recruitment material with your application.

Checklist:

- ❑ I have used layman's terms to describe my research (applications are reviewed by lay members of the committee as well).
- ❑ I have answered all the questions on the form, including those with several parts (refer to the guidance if you're not sure how to answer a question or how much detail is required)
- ❑ I have included any relevant supplementary materials such as
    - ❑ Recruitment material (posters, emails etc)
    - ❑ Sample participant information sheet
    - ❑ Sample consent form.

    Include different versions for different groups of participants eg for children and adults.
- ❑ If I am not going to be using participant information sheets or consent forms I have explained why not and how informed consent will be otherwise obtained.
- ❑ If you are a student have you discussed your application with your supervisor and are they satisfied that you have completed the form correctly? (This will speed up your application).
- ❑ I have submitted a signed copy of my application. (If you are a student your supervisor also needs to sign the form).

Appendix 16. University of Leeds response to ethics committee

Barbara Evans
School of Civil Engineering
University of Leeds
Leeds, LS2 9JT

UNIVERSITY OF LEEDS

Performance, Governance and Operations
Research & Innovation Service
Charles Thackrah Building
101 Clarendon Road
Leeds LS2 9LJ
Tel: 0113 343 4873
Email: j.m.blaikie@leeds.ac.uk

7 June 2012

Response to: MEEC Faculty Research Ethics Committee, University of Leeds

Dear Jennifer

Thank you for taking the time to consider our project looking to study the 'Health and Social Benefits of At-house Water Supplies in Developing Countries in Vietnam, South Africa and Ghana'.

Title of study	**Health and Social Benefits of At-house Water Supplies in Developing Countries in Vietnam, South Africa and Ghana**
Ethics reference	**MEEC 11-043**
Grant reference	**483272**

We acknowledge the 9 areas identified and outlined in your letter (dated 31 May 2012) requiring further information/clarification. Our response is presented below each of the items raised. We would be grateful if you would facilitate a review of our response by the Ethics Committee with a view to re-considering ethical approval for this project.

1. *A2 the approach to seeking ethical approval from different institutions is not really explained. It is presumed that given the size of the project and existing partnerships you have decided to divide it up this way, but a more detailed explanation is required. It is unclear which organisation of the partnership of the Universities of Leeds, East Anglia and North Carolina is taking overall responsibility for the project and why they have not taken the approach of either the lead organisation seeking approval for all aspects, or each institution seeking approval for all aspects of the project? Please could this be clarified.*

The Ethics Committee is correct, the proposed project comprises a partnership between three universities, the University of Leeds (UL), the University of East Anglia (UEA) and the University of North Carolina (UNC).

The UL is the lead organisation for the project. Existing Institutional arrangements/requirements surrounding ethical approval differ between the UK and US Universities. These arrangements render it permissible for UL to submit an application for ethical approval on behalf of UL and UEA. However, staff undertaking research at UNC must secure ethical approval by an Institutional Review Board (IRB), a committee established to review and approve research involving human subjects, within the US.

As such 2 separate procedures have been sought, in parallel, for the same scope of work.

2. *Committee members raised a general concern about the voluntariness of the participants, and the ability of the researchers to ensure this, particularly given the reliance on local "enumerators" to seek consent and translate the project. They would like more detail on how these enumerators are recruited, how the researchers will ensure their ethical expectations regarding voluntary consent, confidentiality etc are met and how any potential power relationship between the enumerators and the local participants would be addressed, to ensure the participants do not feel they have to respond. These details are very hard to address without more information on who the enumerators are and how recruited.*

The term 'enumerator' has been used to refer to local in-country interviewers (herein termed interviewers). Interviewers will be recruited/identified through our in-country partners to undertake the project fieldwork. As the UK project team will hire them directly we have requested that the interviewers meet the following specification:

Each interviewer will possess the following key skills:

- Fluency in local language;
- Fluency in local dialects (if different from the national language);
- Good literacy and numeracy skills sufficient for data collection requirements;
- Excellent social skills (in particular able to demonstrate a professional and respectful attitude to people of all socio-economic backgrounds and an ability to put people of all ages at ease);
- Sensitivity to cultural norms and appropriate behaviours (as appropriate to the area of study);
- Commitment to UK/US ethical standards and adhere to participant confidentiality;
- Awareness of the water and sanitation issues in Vietnam;
- Be available to contribute a minimum of 35hrs/wk to the study between the months of June through to November.

The UK/US project partners also aim to encourage the recruitment of interviewers with existing knowledge of the following:

- Sanitation conditions in the community (communal sanitation facilities, open defecation, gross contamination of water bodies / fields with wastewater);
- Solid waste management;
- Public water sources (access, quality and reliability, number of connections per community);
- Private water sources; and
- Housing quality.

Preliminary discussions with in-country partners (Hanoi School of Public Health (HSPH) in Vietnam, and the Tshwane University of Technology (TUT) in South Africa) on the feasibility of recruiting interviewers with the above skill set are positive.

HSPH and TUT have received expressions of interest from potential interviewers, already known to them from previous in-country research.

The interviewers will be recruited subject to their availability during the field work period (timeline dependent on ethical approval), experience of undertaking sensitive interviews in their country, a good reference describing their technical and socially engaging skills and a recommendation by the local-in-country partners. This process will help engender our trust in the interviewers ability to work independently, translate the project in written and oral form, seek voluntary consent and retain attention to detail.

Further to this, ethical expectations regarding voluntary consent and confidentiality will be supported by the consent process outlined in the ethics application. These include both a process of obtaining pre-agreement with local leaders (i.e. local communist party leaders in Vietnam and tribal leaders in S. Africa) to study a community and the use of voluntary participation consent forms. Each of these mechanisms (including the careful selection and recruitment of interviewers as described above) is designed to safeguard the rights of the participants and provide an avenue through which participants feel they can accept to participate, decline to participate, and/or withdraw from the study at a later date.

3. *A more detailed explanation is required on obtaining consent for the group meetings, particularly the "opportunistic group meetings" - the application focuses on taking consent for interviews, but the researchers are aware that there may be spontaneous group meetings (in addition to organised group meetings) that would provide useful data. How consent is taken in these circumstances and how people are assured they could take part but not have their responses fed back to the wider community needs to be clarified.*

Initially the objective of holding group meetings was to gather significant qualitative data on the issues surrounding participants' health and social lives around water supply. Data was to be collected from predefined groups using audio equipment. Data was to be analysed using emergent theme analysis from written transcripts of audio conversations.

The proposed objective and thus method for any group meetings has now changed. The purpose of the group meetings is to triangulate key or anomalous findings that may arise from the household surveys. A simple checklist of questions for key groups would be used by field teams to cross check any key issues that arise after the household surveys are completed. Key groups that may be invited to participate include women, people living with a physical disability, children involved in the water carrying activities and their guardian/parent, and groups of people from a defined geographic area such as the rural mountains or per-urban city.

At the end of each completed household questionnaire the participant will be asked if they consent to receive an invite from the research team to attend a possible group meeting in the coming weeks. Consenting persons would, on a separate sheet provide their name, gender, age and contact details to receive the invite.

An invitation to attend a group meeting would stipulate the purpose of the meeting (to explore in more detail some of the questions raised in the household questionnaire), stipulate that their attendance would be voluntary and that they would be free to leave the meeting at any time, and that the content of the discussions would be anonymous and would be used to interpret the findings more accurately, and that the (anonymous) findings would be written up in total in both national and international documents and academic publications.

Actual attendees of the meeting would again be provided with written and oral instruction of the purpose and voluntary nature of the meeting. Those who attend the group meeting would be required to provide a signature of attendance for fire safety purposes only and this list of signatures would be disposed of at the end of the meeting. The meetings will be run by two local interviewers (and supported by the UK field leaders), one of whom will run the meeting, while the other will make written notes on the content (only) discussed.

4. *There were also concerns about whether taking written consent is the most appropriate form of consent in these contexts, particularly given, at least in some cases, the low literacy levels. You have proposed getting illiterate participants to put a mark witnessed by someone else on the consent form, but might obtaining recorded verbal consent be more appropriate?*

Consent from participants who agree to do a household questionnaire:

- Written consent will be required by literate participants partaking in the study.
- Written consent will also be required by the parent/guardian of participants under 16 years old partaking in the study.
- Written consent from the guardian/representative of illiterate participants in addition to a written mark by the illiterate person will be requested. Alternatively an audio recording of verbal consent form illiterate participants will also be offered (as proposed by the ethics Committee).

Consent from participants who agree to receive an invitation to attend a group meeting:

- Written consent will be required from participants who complete the household questionnaire and then agree to receive further correspondence from the field team regarding an invitation to attend a group meeting.

Consent from participants who attend group meetings to triangulate the data:

- Actual attendees of group meetings will be asked to sign an attendee registration for fire/safety purposes only. As identified in point 3 above, the rights of all participants will be expressed verbally and provided to each participant in written from at the beginning of each meeting, and the fire registration form will be destroyed upon the completion of the meeting.

5. *There is additionally the proposal to access information in health records without the individual's permission, but seeking permission from the relevant health authorities. This section is unclear - you are requesting aggregated information, which is of less of a concern, but additionally you suggested you would have access to medical records. Please clarify whether you will be requesting aggregated information or access to individual records? If individual records are to be accessed a clear protocol for anonymising the data needs to be put in place.*

The project team does not have access to medical records and does not seek to obtain access to individuals' medical records. It may however make a request to receive anonymous aggregated data (only), which contain no personal identifiers, pertaining to relevant health outcomes mentioned in the household questionnaire.

6. *Encryption of data - the data involved is quite sensitive and the Committee recommends encryption in addition to password protection.*

The project team agree to adopt the ethics Committee's recommendation to encrypt access to the data securing all files with password protectors. Data on laptop/ computers will be stored within an encrypted folder only that will be password protected. The password assistant function will ensure that the password has a high rating and the password-remember option will be deselected. Access to files within the encrypted folder will require a decryption password. Files that are backed up on external hard drives will also be encrypted.

7. *Subsequent agreement with participants on what is included - e.g. photographs of houses (not previously mentioned in application) etc - this is quite personal and the Committee would expect decisions on what photographs can be included to be taken in conjunction with participants, there might also be issues in terms of identifiability.*

Photographs of houses will not be requested as standard from household participants involved in the questionnaire.

Photographs of infrastructure within houses will be requested from a sub-sample of participants, whereby the subject of interest is deemed a typical example found within the community under study.

Infrastructure of interest that may be documented include: roofing material (e.g. slate, straw etc), private water sources (e.g. household tap, yard water connection), methods of household water storage (e.g. in containers in a room or yard) and private sanitation and hygiene infrastructure.

Verbal consent will be required before taking a camera out to photograph the above in homes. All images will be stored separate from the household questionnaire and will not be named, and therefore linked, with the identifying code of the participating household. The photographs will simply be named with the name of the country, community number and example of XX (e.g. "Vietnam_Community1_Example_Straw_Roof", or "South_Africa_Community1_Example_Yard_Well").

8. *The Committee has asked for reassurance that the training will be adequate to manage the sensitive but necessary content of questioning as attached in the appendices, and be in tune with ethics such as voluntary participation.*

The staff at in-country partner organisations are experienced in designing, conducting, and delivering health research. Similar to the UL, the local institutions have their own procedures for obtaining ethical approval at the national level, which the project will secure prior to proceeding with the project.

In addition, the UK/US lead field researchers will recruit interviewers who have existing experience in interviewing within the country of study. Further to this the lead field researchers will deliver training to the interviewers, including the presentation of the project and survey tools, hold discussions about the project and survey tools, roll-playing practice of the survey process and survey tools, and interview shadowing of the first 2 questionnaires during the pilot survey and again during the actual survey.

The training will cover the specifics of each question and measurement being asked or taken, the sequence of delivery of each survey tool, the method of recording participant responses, the individual roles and responsibilities of each interviewer, the shared roles and responsibilities of the interviewers, assessing risks to themselves during the work, assessing situations where participants may require external health or social support services and ways to approach participants with support information on services in the area in a way that minimises risk to themselves and the participants.

9. *Another concern - Nature of the Questions p10 - is regarding the potentially upsetting experience for participants of discussing personal issues such as miscarriage, child death, and any physical or mental incapacity or sickness. In circumstances where researchers/ enumerators are made aware of serious health issues, what resources and risk assessments are in place and what action will be taken to signpost participants onwards to health advice and information where such issues are raised? How are researchers expected to evaluate and manage this kind of information? There is an acknowledgement of a need re counselling services, but this is only one aspect of signposting and support for participants.*

During the course of the household questionnaire, the interviewers will obtain information on the maternal health, child health and physical health of the respondents. The training received by the interviewers will culminate in the completion and signature of a risk assessment that ensures interviewers are mindful of potential risks to themselves during the study. Prior to the training our local partners will propose and agree a framework for provision of support to potentially distressed participants that is locally – appropriate (and this may vary between individual communities of study). Based on the recommendations of our local partners and the piloting of the method, the training of interviewers will include a section on identifying risks which will include identifying participants who may benefit from knowing about external support services, understanding and being able to explain what support services exist (e.g. health advice and information, locally-appropriate support services), and feel comfortable approaching and sharing that information with respondents, in a manner that is safe and non-threatening to the interviewee and interviewer.

Yours sincerely

Barbara Evans

Senior Lecturer, Water Engineering and Environment and MSc Programme Leader

CC: Laura Bates (PDRA)

Appendix 17. University of North Carolina ethics application

General Information

1. General Information

1.Project Title

Health and Social Benefits of At-house Water Supplies in Developing Countries in Vietnam, South Africa, and Ghana

2.**Brief Summary**. Provide a brief non-technical description of the study, which will be used in IRB documentation as a description of the study. Typical summaries are 50-100 words. Please reply to each item below, retaining the subheading labels already in place, so that reviewers can readily identify the content. PLEASE NOTE: THIS SECTION MAY BE EDITED BY THE IRB FOR CLARITY OR LENGTH.

Purpose: This is a multi-country study for the UK Department for International Development to test the hypothesis that increased access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a public, shared water supply.

Participants: Fieldwork will be conducted Ghana (University of North Carolina), South Africa (University of East Anglia) and Vietnam (University of Leeds). Participants in UNC's fieldwork will include approximately 900 household members (children to adults) from 200 randomly selected households in four communities in the Ghana's Ashanti region.

Procedures (methods): The field study utilizes a mixed methods design utilizing qualitative and quantitative methods that include face-to-face structured surveys and interviews, structured observations and focus group meetings.

3.Is this new study similar or related to an application already approved by a UNC-Chapel Hill IRB? Knowing this will help the IRB in reviewing your new study.

No

2. Project Personnel

1.Will this project be led by a STUDENT (undergraduate, graduate) or TRAINEE (resident, fellow, postdoc), working in fulfillment of requirements defined by coursework at the University?

No

2.List all project personnel beginning with principal investigator, followed by faculty advisor, co-investigators, study coordinators, and anyone else who has contact with subjects or identifiable data from subjects.

- List ONLY those personnel for whom this IRB will be responsible; do NOT include collaborators who will remain under the oversight of another IRB **for this study**.
- If this is Community Based Participatory Research (CBPR) or you are otherwise working with community partners (who are not functioning as researchers), you may not be required to list them here as project personnel; consult with your IRB.
- If your extended research team includes multiple individuals with limited roles, you may not be required to list them here as project personnel; consult with your IRB.

The table below will access campus directory information; if you do not find your name, your directory listing may need to be updated.

Last Name	First Name	Department Name	Role (with the exception of 'Other,' all roles will have access to edit the application)	Detail
Bartram	Jamie	Environmental Sciences and Engineering	Principal Investigator	view
LoBuglio	Joe	Environmental Sciences and Engineering	Project Manager or Study Coordinator	view
Rhoderick	Ashley	Environmental Sciences and Engineering	Research Assistant	view

NOTE: The IRB database will link automatically to UNC Human Research Ethics Training database and the UNC Conflict of Interest (COI) database. Once the study is certified by the PI, all personnel listed (for whom we have email addresses) will receive separate instructions about COI disclosures. The IRB will communicate with the personnel listed above or the PI if further documentation is required.

3. If this research is based in a center, institute, or department (Administering Department) other than the one listed above for the PI, select here. Be aware that if you do not enter anything here, the PI's home department will be AUTOMATICALLY inserted when you save this page.

Department	Environmental Sciences and Engineering

3. Funding Sources

1. Is this project funded (or proposed to be funded) by a contract or grant from an organization external to UNC-Chapel HIll?

Yes

Funding Source(s) or Sponsor(s)

Sponsor Name	UNC Ramses Number	Sponsor Type	Prime Sponsor Name	Prime Sponsor Type	Sponsor/Grant Number	Detail
Department For International Development (dfid)	Currently Not Available	Other				view

2. Is this study funded by UNC-CH (e.g., department funds, internal pilot grants, trust accounts)?

No

3. Is this research classified (e.g. requires governmental security clearance)?

No

4. Is there a master protocol, grant application, or other proposal supporting this submission (check all that apply)?

- ✔ Grant Application
- ✘ Industry Sponsor Master Protocol
- ✘ Student Dissertation or Thesis Proposal
- ✘ Investigator Initiated Master Protocol
- ✔ Other Study Protocol

4. Screening Questions

The following questions will help you determine if your project will require IRB review and approval.

The first question is whether this is RESEARCH

1. Does your project involve a systematic investigation, including research development, testing and evaluation, which is designed to develop or contribute to generalizable knowledge? PLEASE NOTE: You should only answer yes if your activity meets all the above.

Yes

The next questions will determine if there are HUMAN SUBJECTS

2. Will you be obtaining information about a living individual through direct intervention or interaction with that individual? This would include any contact with people using questionnaires/surveys, interviews, focus groups, observations, treatment interventions, etc. PLEASE NOTE: Merely obtaining information FROM an individual does not mean you should answer 'Yes,' unless the information is also ABOUT them.

Yes

3. Will you be using identifiable private information about a living individual collected through means other than direct interaction? This would include data, records or biological specimens that are currently existing or will be collected in the future for purposes other than this proposed research (e.g., medical records, ongoing collection of specimens for a tissue repository).

No

The following questions will help build the remainder of your application.

4. Will subjects be studied in the Clinical and Translational Research Center (CTRC, previously known as the GCRC) or is the CTRC involved in any other way with the study? If yes, this application will be reviewed by the CTRC and additional data will be collected.)

No

5. Does this study directly recruit participants through the UNC Health Care clinical settings for cancer patients **or** does this study have a focus on cancer or a focus on a risk factor for cancer (e.g. increased physical activity to reduce colon cancer incidence) **or** does this study receive funding from a cancer agency, foundation, or other cancer related group? (If yes, this application may require additional review by the Oncology Protocol Review Committee.)

No

6. Are any personnel, organizations, entities, facilities or locations in addition to UNC-Chapel Hill involved in this research (e.g., is this a multi-site study or does it otherwise involve locations outside UNC-CH, including foreign locations)?

Yes

5. Multi-site Study Information

1. Will this study be conducted in locations outside the United States?

Yes

Will your research project involve the Galapagos Islands, Ecuador?

No

If yes, your application will be reviewed by the UNC Center for Galapagos Studies. This Center will be included in routing for approvals after you submit.

Are any of the countries on the U.S. State Department Travel Warning List? See list found at http://www.travel.state.gov (look for “Travel Warnings”). See also the University policy at http://provost.unc.edu/policies/UNC%20Travel%20Policy%2010.18.2010.pdf

No

2. Is UNC-CH taking or being asked to take reponsibility for the oversight of research by individuals, groups or organizations outside of UNC-CH (e.g., as lead site, study headquarters or IRB of record for other sites)?

No

Are you requesting that UNC-CH rely on an external IRB for continuing review and approval of this study?

No

3. Describe the role of UNC Chapel Hill and UNC Chapel Hill investigator(s) in this study.

A project team, comprising experts and researchers in water and health specialist groups from world-class research institutions, have joined forces to deliver an international study on the ‘Public Health and Social Benefits of At-house Water Supplies’ for the UK Department for International Development.

The institutions include, 1. the water@leeds team at the University of Leeds, 2. the University of East Anglia, 3. the Water Institute at the University of North Carolina, 4. the London School of Hygiene and Tropical Medicine and 5. The University College London.

The following application comprises a formal request for ethical approval on behalf of the University of North Carolina only.

All other University partners will either request ethical approval independently from their governing institution (e.g. the

University of Leeds and the University of East Anglia) or do not require ethical approval and constitute as advisory members (London School of Hygiene and Tropical Medicine and The University College London) to the project only (with regards to method and data interpretation).

UNC will be collaborating with the University of Leeds (UL) and the University of East Anglia (UEA) on this project. The University of Leeds, with Ms. Barbara Evans as principle investigator, is overseeing and leading the entire three multi country study in which UL is conducting field work in Vietnam, UEA is conducting field work in South Africa and UNC is conducting field work in Ghana.

The lead field researchers from UNC will be based in country during the fieldwork to oversee the project. Their roles will include the facilitation of relationships with local institution partners, selection of possible households for inclusion in the pilot study and final study separately, securing mechanisms within respective countries to obtain consents to proceed from local institution partners, community leaders and interviewees. They will also be responsible for the training, validation and support of enumerators, data management, oversee the process of transcription and translation into English of qualitative interview data by an in-country researches. The lead researchers will then use the development of emergent themes for exploration within on-going focus groups. They will also manage adherence to the research protocol and data protection rights.

The UNC team is also collaborating on the literature review and leading on the analysis of global data sets.

Researchers are reminded that additional approvals may be needed from relevant "gatekeepers" to access subject.

Exemptions

Request Exemption

Some research involving human subjects may be eligible for an exemption which would result in fewer application and review requirements. This would not apply in a study that involves drugs or devices, involves greater than minimal risk, or involves medical procedures or deception or minors, except in limited circumstances.

Additional guidance is available at the OHRE website. Exemptions can be confusing; if you have not completed this page before, please review this table with definitions and examples before you begin.

1. Would you like your application evaluated for a possible exemption?

No

Part A. Questions Common to All Studies

A.1. Background and Rationale

1. Provide a summary of the background and rationale for this study (i.e, why is the study needed?). If a complete background and literature review are in an accompanying grant application or other type of proposal, only provide a brief summary here. If there is no proposal, provide a more extensive background and literature review, including references.

UK

The Department for International Development was created in 1997 to tackle the challenges of global poverty and to help poor people build better lives for themselves. Poor health, malnutrition, lack of education and social exclusion are all major factors contributing to, and indicators of, poverty. Poor sanitation and hygiene, as well as insufficient access to safe water, are among the most significant causes of these factors. This vicious cycle of cause and effect can perpetuate poverty for generations but is also one that can be reversed such that improvements in drinking-water, sanitation and hygiene form integral components of a motor to accelerate socio-economic development; one that benefits especially the poor and socially excluded.

Access to clean, safe water supplies is therefore crucial in the fight against poverty but to date we have limited information about the quantity and level of service required to secure significant marginal health benefits (Howard & Bartram, 2003). What is known is that water usage patterns vary considerably with the proximity and convenience of the sources used (Howard, Teuton, Luyima, & Odongo, 2002). However, the exact benefits (both health and social) of at-house water supply remain unclear.

This research project aims to “test the hypothesis that increased access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply.”

Establishing the validity of this hypothesis presents several challenges to the researcher, not least amongst which is the extremely variable contexts within which water supplies are delivered.

A further challenge arises due to the linkages between water, sanitation and hygiene. It is known for example that improved access to water facilitates good hygiene. Similarly good hygiene can prevent recontamination after collecting water from the source. Water access also greatly facilitates good sanitation practices. For example water is required to make proper use of pour-flush latrines. Water availability has been shown to be associated with the long term use of latrines in certain circumstances. At the same time, inadequate sanitation may threaten the quality of nearby water sources.

The health impacts of poor water supply, inadequate sanitation and poor hygiene have been documented extensively. (Bartram & Cairncross, 2010) (Cairncross, Hunt, Curtis, Fung, & Schmidt, 2010) (Cairncross & Valdmanis, 2006) (Curtis, Schmidt, Luby, Florez, Toure, & Biran, 2011) However, due to methodological issues, especially the potential for confounding and bias, such data are not always easy to interpret (Blum & Feacham, 1983) (Schmidt & Cairncross, 2009). The link is strong enough however to enable us to assume a significant health impact of water, sanitation and hygiene interventions on a range of diseases and this is confirmed by burden of disease data.

However, intervention measures have rarely been directly compared; it is difficult to assess the health impact for example of at-house water access as compared to public water access. In their 2003 review Howard and Bartram suggested four service levels for water supply with different potential to meet requirements to sustain good health. However, we have little information about how estimated quantities of water "may reduce where water supplies are intermittent and the risks of ingress of contaminated water into domestic water supplies [may] increase" (Howard & Bartram, 2003).

The Howard and Bartram analysis was based on estimates of the quantities of water that would be collected at each level of service and it is this linkage which is less well developed in the literature. The focus of their analysis was the use of water for consumption and hygienic practices, which they noted were likely to "have direct consequences for health both in relation to physiological needs and in the control of diverse infectious and non-infectious water-related disease". Use of water for amenity purposes (for instance car washing) and productive purposes were excluded. For our analysis we may revisit the implications of availability of water for productive use but are likely to remain focused on water availability for consumption and for hygiene.

delete space

The method draws on three research components to facilitate this understanding: a review of both scientific and grey literature; analysis of existing global data to explore associations between levels of water service, quality of service and health and social outcomes; and field studies located within three developing countries utilising qualitative and quantitative fieldwork data collection and analysis.

2. State the research question(s) (i.e., specific study aims and/or hypotheses).

This research project aims to "*test the hypothesis that increase access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply.*"

Three overarching research questions drive the research to test the hypothesis that greater health, social and economic benefits are realized as a result of an at-house water supply as compared to a public water supply.

They are:

1. What are the patterns of water usage (including quantities used and purposes) in the context of distance to source, levels of sharing, reliability and water quality?

2. What health outcomes are associated with the different quantity of water consumed, and the different levels of service of water supply?

3. What are the socio-economic benefits derived from different levels of service of water supply?

A.2. Subjects

1. Total number of subjects proposed across all sites by all investigators (provide exact number):

2700

2. Total number of subjects to be studied by the UNC-CH investigator(s) (provide exact number):

900

3. If the above numbers include multiple groups, cohorts, or ranges or are dependent on unknown factors, or need any explanation, describe here:

The numbers above depend on household sizes that will be an unknown factor until households are actually selected from within recruited communities. We anticipate an average household size of 4 to 5 people.

4. Do you have specific plans to enroll subjects from these vulnerable or select populations:

✔ Children (under the age of majority for their location)
Note that you will be asked to provide age ranges for children in the Consent Process section.

✔ Non-English-speaking

✔ Patients (i.e., have a specific disease, disorder or condition regardless of where they receive their healthcare)

✘ Prisoners, others involuntarily detained or incarcerated (this includes parolees held in treatment centers as a condition of their parole)

✘ Decisionally impaired

✘ Pregnant women

✘ HIV positive individuals

✘ UNC-CH Students
Some research involving students may be eligible for waiver of parental permission (e.g., using departmental participant pools).See SOP 32.9.1

✘ UNC-CH Employees

✘ People who are likely to be involved in abusive relationships, either as perpetrator or victim (See SOP)

5. If any of the above populations are checked, describe how you plan to confirm status in one or more of those groups (e.g., pregnancy, psychological or HIV testing)

The subjects' language will be identified through questionnaires delivered by local enumerators in the dominant local language, Twi.

Children will be identified through the questionnaire. The head of the household will be asked to identify the ages of all people living in the household.

"Patients" i.e. those with musculoskeletal disabilities, will be identified through the interviewee's response to the household survey.

6. If any of the above populations are checked, please describe your plans to provide additional protections for these subjects

The research will target households in communities that have varying levels of access to water supply and sanitation. These households may or may not contain vulnerable groups. Vulnerable groups include: children, elderly, people with disabilities, people with low literacy levels, the poorest members of the community, and immune-compromised persons.

Both vulnerable and non-vulnerable groups of people have equal rights to, and reliance on, water for consumption and use. Therefore our research neither targets nor discriminates between vulnerable and non-vulnerable groups of people.

However, it is important to include these groups as there is strong evidence that vulnerable subgroups, especially young children suffer disproportionately from the adverse health impacts of inadequate water supply and also take a major burden of the responsibility for carrying water. As such we seek to have a representative sample that includes vulnerable groups as they would likely be most adversely affected by any problems in water supply and sanitation.

Non-vulnerable groups speaking on behalf of vulnerable groups

Participating interviewees will be asked questions on behalf of all residents within the household, including residents from ‘vulnerable groups’; namely children under 16 years and ‘‘other vulnerable groups’ such as people with physical disabilities (such as musculoskeletal disorder). Participating interviewees will be asked questions about their own health and, where necessary, that of vulnerable individuals in their household who are unable to respond themselves

Vulnerable groups invitation to be interviewed

Some questions however within the structured interview will be relevant to individuals assuming a specific role within the household, namely those responsible for the collection of water from outside the home. These individuals are likely to include children (both male and female), less than 16 years old (some of whom may have a physical disability).

The research teams' both working and learned knowledge on water collecting practices in developing countries indicate that children under the age of 16 years often adopt responsibility for household water collection. The research team acknowledges equal right to water and more specifically aim to secure improved access to water within disadvantaged groups. As a result we feel it pertinent to invite such individuals (subject to appropriate consent procedures) to participate in the survey.

Questions about water collecting practices that may involve the inclusion of children under 16 years relate to the identification the source of household water, but also the social (e.g. time away from school to collect water), and health outcomes associated with the collection of water. For individuals who collect water, we will measure their weight and height to calculate Body Mass Index (BMI), with the aim of determining whether weight of water carried compared to BMI is a risk factor for pain or movement disorders.

Adults and young persons over 16 years who have a physical disability may also be classed as a vulnerable group and would be invited to participate subject to appropriate consent procedures.

Safeguarding vulnerable groups

Written agreement for the research team to work in selected communities will be requested from community leaders of selected villages and urban areas prior to undertaking any field survey work. Consent will be sought from household members invited to participate in the survey, and will be either written or oral as appropriate depending on household levels of literacy. Oral permission will be sought from household members to recruit into the study and thereafter, should they be willing to participate, written informed consent will be sought. Consent will be indicated by either a written signature, or in the case of participants with limited literacy, a mark witnessed by another household member. Consent will be requested through face-to-face meetings, a written information sheet about the project and a native speaking interviewee and translator.

Both oral consent from children under 16 years with or without physical disability, and written consent from an accompanying adult relative or guardian living within the household, would be required prior to inclusion of children under 16 years in the study.

Adults and young persons over 16 years who have a physical disability would be asked to provide written consent to participate (subject to their level of disability). If their disability meant they were unable to provide written consent, oral consent would be required.

7. Age range of subjects:

Minimum age of subject enrolled	0
	months
Maximum age of subject enrolled	99
» If no maximum age limit, indicate 99	
	years

A.3. Inclusion/exclusion criteria

1. List required characteristics of potential subjects (i.e., inclusion and exclusion criteria). If not covered, list also characteristics that would preclude their involvement.

Community inclusion criteria: variation in water supply between households such that there are various levels of water service in the community. This implies that some households have improved water at the home (piped or private boreholes) and others are using a public, shared supplies at various distances from the home.

Community exclusion criteria: denial of permission from the community leaders to administer the study in that location.

Household exclusion criteria: unwillingness to participate, inability to comprehend and answer questionnaires and interviews in the dominant language, and the exclusive use of bottled water for household drinking water.

2.Justify any exclusion based on race, gender or ethnicity

There is no exclusion based on race, gender, or ethnicity.

3.Will pregnant women or women who become pregnant be excluded or withdrawn?

No

A.4. Study design, methods and procedures

Your response to the next question will help determine what further questions you will be asked in the following sections.

1.Will you be using any **methods or procedures commonly used in biomedical or clinical research** (this would include but not be limited to drawing blood, performing lab tests or biological monitoring, conducting physical exams, administering drugs, or conducting a clinical trial)?

Yes

2.Describe the study design. List and describe study procedures, including a sequential description of what subjects will be asked to do, when relevant.

The research will develop our understanding of the social and economic benefits of in-home or private in-yard water connections compared to shared or public water supplies and also the social and economic drivers of and barriers to the uptake of such connections. To do this the project proposes to collect both community level context data and house hold detailed data.

The study will combine both quantitative and qualitative elements so as to provide information on the strength of association between potential risk factors and health and social outcomes. The proposed mixed method study will collect data at community and household levels through (i) household surveys coupled with (ii) structured observations and (iii) natural group meetings:

Household Surveys

Household participants recruited to the study will be asked to volunteer their time to complete two surveys about their level of service of water, their health and their social behaviours relating to water. On the first visit, subjects will be asked questions about the health of each member within the household. On the second visit, subjects will be asked questions about their household and water supply. Enumerators fluent in the local dialect will conduct the questionnaires, which are expected to take no more than 2 hours of the participant's time per visit.

Questions about water collecting practices that may involve may be asked of vulnerable groups related to the identification of their household water sources outside the home, as well as the social (e.g. time away from school to collect water), and health outcomes associated with the collection of water. For individuals who collect water, we will measure their weight and height to calculate Body Mass Index (BMI), with the aim of determining whether weight of water carried compared to BMI is a risk factor for pain or movement disorders.

Structured Observation

This will involve the use of the following tools: structured observation, GPS-based mapping of infrastructure, collection of at source water quality data (where available) through the assemblage of existing utility data, community mapping, transect walks, interviews with local service providers, interviews with community leaders.

Community participants recruited to the study will not be asked to do anything other than carry on their daily business so that the researchers' structured observations can be made. Approval to observe the community will first be obtained by community leaders.

Triangulation through natural-group discussions and semi-structured interviews

Additional qualitative data on the household and community experience of water supply and related outcomes will be collected through a series of natural-group discussions and semi-structured focused groups with individuals and selected groups of participants (such as groups of people who naturally gather together plus the facilitated gathering of groups that are less accessible to ensure discussions do not discriminate against more disparate or private groups of people). These will explore in greater detail the themes identified in the structured interview and observations. They will also provide additional information on how current water supply and service systems impact people and communities. Participants would be asked to volunteer their time to contribute to a single group session. Light refreshments will likely be provided. No travel costs will be offered as it is hoped that the event would take place in a local venue.

Water Quality Data

Water samples will be taken from the households that participate in the survey. The samples will be collected by enumerators and carefully entered into a sampling log book to ensure accurate records. They will then be transported on ice to the Department of Civil Engineering at KNUST to be tested for various physio-chemical and bacteriological parameters. The water samples will be examined along the following physio-chemical parameters: pH, turbidity, dissolved oxygen, electrical conductivity, total dissolved solids, total suspended solids, ammonida, nitrate, phosphate, arsenic, fluoride, iron, magnesium, aluminum, and chlorine residual concentration. The samples will also be examined for the concentrations of the following: e-coli, rotavirus, vibro cholerae, and c.jejuni. The lab techician will also keep a log book of samples to ensure continued accuracy and tracking.

3.If subjects are assigned or randomized to study "arms" or groups, describe how they are assigned.

Not applicable.

4.Describe any follow up procedures.

Household surveys will be conducted over two different visits. In the first visit the survey will explore levels of service and water practices. At the end of the survey the enumerator will schedule the second survey, on health and social outcomes, with the head of the household. If the principal water carriers are not collecting water during the first survey, then their water fetching practices will be observed during the second visit.

5.Duration of subject's participation

Interviewers fluent in the local language (Twi) will conduct two surveys on two separate occasions, each of which is expected to take 1 to 2 hours of the participants' time. Observation of participants' water carrying practices from the home will require additional time, however, this depends upon the distance from the household to the water source.

6.Duration of entire study (include start and stop dates, where known).

The entire study will last from January 1, 2012 until December 31, 2012. The field study will begin in June 2012 and will end in November 2012.

7.Will this study use any of the following methods?

- ✔ Audiotaping
- ✘ Videotaping or filming
- ✔ Behavioral observation - (e.g., Participant, naturalistic, experimental, and other observational methods typically used in social science research)
- ✘ Pencil and paper questionnaires or surveys
- ✘ Electronic questionnaires or surveys
- ✘ Telephone questionnaires or surveys
- ✔ Interview questionnaires or surveys
- ✘ Other questionnaires or surveys
- ✔ Focus groups
- ✔ Diaries or journals
- ✘ Photovoice
- ✔ Still photography

8. If there are procedures or methods that require specialized training, describe who (role/qualifications) will be involved and how they will be trained.

Lead field researchers from the University of North Carolina will be based in country during the fieldwork to oversee the project. Their roles will include the facilitation of relationships with local institution partners, selection of possible households for inclusion in the pilot study and final study separately, securing mechanisms within respective countries to obtain consents to proceed from local institution partners, community leaders and interviewees. They will also be responsible for the training, validation and support of enumerators, data management, oversee the process of transcription and translation into English of qualitative interview data by in-country researches. The lead researchers will then use the development of emergent themes for exploration within on-going focus groups. They will also manage adherence to the research protocol and data protection rights.

Enumerators for household surveys will be trained in conducting the surveys and interviews, obtaining informed consent, household selection through randomization, the use of GPS devices to obtain coordinates of community water sources and households with permission, and measurements of height and weight for physical examinations. Enumerators, translators and transcriptionists will have at least a high school diploma and be fluent in English and the local language. Data entry personnel will be screened for basic computer skills and trained to use the data entry forms in Access or EpiData.

9. Are there cultural issues, concerns or implications for the methods to be used with this study population?

No

A.4.A. Biomedical methods and procedures

1. Is this an interventional study that involves treatment of a medical disease or condition?

No

2. Is this a Clinical Trial?

No

3. If the study involves the use of placebo control, provide justification

Not applicable.

4. Will this study involve drugs, biologics or other substances?

No

5. Will this study involve investigational devices, instruments, machines or software?

No

6. Does your study involve any of the following? (check all that apply)

- ✗ Embryonic stem cells
- ✗ Fetal tissue
- ✗ Genetic testing (see GINA and GWAS)
- ✗ Clinical laboratory tests
- ✗ Testing for communicable diseases that have mandated reporting requirements (link to state guidance)
- ✗ Point of Care (POC) testing done by hospital, clinic or research personnel (not by subject). Examples include urine pregnancy testing, glucose monitoring, coagulation testing, etc.
- ✗ Diagnostic or therapeutic ionizing radiation, or radioactive isotopes, which subjects would not receive otherwise if not participating in this research study. Do not check if all radiation is administered as standard of care.

- ✗ Gadolinium administered as a contrast agent
- ✗ Recombinant DNA or gene transfer to human subjects

7.Will your study involve storage of specimens for future research?

No

A.5. Benefits to subjects and/or society

1.Describe the benefit to society based on scientific knowledge to be gained

Societal benefits include credible information on connection and sustained use of the studied communities' piped water systems, the ability of the systems to improve household water quality in field use and the impact of the system on community and household burdens of diarrheal disease and social impacts. The study aims to provide scientifically credible data on the ability of this community piped water system to reduce household diarrheal disease in field use; no such data now exist. Data that measure the quantities and purposes of water used, measure the reduction in diarrheal disease and other waterborne illnesses as a result of piped water systems at varying distances from the home can provide valuable information on the benefits of different levels of access to water services. Such data will inform water supply implementation stakeholders and other decision-makers about the effectiveness of piped water services closer to the home as a water development model. Our results could be the basis for justification of investing in piped water systems at the household level as opposed to shared community supplies.

The findings will be used to inform the development of future community workshops that highlight health outcomes relevant to the community, and suggest interventions linked to these outcomes, which are acceptable and desirable to the community. The findings will therefore lead to the development and use of health outcome measures, which are meaningful and relevant to individual and community needs and can be used to monitor the impact of water and sanitation interventions. Appropriate outcome measures are important to monitor the effects of water supply systems on health and evaluate changes to water supply systems. This may lead to improvement of the services provided to the community in the future.

2.Does this study have the potential for direct benefit to individual subjects in this study?

No

Consider the nature, magnitude, and likelihood of any direct benefit to subjects. If there is no direct benefit to the individual subject, say so here and in the consent form, if there is a consent form. Do not cite monetary payment or other compensation as a benefit.

Explain

No Answer Provided

3.Are there plans to communicate the results of the research back to the subjects?

Yes

If yes, describe

In terms of direct communication back to the subjects, the research team plans to return to the communities that were involved in the study for an open public meeting so that people can hear how the interviews have been interpreted and to create an opportunity for people to comment further.

There will also be indirect communication of the results as we will communicate them to other scientists with appropriate peer review and communicate the results to other interested parties such as national sponsors (UK Government Department for International Development), international water and sanitation community (the Joint Monitoring Program for Water Supply and Sanitation) and within study country conferences. We will submit our methods and results to peer review (for example, review for publication) as the peer review process plays an important role in improving study protocols and scientific reports. We will strive to ensure that, at a minimum, both positive and negative study results are interpreted and reported on accurately.

A.6. Risks and measures to minimize risks

For each of the following categories of risk you will be asked to describe any items checked and what will be *done to minimize the risks. Where possible, describe the likelihood of the risks occurring, using the following terms:*

- ***Very Common*** *(approximate incidence > 50%)*
- ***Common*** *(approximate incidence > 25%)*
- ***Likely*** *(approximate incidence of 10-25%)*
- ***Infrequent*** *(approximate incidence of 1-10%)*
- ***Rare*** *(approximate incidence < 1%)*

1.Psychological

- ✔ Emotional distress
- ✔ Embarrassment
- ✘ Consequences of breach of confidentiality
- ✘ Other

Describe any items checked above and what will be done to minimize these risks

The information sheet outlines the content of the survey questions thereby obtaining the participant's prior consent by forewarning him or her of the nature of participation. The majority of the survey questions are not considered to be intrusive and or cause distress given they relate to household demographics, household health (eye, skin, diarrhoea and musculoskeletal pain), household assets and income, and level of service of water supply.

However some questions may be potentially distressing and intrusive. We predict this risk to be infrequent. These questions pertain to miscarriage, child death or perceptions around disability. Additional steps are proposed in an effort to acknowledge the potentially distressing nature of these questions. These include the field research team making provisions for the in-country enumerators to be properly trained to deliver each question in a professional, discrete and respectful manner. Whilst they will not be trained to counsel distressed participants they will be trained in ways to offer supportive information such as details of appropriate points of contact (e.g. counsellors offering support in grievance, loss or depression),

Furthermore the questions are to be asked within the private environment of the participant's home so to reduce any potential embarrassment associated with health or wealth questions.

Lead field researchers shall remain in situ during the fieldwork to monitor and audit the research, the research conduct and respond to any unforeseen adverse circumstances. We estimate the risk for psychological distress to be infrequent.

2.Social

- ✘ Loss of reputation or standing within the community
- ✘ Harms to a larger group or community beyond the subjects of the study (e.g., stigmatization)
- ✘ Consequences of breach of confidentiality
- ✘ Other

Describe any items checked above and what will be done to minimize these risks

Not applicable.

3.Economic

- ✘ Loss of income
- ✘ Loss of employment or insurability
- ✘ Loss of professional standing or reputation
- ✘ Loss of standing within the community
- ✘ Consequences of breach of confidentiality

✔ Other

Describe any items checked above and what will be done to minimize these risks

Taking part in the study will take up the participant's time, during observation, interview and/or during group discussion work. Observation and assessment will be pre-arranged at a time agreeable and convenient to the participant, to minimise any disruption to usual activities as much as possible. We estimate this risk to be infrequent.

4.Legal

✘ Disclosure of illegal activity
✘ Disclosure of negligence
✘ Consequences of breach of confidentiality
✘ Other

Describe any items checked above and what will be done to minimize these risks

Not applicable.

5.Physical

✘ Medication side effects
✔ Pain
✔ Discomfort
✘ Injury
✘ To a nursing child or a fetus (either through mother or father)

Describe any items checked above, including the category of likelihood and what will be done to minimize these risks

The purpose of the study is to investigate the health effects of carrying water, which has potentially negative health impacts such as injury or strain of the musculoskeletal system (which may for example manifest as neck or back pain). Therefore, participants will not be asked to do any tasks other than what they would normally do and care will be taken to avoid or minimise repetition of tasks during observation. Participants will be informed that they should perform tasks in the usual manner that they would be performed and asked not to perform tasks which they believe may hurt or harm them. We estimate physical risks from repeating daily tasks for observation to be likely, but will not be outside of the normal strain, discomfort or pain the participants would experience from daily water carriage.

It is expected that the likelihood for minor discomfort from measuring height and weight to be infrequent. Minor discomfort may be experienced by children if they have prior negative associations with the scale from hospital or doctor's visits. Our colleagues have reported childhood fears of the scale due to associations with getting shots during fieldwork in El Salvador. Enumerators will be trained to act courteously and gently, working with the parents, in weighing and measuring children.

6.Unless already addressed above, describe procedures for referring subjects who are found, during the course of this study, to be in need of medical follow-up or psychological counseling

See above, A6.1

7.Are there plans to follow subjects or partners of subjects who become pregnant while enrolled in this study?

No

A.7. Data and safety monitoring

1. When appropriate, describe the plan for monitoring the data to ensure the safety of participants. These plans could range from the investigator monitoring subject data for any safety concerns to a sponsor-based data and safety monitoring board or committee (DSMB, DSMC, DMC), depending on the study. For studies that do not raise obvious safety concerns, you may still describe your plans for monitoring the study as it progresses.

This study is not anticipated to negatively affect the safety of participants.

Day-to-day monitoring of data collected in the field will be supervised by UNC researchers. Data entry will occur on a daily basis after collection and will be revised for inconsistencies and concerns. Enumerators will regularly debrief the supervisors on any issues that arise in the field. Additionally, the supervisors will oversee or duplicate a subset of interviews/questionnaires to ensure proper data collection techniques and review with enumerators the areas that need to be improved.

Progress on the research will be reported to the UNC Principal Investigator (Jamie Bartram), project lead (University of Leeds) and ultimately to the project's advisory team and the funder, the UK Department of International Development.

2. If not already addressed above, describe the plans for aggregate review of unanticipated problems (including but not limited to adverse events) across all sites, in order to monitor subject safety.

Addressed above.

3. What are the criteria that will be used to withdraw an INDIVIDUAL SUBJECT from this study or halt the research intervention (e.g., abnormal lab tests, allergic reactions, failure or inability to comply with study procedures, etc.)?

We do not anticipate needing to withdraw any individual subject from the study since we are not conducting a research intervention. However, participants will be able to withdraw from participation in the study at any time by the simple expedient of requesting to terminate a household interview or by withdrawing from a focus group. This will be made clear to all participants by the enumerators at the start of each interaction.

Completed structured interviews will collect details such as address, community area, and level of service of water supply from which personal identifiers can be inferred. A key issue concerning health information is whether the individual concerned is "identifiable" from the information. Matters of confidentiality identified and discussed above (section A.10) will remain particularly relevant to this section of the method. Personal identifiers will be removed during the entry of the data and prior to transfer from the country of data collection. Again, any published or analysed data will be made anonymous prior to analysis, write up and reporting.

4. Are there criteria that will be used to stop the ENTIRE STUDY prematurely (e.g., safety, efficacy, unexpected adverse events, inability to recruit sufficient number of subjects, etc.)?

No

5. Will this study involve a data and safety monitoring board or committee?

No

A.8. Data analysis

1. Describe the analytical methods to be used (qualitative or quantitative)

Data analysis will involve the data entry onto a purpose built Microsoft Access database and transferred for analysis onto a statistical program (i.e. STATA) to perform analysis. Statistical analysis will be directed by Professor Paul Hunter from the University of East Anglia and Dr Wolf-Peter Schmidt from the London School of Hygiene and Tropical Medicine and supported by the larger research team. It is anticipated that analysis will involve modelling of data using multi-linear regression. Qualitative data generated during natural group meetings and structured observation methods will be cross-checked and interpreted using emergent theme analysis facilitated by Nvivo software.

2. Explain how the sample size is sufficient to achieve the study aims. This might include a formal power calculation or an explanation of why a small sample is sufficient (e.g., qualitative research, pilot studies)

See Appendix A, Sample Size and Power Calculations for Cross-Sectional Study of Community Piped Water Systems versus Non-piped Households in Ghana.

A.9. Identifiers

1. Check all of the following identifiers you will be receiving. This does not apply to information on consent forms.

- ✔ Names
- ✔ Telephone numbers
- ✔ Any elements of dates (other than year) for dates directly related to an individual, including birth date, admission date, discharge date, date of death. For ages over 89: all elements of dates (including year) indicative of such age, except that such ages and elements may be aggregated into a single category of age 90 and older
- ✔ Any geographic subdivisions smaller than a State, including street address, city, county, precinct, zip code and their equivalent geocodes (e.g. GPS coordinates), except for the initial three digits of a zip code
- ✘ Fax numbers
- ✘ Electronic mail addresses
- ✘ Social security numbers
- ✘ Medical record numbers
- ✘ Health plan beneficiary numbers
- ✘ Account numbers
- ✘ Certificate/license numbers
- ✘ Vehicle identifiers and serial numbers (VIN), including license plate numbers
- ✘ Device identifiers and serial numbers (e.g., implanted medical device)
- ✘ Web universal resource locators (URLs)
- ✘ Internet protocol (IP) address numbers
- ✘ Biometric identifiers, including finger and voice prints
- ✘ Full face photographic images and any comparable images
- ✔ Any other unique identifying number, code, or characteristic, other than dummy identifiers that are not derived from actual identifiers and for which the re-identification key is maintained by the health care provider and not disclosed to the researcher

2. For any identifiers checked, how will these identifiers be stored in relationship to the research data?

- ✔ with the research data (i.e., in the same data set and/or physical location)
- ✔ separate from the research data (i.e., coded with a linkage file stored in a different physical location)

Describe:
The parameters of confidentiality will be discussed and agreed with partner institution in Ghana, as well as community leaders in selected areas of study. The project team will adhere to data protection of confidential records and in particular be responsible for safeguarding completed survey forms and consent forms from loss or disrepair. Methods to support this include the photocopying of all questionnaires so that two sets are stored in two places at any one time, the storage of transcribed data from hard copy to electronic copy on a password controlled internet filing site, and encrypted or pass word protected storage of files that ensures the information can only be reviewed by the project team only (e.g. password protected pen drives and lap tops, lock secured filing of hard copied forms). Any published or analysed data will be anonymised prior to analysis, write up and reporting. A key issue concerning health information is whether the individual concerned is “identifiable” from the information. The structured interviews will collect details such as address, community area, and level of service of water supply from which personal identifiers can be inferred. The observational component will

predominantly collect anonymous data, defined as data that is collected without personal identifiers and from which no personal identifier can be inferred. However some observational data will be linked to the participant involved (e.g. a measurement related to water carrying performed by a particular individual). Such data would involve the collection of identifiable data such as the individual's name, date of birth or address. Matters of confidentiality identified and discussed above will remain particularly relevant to both structured interview and observational methods of data collection. Personal identifiers, however, will be removed during the aggregation of the data and prior to export from the country of data collection. They will be coded in a linkage password-protected file separate from the primary data source. Again, any published or analyzed data will be made anonymous prior to analysis, write up and reporting.

3. Are you collecting Social Security Numbers to be used as a unique identifier for study tracking purposes for national registry or database? (Do not check yes if collecting SSN *only* for payment purposes; this will be addressed later.)

No

A.10. Confidentiality of the data

1. Describe procedures for maintaining confidentiality of the data you will collect or will receive (e.g., coding, anonymous responses, use of pseudonyms, etc.).

The research team will adhere to University of Leeds policy and guidelines on data security, and specifically must ensure that personal data belonging to each participant is kept securely by the research team and that this personal information is not disclosed either orally or in writing, or in any other way, intentionally or otherwise to any unauthorised third party and that doing so could considered gross misconduct in certain cases.

The research team does not intend to use a person external to the team to process the data on the team's behalf but should circumstances change, the Principal Investigator will ensure a written contract is created between the parties, which specifies that the processor agrees to act on the University's instructions and to abide by the provisions of the Data Protection Act in connection with data security.

The research team will make reasonable efforts to ensure that all personal information is kept securely and will pay particular attention to the security of sensitive data. All personal data will be accessible only by those who need to use it and sensitive data will be either be kept in a lockable room with controlled access, or kept in a locked filing cabinet, or kept in a locked drawer, or protected by password if held on a computer, or kept only on disks which are themselves kept securely.

Off-University site use of personal data presents a potentially risk of loss, theft or damage and the institutional and personal liability that may accrue from the off-site use of personal data is similarly increased. For these reasons, authorised research team members will anonymise all personal data upon collection and prior to leaving the country of data collection. The research team will take appropriate security precautions in respect of day-to-day PC usage in-country for data that has not yet been anonymised. This will include care to ensure that data on the screens of PCs and terminals are not visible except to unauthorised research team members and that computer passwords are kept confidential. Screens will not be left unattended when personal data is being processed and manual records will not be left where they can be accessed by unauthorised research team members. When manual records containing personal identifiers are no longer required, they will be shredded or bagged and disposed of securely. Participants will be assigned a number referent upon recruitment to the study thereby preserving participant anonymity. All communications between the two sites will employ the use of number referents for participants.

2. Describe how data will be transmitted among research team (i.e., personnel listed on this application).

The team will adhere to the following:

Risks to participant confidentiality (during data transfer between in-country project sites and UK project sites) will be mitigated through the removal of personal identifiers to all project data prior to leaving the country of data collection. The research team will make reasonable efforts to ensure that all personal information is kept securely and will pay particular attention to the security of sensitive data. All personal data will be accessible only by those who need to use it and sensitive data will be either be kept in a lockable room with controlled access, or kept in a locked filing cabinet, or kept in a locked drawer, or protected by password if held on a computer, or kept only on disks which are themselves kept securely with access permissions granted to members of the research team only.

The University's policy and guidelines on data security, and specifically ensure that personal data belonging to each participant is kept securely by the research team and that this personal information is not disclosed either orally or in writing, or in any other way, intentionally or otherwise to any unauthorised third party and that doing so could considered gross misconduct in certain cases. All computer's will have antivirus/antispyware software installed and be regularly updated where technologically feasible.

The research team does not intend to use a person external to the team to process the data on the team's behalf but should circumstances change, the Principal Investigator will ensure a written contract is created between the parties, which specifies that the processor agrees to act on the University's instructions and recommended security provisions. Once returning to respective universities in the US or UK, data will be exchanged only using a secured network connection or VPN.

Off-University site use of personal data presents a potentially risk of loss, theft or damage and the institutional and personal liability that may accrue from the off-site use of personal data is similarly increased. For these reasons, authorised research team members will anonymise all personal data upon collection and prior to leaving the country of data collection. The research team will take appropriate security precautions in respect of day-to-day PC usage in-country for data that has not yet been anonymised. This will include care to ensure that data on the screens of PCs and terminals are not visible except to unauthorised research team members and that computer passwords are kept confidential. Screens will not be left unattended when personal data is being processed and manual records will not be left where they can be accessed by unauthorised research team members. When manual records containing personal identifiers are no longer required, they will be shredded or bagged and disposed of securely. Participants will be assigned a number referent upon recruitment to the study thereby preserving participant anonymity. All communications between the two sites will employ the use of number referents for participants.

3. Are you collecting sensitive information such as sexual behavior, HIV status, recreational drug use, illegal behaviors, child/physical abuse, immigration status, etc?

No

4. Do you plan to obtain a federal Certificate of Confidentiality for this study?

No

5. If relevant, discuss the potential for deductive disclosure (i.e., directly identifying subjects from a combination of indirect IDs).

There is a potential for identifying subjects through a combination of indirect IDS through GPS coordinates, which will be used in GIS analyses of the distances between water source and household and other spatial relationships. However, this information will not be distributed outside of the research team and therefore does not pose a risk for deductive disclosure to outside researchers or the public.

6. Will any of the groupings or subgroupings used in analysis be small enough to allow individuals to be identified?

Yes

Describe these groupings and sample sizes projected.

GPS coordinates of the households and water sources would allow households to be identified.

Primary sampling units (PSUs): 4 communities in Ashanti region (likely Abuakwa, Nkawie, Asuofua, Barekese)

Secondary sampling units: (SSUs): households (~200)

Tertiary sampling units (TSUs): individual subjects (800-900 assuming 4-5 people per household)

A.11. Data sharing and transmission

1. Check all of the following who will receive identifiable data (contains any of the 18 identifiers listed above) outside the immediate research team (i.e., not listed as personnel on this application)? *

- ✗ No one
- ✗ Coordinating Center
- ✗ Statisticians
- ✗ Consultants
- ✓ Other researchers
- ✗ Registries
- ✗ Sponsors
- ✗ External labs for additional testing
- ✗ Journals
- ✗ Publicly available dataset
- ✗ Other

If other, please specify.
Our partnering universities, UL, UEA, London School of Hygiene and Tropical Medicine, and the University College London will have access to the data as well as Kwame Nkrumah University of Science and Technology (KNUST), our partnering institution in Ghana.

2. For any recipients checked above, explain the confidentiality measures to be taken

Please refer to Section A 10.2.

A.12. Post-study disposition of identifiable data or human biological materials

1. Describe your plans for disposition of data or human biological specimens that are identifiable in any way (directly or via indirect codes) once the study has ended. If you plan to destroy linkage codes or identifiers, describe how and when this will be done.

Personal identifiers however will be removed during the aggregation of the data and prior to export form the country of data collection. Again, any published or analysed data will be made anonymous prior to analysis, write up and reporting. When manual records containing personal identifiers are no longer required, they will be shredded or bagged and disposed of securely. GIS data will be kept securely along with the non-personal data for at least 10 years.

Part B. Direct Interaction

B.1. Methods of recruiting

1. Check all the following means/methods of subject recruitment to be used:*

- ✓ In person
- ✗ Participant pools
- ✗ Presentation to classes or other groups
- ✗ Letters
- ✗ Flyers
- ✗ Radio, TV recruitment ads
- ✗ Newspaper recruitment ads

- ✖ Website recruitment ads
- ✖ Telephone script
- ✖ Email or listserv announcements
- ✖ Other

2.Describe how subjects will be identified

Communities will be identified from national housing databases and screened to ensure a range of contexts are included in the study. Relevant factors will include:

- Levels of access to water relative to distance from home and that these water source points can be or have been readily mapped (i.e. households with a private water supply in the home or yard vs. households who share a water supply with a defined group of people vs. Households who share a communal water supply);
- Density of housing in a given area (density ranges within Vietnam range from 1 person per squared kilometre to 1000 persons per squared kilometre and so areas that exhibit both high and low density in a given province would be selected)

Additional factors that determine the identification of communities within the study relate to the communities willingness to participate. Households will then be selected from such communities through stratified random sampling and invited to participate in the study. Up to 300 households will be identified with a view to engaging 200 in the study.

Similarly a series of natural-group discussions and semi-structured focused groups with individuals and selected groups of participants will include opportunistic group discussions with, people who naturally gather together, plus groups that may be less accessible in public environments. Access to less accessible groups will require local knowledge and / or community members to support their invitation into the project and ensure the study does not discriminate against more disparate or private groups of people. These discussions aim to elaborate on participant's beliefs, understandings and feelings towards their current water supply and service systems.

The study hopes to recruit participants with varying levels of physical disability. The study design however does not place an unfair burden of participation in the research on vulnerable members from which other members of the community are intended to benefit.

3.Describe how and where subjects will be recruited and address the likelihood that you will have access to the projected number of subjects identified in A.2.

Community leaders will be approached by the field researchers in the project seeking their agreement that the study be conducted in their area. Their permission will be sought not only demonstrate respect for local leadership mechanisms but will also help to identify informed representatives of a community who could act as an additional communication pathways and provide information to other community members about the project and/or the researchers' presence.

Both local enumerators and lead field researchers will meet with local authorities and community leaders and discuss the project by providing them with a presentation and / or round table discussion to introduce the project. Key points that will be provided include the key drivers behind the project, the health and social concerns of focus related to water supply and sanitation, the UKs contribution to international development and the proposed method of data gathering and participant engagement. The researchers will invite local authorities and community leaders to raise any questions and concerns so to talk through them directly.

The field team will explore the preferred etiquette of the local authorities or community leaders to enter and walk around the village so to map the points of water source as well as identify households that may agree to participate in the project. Where community leaders are in support of our work it may be appropriate to receive an orientation to the area and introduction to some of the households within the research area. This would serve as a reconnaissance of the area, opportunistic introduction to members of the community, and community acceptance of our temporary presence within their home area.

We believe there is a high likelihood that we will obtain the number of subjects that we outlined in Section A.2. Households will be equally distributed amongst the recruited communities, for example given four recruited communities, we would survey 50 households within each community. The exact number of participants will depend on the household size.

It is anticipated that the random stratification will result in sufficient numbers of participants with a disability for analysis. If however the random sample results in too few participants with disability for analysis, purposive sampling will be carried out to ensure recruitment of a representative sample of people with physical disability (both adults and children), which is a particular health outcome of interest.

4.Describe how you will protect the privacy of potential subjects during recruitment

Each household randomly identified using stratified sampling will be invited to participate in the project. Personal invitations to each household will entail a visit by a field team member, namely a local enumerator who will hold a valid identification card, explain the background to the project and invite the household to participate. Willing participants will be asked to sign a consent form to confirm they understand the purpose of the project, that the project will involve the collection of data for analysis, that their personal data will remain confidential, and that they are able to freely withdraw from the project at any time in which case their personal data will be removed from future analysis but data that has been analysed in aggregate will remain in the project data set.

Every participant will receive information about the project including information concerning who the enumerators are, the proposed research, whether it has received in-country and community approval and the fact that it is seeking voluntary involvement of household participants in the area. All enumerators will be honest, accurate and consistent in providing information relating to the research and properly trained and culturally sensitive enumerators who will carry identification will carry out the researchers and interviewers.

The local enumerators will provide each household with a locally transcribed information sheet informing them about the project. The enumerators will then discuss the project with all adults available at household at the time of survey. Discussions will involve talking through the aims and method of the study and the roles and rights of participating households. The information sheet outlines the content of the survey questions thereby forewarning him or her of the nature of participation. The information sheet will also inform participants that they may withdraw from the study at any time during the survey or after the survey and the enumerators will support potential participants understanding of this.

The sheet will contain an area to certify consent to participate and an example of which has been provided for review by the ethics committee at the University of Leeds. This approach supports the informed consent process i.e. it will provide adequate information in a form and manner that enables it to be understood and an informed judgement made and any consent is voluntary in nature.

Should oral agreement to participate in the study be given by participants living with the household, written signatures will be collected for each participant, or on behalf of each participant (where literacy is limited or the participant involves an individual from a vulnerable group) to confirm this agreement and documented on two copies of the participant information sheet (one to be held by the participant and the other to be held by the study team). Written agreement to participate will be a prerequisite to proceeding with the questionnaire survey.

The project will not induce participants to participate in the research and will offer no financial or material reward for their involvement.

Lead field researchers shall remain in situ during the fieldwork to monitor and audit the research, the research conduct and respond to any unforeseen adverse circumstances.

Extra steps to protect potentially vulnerable groups

Some structured household questions will be directed to residents responsible for a given role. Where the individual undertaking that role is a child (less than 16 years) additional consent from both the child (oral) and adult (written consent on behalf of the child) will be required. Questions would only be directed to a child providing they were able to understand the project, were old enough to respond, provided verbal agreement to be asked some questions regarding their role (e.g. as a water collector), and that a parent or adult guardian residing within the same household agreed to the child's participation in the survey and provided an additional consent to permit the interviewee to proceed with the structured questions. Where children or vulnerable individuals are recruited to the study, enumerators and researchers will also be trained to be sensitive to any signs of distress or indications that the participant no longer wishes to continue with the study. Should this occur, such individuals would be offered the opportunity to withdraw from the study.

5.Describe how subjects will be contacted, if not addressed above

For communities in which collective decision-making is customary, as is the case in Vietnam and South Africa, community leaders able to express the collective will, will be the field teams first point of contact in our approach to recruit households into the study. A community leader may express agreement or refusal on behalf of a community and this agreement or refusal to participate in the study will be respected.

Identified households would be invited to participate only upon agreement to proceed by these community/area leaders. Household members in areas randomly selected, and agreed to for study by community leaders, would be personally invited to participate in the survey by enumerators fluent in the local dialect. Should an individual make themselves known to the study group to volunteer in the study community leaders had declined, individuals would be given information on the project and reasons why community leaders have declined to take part and inform them therefore that members of the community will no longer be invited to volunteer in the study.

6.Describe who will do the recruiting

The lead researchers from UNC and KNUST, and any necessary translators will approach the identified community leaders to recruit communitites and households into the study.

7.Describe efforts to ensure equal access to participation among women and minorities

We are focusing on water use practices and health at the household level with a particular interest in the socioeconomic and health impacts of water collection, use, and quality upon women and children. We will therefore survey the female head of household and include women in the focus groups. There is also a focus of such impacts upon those with physical disabilities, however the study design does not place an unfair burden of research participation on vulnerable members of society. The selection of households is randomized ensuring that majority and minority populations will be included in the study with the only exclusion criteria being a limited understanding of the local language by the head of household in which the survey will be conducted.

B.2. Protected Health Information (PHI)

Protected Health Information (PHI) is any identifiable information about the subject's health that relates to their participation in this research and is obtained from sources other than the subject, such as medical records, health care providers, insurance plans, etc. more

1.Are you requesting a limited waiver of HIPAA authorization?
If you need to access Protected Health Information (PHI) to identify potential subjects who will then be contacted, you will need a limited waiver of HIPAA authorization. This does not apply to situations where you will never contact subjects directly (e.g., retrospective chart review), in which case you should request a full waiver under section D.

No

2.Will you need to access PHI for reasons OTHER than the identification of potential subjects (e.g., ongoing use of medical records to conduct the study), as addressed above? In this case you will need a HIPPA Authorization.

No

B.3. Subject Contact, Duration and Privacy

1.Number of contacts per subject

2

2.Duration of each contact. If multiple contacts, provide the range or average time for each contact.

1 hour

3. Total duration of individual subject's participation, including follow up evaluation, if applicable

   2-4 hours

4. List the locations where subjects will be studied, both on and off the UNC-CH campus.

   The subjects will be surveyed within their home for the household interview. They will be anonymously observed at all public water points and sources within the community. Focus groups will meet at a public location within the community to be identified with assistance from local leaders.

5. Describe procedures that will ensure privacy of the subjects in this study. Examples include the setting for interviews, phone conversations, or physical examinations; communication methods or mailed materials (e.g., mailings should not indicate disease status or focus of study on the envelope)

   Subjects for the household interview will be conducted privately within their home.

B.4. Incentives for participation

1. Are there incentives (monetary or non-monetary) for subjects to participate?

   No

2. Are you collecting Social Security Numbers for payment and/or tax-related purposes?

   No

B.5. Costs to be borne by subjects

1. Will there be any costs that subjects will incur related to participation in the study? Do not include costs for standard care for which patients would be billed if they were not in this study. Also do not include the time spent participating in the study.

   No

Part D. The Consent Process

D.1. Obtaining informed consent from subjects

The standard consent process is for all subjects to sign a document containing all the elements of informed consent, as specified in the federal regulations. Some or all of the elements of consent, including signatures, may be altered or waived under certain circumstances. If you will be requesting a waiver answer "not applicable" for any of the following questions that will not pertain to this study. You will be asked to provide relevant information in the section below on waivers.

1. Will children under the age of majority in their locale (18 years in NC) be enrolled?

   Yes

Please explain the process for obtaining parental permission (unless waiver of permission will be requested later)

The research teams’ working and learned knowledge on water collecting practices in developing countries indicate that children under the age of 16 years often adopt responsibility for household water collection (i.e. individuals are likely to include children, both male and female, less than 16 years old (some of whom may have a physical disability).

Both oral consent from children under 17 years with or without physical disability, and written consent from an accompanying adult relative or guardian living within the household, would be required prior to inclusion of children under 17 years in the study.

Adults and young persons over 17 years who have a physical disability would be asked to provide written consent to participate (subject to their level of disability). If their disability meant they were unable to provide written consent, oral consent would be required.

Check the characteristics of children to be enrolled: *

- ✔ 0 - 6 years
- ✔ 7 - 14 years
- ✔ 15 - 17 years

Explain the process for obtaining the assent of the child (unless waiver of assent will be requested later)

It is envisaged that children under 16 years may be tasked with this role and therefore the research considers the inclusion of 'vulnerable groups' as recognised by ethical review process and research practice. Both oral consent from children under 16 years with or without physical disability, and written consent from an accompanying adult relative or guardian living within the household, would be required prior to inclusion of children under 16 years in the study. Questions would only be directed to such individuals providing they were able to understand the project, were old enough to respond, provided verbal agreement to be asked some questions regarding their role as a water collector, a parent or adult guardian residing within the same household agreed to the child's participation in the survey and provided an additional signature to permit the interviewee to proceed with the structured questions or in the case of participants with limited literacy, a mark witnessed by another household member. The project will not induce participants to participate in the research and will offer no financial or material reward for their involvement.

2.Will adult subjects be enrolled in your study?

Yes

Explain the process for obtaining consent from the subject or the subject's legally authorized representative, if relevant

Written agreement for the research team to work in selected communities will be requested from community leaders of selected villages and urban areas prior to undertaking any field survey work. Consent will be sought from all participating household members invited to partake in the survey through face-to-face meetings, communicated through a native speaking interviewer and a written information sheet about the project. Consent will be indicated by either a written signature, or in the case of participants with limited literacy, a mark witnessed by another household member.

3.Will decisionally-impaired subjects be enrolled in your study? (includes unconscious patients, some psychiatric disorders, others who lack the capacity to give consent)

No

4.Are you planning to obtain consent from any Non-English speaking subjects?

Yes

Click here to obtain the Translation Verification form, which should be completed and uploaded with Attachments at the end of the application.

If you will be obtaining consent in Spanish, consent form templates are provided on the OHRE website. If you will be obtaining consent in other languages, you will need to upload translations of the English consent form(s) once approved by the IRB.

Describe how consent in the native language will be obtained. Address both written translation of the consent and the availability of oral interpretation. It is expected that the information in the consent document(s) will be communicated to participants or their legally authorized representative (LAR).

Arrangements will be made to recruit enumerators who have excellent verbal and written skills in both English and the local dialect. They will be required to verbally explain the project and talk through the written information sheet (that has been translated from English into the local dialect and back translated for cross checking) to support the participants understanding of the project.

5.Describe who (name and role) will be obtaining consent or parental permission.

Trained enumerators will obtain consent or parental permission from potential participants in the study. The enumerators will be screened and identified in country prior to the implementation of the survey.

6. Describe any steps that will be taken to minimize coercion or undue influence during the consent process. These might include a waiting period between the initial consent discussion and obtaining consent, or obtaining consent by someone other than a person with perceived authority (e.g., professor, employer, treating physician).

Consent will be obtained in the local language from locals who are not in positions of perceived authority. Coercion or undue influence will be minimized during the consent process by emphasizing the participants rights to not join the study, stop participating at any time or refuse to answer a question.

7. Has the sponsor of this study provided a model consent form?

No

D.2. Waiver of written documentation of informed consent

The default is for subjects to sign a written document that contains all the elements of informed consent. Under limited circumstances, the requirement for a signed consent form may be waived by the IRB. For example, this might occur for phone or internet surveys, when a signed consent form is either impractical or unnecessary, or in circumstances where a signed consent form creates a risk for the subject.

1. Are you requesting a waiver of any aspect of written (signed) documentation?

No

D.3. Full or partial waiver of consent

The default is for subjects to give informed consent. A waiver might be requested for research involving only existing data or human biological specimens. More rarely, it might be requested when the research design requires withholding some study details at the outset (e.g., behavioral research involving deception). In limited circumstances, parental permission may be waived. This section should also be completed for a waiver of HIPAA authorization if research involves Protected Health Information (PHI) subject to HIPAA regulation, such as patient records.

1. Are you requesting any of the following:

✗ a waiver of informed consent in its entirety

✗ a waiver or alteration of some of the elements of informed consent

✗ a waiver of HIPAA authorization (If you are accessing patient records for this research, you must also request a waiver of HIPAA authorization)

2. If your request for a waiver applies to some but not all of your subject groups and/or consent forms, please describe and justify

No Answer Provided

3. Does this request for waiver support a study design that involves deception or withholding of information?

No Answer Provided

Consent Forms

	File Name	Document Type
✓	Adult Consent Form	Adult Consent Form
✓	Assent Form Ages 15-17	Assent Form Ages 15-17
✓	Assent Form Ages 7-14	Assent Form Ages 7-14
✗	Focus Group Consent	
✓	Parental Permission Form	Parental Permission Form

view consent forms

Attachments

	File Name	Document Type
✗	Diaries Journal Guide Required	Diaries Journal Guide
✗	Focus Group Guide Required	Focus Group Guide
✗	Interview Questionnaire Survey Required	Interview Questionnaire Survey
✗	Observation Guide Required	Observation Guide
✗	Translation Verification Required	Translation Verification
✓	UL_UNC_LSHTM_UEA_Bid_Parts_A_and_B Final (g) 011111.docx Required	Grant Application
✓	2012_02_20_DFID_Inception_Report_LB.pdf Required	Other Study Protocol

view attachments

Addenda

Data Security Requirements

view addenda

By certifying below, the Principal Investigator affirms the following:

I will personally conduct or supervise this research study. I will ensure that this study is performed in compliance with all applicable laws, regulations and University policies regarding human subjects research. I will obtain IRB approval before making any changes or additions to the project. I will notify the IRB of any other changes in the information provided in this application. I will provide progress reports to the IRB at least annually, or as requested. I will report promptly to the IRB all unanticipated problems or serious adverse events involving risk to human subjects. I will follow the IRB approved consent process for all subjects. I will ensure that all collaborators, students and employees assisting in this research study are informed about these obligations. All information given in this form is accurate and complete.

This study proposes research that has been determined to include Security Level 2 data security requirements. I agree to accept responsibility for managing these risks appropriately in consultation with departmental and/or campus security personnel. The Data Security Requirements addendum can be reviewed here.

If PI is a Student or Trainee Investigator, the Faculty Advisor also certifies the following:

I accept ultimate responsibility for ensuring that this study complies with all the obligations listed above for the PI.

Certifying Signatures:

Signature: ______________________ **Date:** ______________

Jamie Bartram

The expectation is that this approval is being given on behalf of the head of the Department, Division, or Center. If the chair or director is an investigator on this project or otherwise conflicted in approving it, the Vice-Chair or Chair's designee should review it. By approving, you are certifying the following on behalf of your department, division or center:

- This research is appropriate for this Investigator and our department
- The investigator(s) are qualified to conduct the research
- There are adequate resources (including financial, support and facilities) available
- For units that have a local review committee for pre-IRB review, this requirement has been satisfied
- I support this application, and hereby submit it for further review

This study proposes research that has been determined to include Security Level 2 data security requirements. I agree to accept responsibility for managing these risks appropriately in consultation with departmental and/or campus security personnel. The Data Security Requirements addendum can be reviewed here.

If you are approving for other purposes (e.g., CTRC, DSMB, IBC, PRC, RSC, or other review committees), you affirm the following:

- The proposed submission is approved and may be forwarded for IRB review.

This study proposes research that has been determined to include Security Level 2 data security requirements. I agree to accept responsibility for managing these risks appropriately in consultation with departmental and/or campus security personnel. The Data Security Requirements addendum can be reviewed here.

Department Approval Signatures:

By signing in the appropriate space, the Department Chairperson(s) is indicating only that he/she has seen and reviewed this submission

Department: Environmental Sciences and Engineering

Signature: ______________________ **Date:** ______________

Name & Title: ______________________

Appendix 18. Adult participant information and consent form

Appendix 18 **Informed consent form**

The University of East Anglia in the UK, together with Tshwane University of Technology in Pretoria are conducting a research study in the area, to evaluate the benefits of having a private water supply in the home versus having an external shared water supply.

We would now like to explain the project and then invite your participation.

What is the study for?

We are doing this study to find out whether or not having a tap in the house is better for the people living in the house than having to walk to a tap or well in the neighbourhood. We want to see whether having a tap in your house is better for your health, and whether it helps you in your daily living and work.

Why have I been chosen?

There was no particular reason for choosing your household. Your house was randomly chosen, which means that any house in the community could have been chosen to be in the study.

Do I have to take part?

No. This study is completely voluntary. It is up to you and your family to decide whether you want to take part.

If you decide not to take part there will be no effect on your health care services or water services.

What kind of information will be collected?

We will collect information such as your name, age, ethnic group, health, income and your opinions about the water and sanitation situation in your area.

What happens next if I agree to take part in the study?

You have time to think about whether to agree to take part– please say how much time you want to decide.

If you do agree to take part in the study, we will ask you to

- Sign a consent form with your name and address. This will be used for your household identification only and will not be made public.
- Straight after that or at a later time if you prefer, we will ask you and your family members to answer some interview questions about your family and each person's health.
- On another day, we will ask you to answer a second interview about your household and water supply.
- The two separate <u>interviews</u> will happen here on your premises or at another location if you prefer. Each interview will take approximately 45 minutes.
- Some questions may be of a sensitive nature and will be about:
    - Your <u>health</u>, and that of your family's health, in particular illnesses you may have experienced
    - The <u>feelings</u> you have about the water, sanitation and hygiene situation in your area
    - Aspects about your home environment, your household income and other activities related to water, sanitation and hygiene

We will also ask that you allow us to

- <u>Observe</u> the way your family collect water and practise hygiene during a time convenient to you.
- Walk with the family member who normally collects water for your household on one water collection trip to your water source and back home, while that person carries the amount of water that they would

normally collect in one trip, carrying it in their usual way. During that trip we request to use a small device which will tell us your heart rate while you walk and carry water, as well as record the route, distance and time taken for the trip. To monitor your heart rate, the device will be the size of a wrist watch and placed either around your wrist or upper arm.

- Take measurements of you and each family member's height and weight and waist circumference.

- Take photos of your house as well as the water, sanitation and hygiene infrastructure. This is for our records and recall purposes and for use in presentations to other researchers.

- Later this month there may also be an opportunity for you and your family or friends to join a discussion about aspects of water access during a group meeting, which will take place at ____________ and take approximately 90 minutes.

How will this information be kept confidential?

We guarantee to keep all information you give us confidential. All stored information will be kept secure and all records will be made anonymous as soon as practical so that it will be impossible to identify which comments and responses were yours after data collection is complete.

After the project is completed and all the data have been analysed, we will come back to your community and give feedback on what we have found during the study. This will be done in such as way that you, your family and your premises will not be identified;

The final results may be published in national and international scientific journals. This will be done in such as way that you, your family and your premises will not be identified and will help inform the International society on how best to direct water and sanitation projects.

What if I have a question or there is a problem?

- Should you agree to participate and later feel that you no longer want to be part of the study, you can withdraw at any time - even if you have signed this consent form. You will not have to give reasons for withdrawing and your information will not be included in the results of the study
- You are free to ask any questions, at any time, about the study

Are there any risks in taking part in this study?

No, there are no risks in taking part in this study. However, you might find some of the questions about your health uncomfortable.

What are the benefits in taking part in this study?

We will report the findings of our research to your community, government and water service providers, but also to an important meeting of the JMP task force in October 2012. They are a group of people who will set targets and goals for improving access to safe drinking water in many communities around the world and who will advise governments about what they should aim to achieve from now on. Your answers may help in deciding changes that need to be made to water policy.

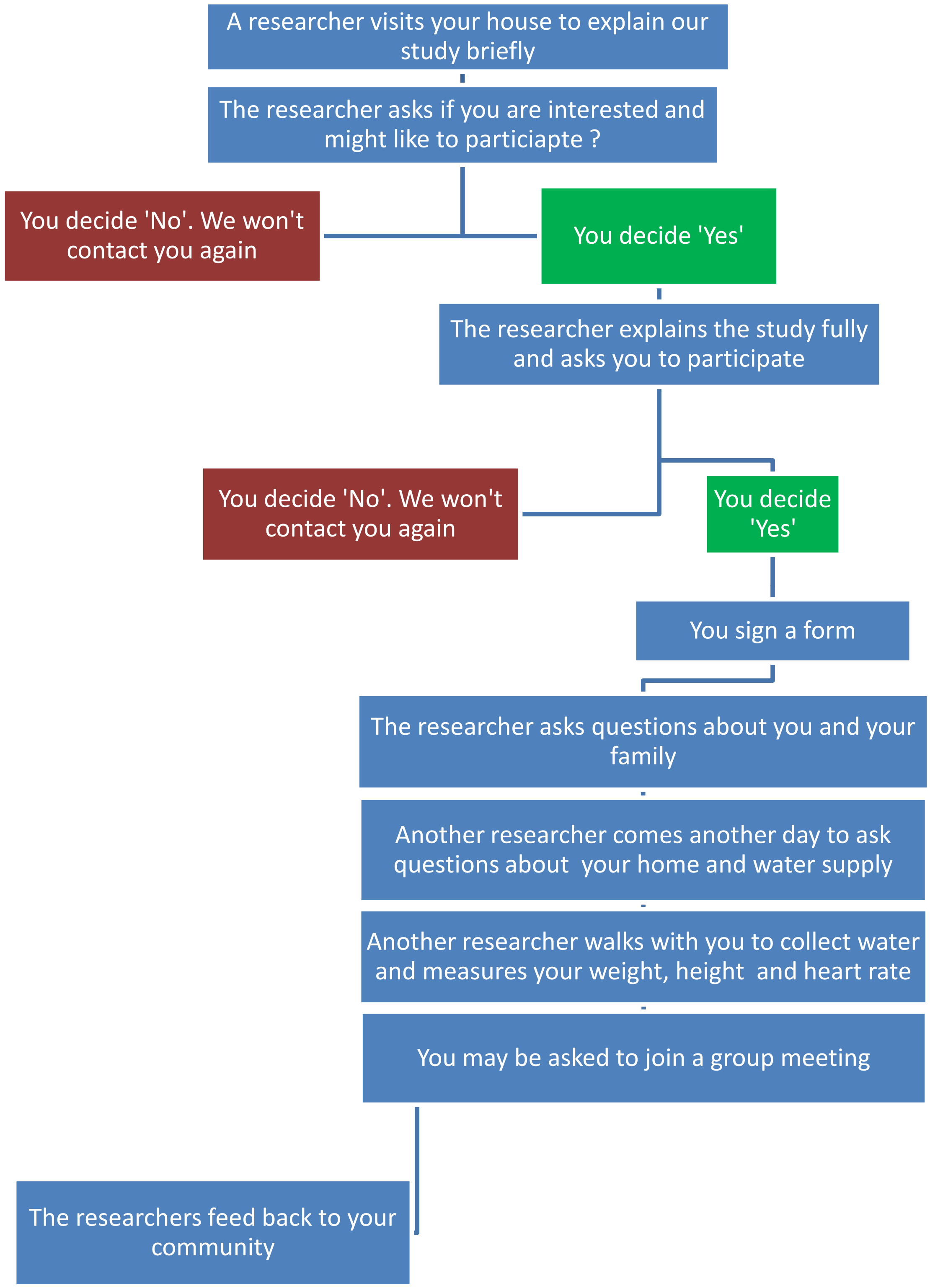
No monetary compensation is offered for your participation nor will you be expected to pay anything.

Who has checked this study?

Our project has been approved by the ethics committees of University of East Anglia and Tshwane University of Technology as well as the Limpopo Provincial Department of Health.

The primary investigator and person in charge of this project is __________. He/she can be contacted during office hours at Tel __________. Should you have any questions regarding this study, please can contact them.

Study Flow diagram



Date _______________

We now invite you to participate in this study.

Respondent:

- I have heard the proposed activities of the project. The activities are clear to me; [ ]
- I understand that there will be no harm to me and my family; [ ]
- I understand that participation in this research project is completely voluntary; [ ]
- I was given adequate time to think about the issue before I consent; [ ]
- I have not been pressurised to participate in any way; [ ]
- I understand that I may withdraw from the study at any time without supplying reasons and without prejudice; [ ]
- I was and still am provided the opportunity to ask questions; [ ]
- I understand that I will not receive any monetary compensation for my participation and that participation will not cost me anything; [ ]
- I understand that this research project has been approved by the Research Ethics committee of the University of ____________; [ ]
- I consent to supply personal details of me and my family with the proviso that the they will not be used in any way to breach confidentiality; [ ]
- I am fully aware that the results of these projects will be used for scientific purposes and may be published. I agree to this, provided my privacy is guaranteed. [ ]

Consent: Option A

I hereby consent to participate in this project and can sign for this consent.

1______________________ __________________ ________________ ________

Name of respondent Signature Place Date

2______________________ __________________ ________________ ________

Name of respondent Signature Place Date

3______________________ __________________ ________________ ________

Name of respondent Signature Place Date

4______________________ __________________ ________________ ________

Name of respondent Signature Place Date

5______________________ __________________ ________________ ________

Name of respondent Signature Place Date

Consent: Option B

I hereby consent to participate in this project and but am unable to sign. I have requested a household resident to confirm on my behalf.

Name of respondent	Mark of respondent	Place	Date
Name of Witness	Mark of witness	Place	Date

Consent: Option C

I hereby consent to participate in the project but require parental or guardian consent.

Name of respondent	Mark of respondent	Place	Date
Name of Parent/Guardian	Mark of respondent	Place	Date

Statement by Interviewer

I have provided the respondent(s) with a copy of the project information sheet. [ ]

I have answered the respondent(s) questions honestly to the best of my knowledge. [ ]

I have left a signed copy of this consent form _________________ with the respondent(s). [ ]

Name of interviewer	Signature	Place	Date

Appendix 19. Child participant information and consent form

Date _______________

Appendix 19 **Informed consent form**

Who are we and why are we here?
We are researchers from a University
We are doing a study about water supply in your village.
We would like to explain the study and then invite you to be in the study.

What is the study for?
We are doing this study to find out whether or not having a tap in the house is better for the people living in the house than having to walk to a shared tap or well.

Why me?

There was no particular reason for choosing your household. Your house was picked by chance.

Do I have to take part?

No. It is up to you and your family to decide whether you take part.

What will happen if I am in the study?

We will ask you

- your name and age and about the things you do
- if you have been sick
- to sign a piece of paper with your name and address

On another day, we will ask you more questions about your house and water.

We will also

- Watch how your family collect water
- Walk with a person who normally collects water for one trip. During that trip the person carrying water will wear a small object like a watch on their arm, which will tell us how your heart beats while you carry water, as well as the distance and time taken for the trip
- Measure each person's height, weight and waist
- Take some photos around your house for our records and memory
- Later this month there may also be a meeting about water for you and your family or friends to join, which will take place at ____________ and take about an hour and a half.

How will this information be kept confidential?

We will only let people in our research team see your information. We will change your name and address to a number, so that others cannot work out who said what.

We will come back to your village and explain what we find out. We will also write about what we find out for other researchers, to help people see how to make water supplies better. We will make sure that you, your family and your home will not be recognised in anything we write.

What if I have a question or there is a problem?

You are free to ask any questions, at any time.
Even if you start in the study, you can stop at any time. You won't have to explain why.

Can I be hurt in the study?

No, but you might find some of the questions upsetting and not want to answer. It is o.k. if you don't want to answer something.

Do I get anything for being in the study?

No, but we hope that what we find out will help people know how to make water supplies better in the future.

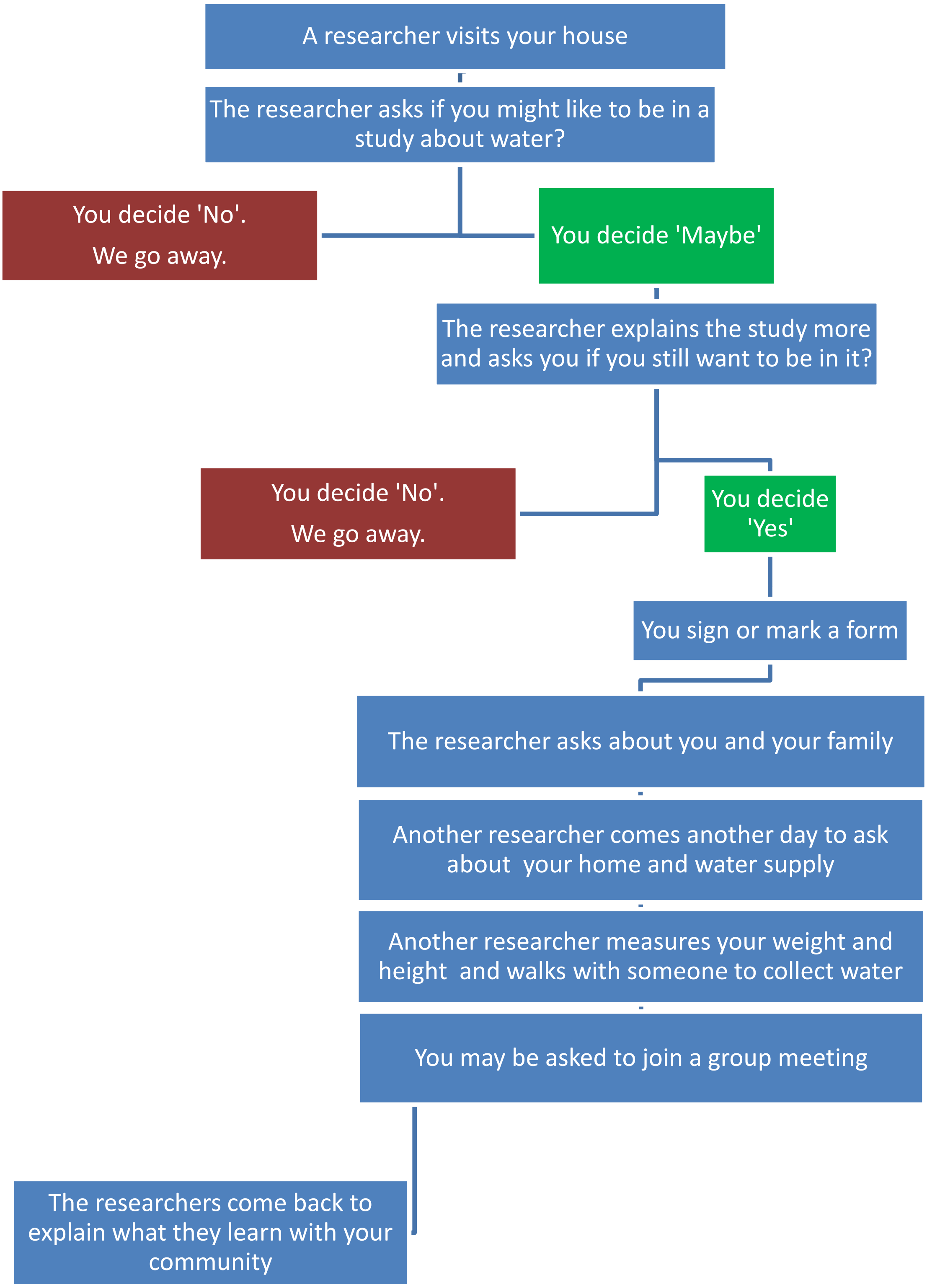
Who has checked this study?

Other people have checked what we plan to do and agreed that it is a good idea and safe.

The person in charge is ____.

If you have any questions, he/she can be contacted during day time at Tel ______________________.

Study Flow diagram



Date ________________

We now invite you to participate in this study.

Respondent:

- I have heard and understood what will happen in the study [ ]
- I understand that there will be no harm to me and my family [ ]
- I understand that I don't have to be in the study [ ]
- I had time to think before I said yes or no [ ]
- I have not been made to be in the study [ ]
- I understand that I can stop being in the study if I want to [ ]

- I had a chance to ask questions, and can ask more [ ]
- I understand that I will not be given anything for doing the study [ ]

- I understand that this study has been checked and approved by other people [ ]

- I am happy to supply personal details of me and my family as long as they will not be used in any way to identify me to people, except the study team [ ]
- I am aware that the results of the study may be written about to share with others. I agree to this, as long as my privacy is guaranteed. [ ]

Consent: Option A

I hereby consent to participate in this project and can sign for this consent.

1________________________	____________________ ________	________________
Name of respondent	Signature Date	Place
2________________________	____________________ ________	________________
Name of respondent	Signature Date	Place
3________________________	____________________ ________	________________
Name of respondent	Signature Date	Place
4________________________	____________________ ________	________________
Name of respondent	Signature Date	Place
5________________________	____________________ ________	________________
Name of respondent	Signature Date	Place

Date ________________

Consent: Option B

I hereby consent to participate in this project and but am unable to sign. I have requested a household resident to confirm on my behalf.

Name of respondent	Mark of respondent	Place	Date
Name of Witness	Mark of witness	Place	Date

Consent: Option C

I hereby consent to participate in the project but require parental or guardian consent.

Name of respondent	Mark of respondent	Place	Date
Name of Parent/Guardian	Mark of respondent	Place	Date

Statement by Interviewer

I have provided the respondent(s) with a copy of the project information sheet. [ ]

I have answered the respondent(s) questions honestly to the best of my knowledge. [ ]

I have left a signed copy of this consent form ________________ with the respondent(s). [ ]

Name of interviewer	Signature	Place	Date

Appendix 20. **Workshop booklet: 2016 Water and Health Workshop for stakeholder feedback, Makhado Town, South Africa**

Appendix 20

Water and Health Workshop
Makhado Town, South Africa
16th March 2016

Mokoena, 2010

Workshop Programme (Wednesday 16th March):

Time	Activity
8.30	Arrival, registration, confirmation of consent to participate, re-imbursement of delegate travel costs and coffee/biscuits
9.00	Welcome and introductions
9.30	DFiD funded survey 2013: feedback of study findings
10.15	**Refreshment break**
10.35	Chief of region invited to up-date the meeting on issues affecting the villages in the region, particularly any important changes or events since 2013
11.00	Presentation of mobile phone app and new proposal for community based data collection to improve water services
12.00	**Lunch**
13.00	Small group activity (4 groups): discussion of strengths and weaknesses of the app and proposal, opportunities and barriers of putting it into practice
14.00	Groups to share and feedback their views
15.00	**Refreshment break**
15.20	Whole group discussion on way forward and identification of an action plan
16.00	Final comments and delegate feedback about workshop
16.30	Close

Presentation 1: Summary of Study Findings

HEALTH AND SOCIAL IMPACTS OF AT-HOUSE WATER SUPPLY

Mokoena et al, 2010

RESEARCHERS

Kwama Nkrumah University of Science and Technology, Ghana

Professor Esi Awuah, Leslie Danquah

Tshwane University of Technology, South Africa

Dr Stanley Mukhola, Matodzi Michael Mokoena, Lutendo Syliva Mudau

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University of East Anglia, U.K. Paul Hunter, Jo-Anne Geere and Batsirai Majuru

London School of Hygiene and Tropical Medicine, U.K. Wolf-Peter Schmidt

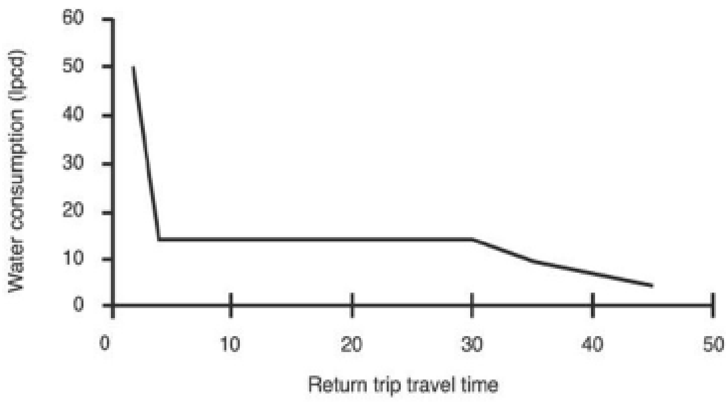
RESEARCH OBJECTIVE

"test the hypothesis that an at-house water supply will deliver significantly greater health and social benefits than those derived from a shared public water supply"

Mokoena et al, 2010

What our reviews of other studies found

WATER COLLECTION TRIP TIME AND WATER USE



Graph of relationship between travel time (min) and water consumption (lpcd) Cairncross (1987)

"The source is less than 1 kilometer away from its place of use and that it is possible to reliably obtain at least 20 liters per member of a household per day." – WHO, 2013

Evans et al, 2013

DISTANCE AND WATER QUANTITY

Small number of studies withdifferent designs, methods and analyses

Urban and rural settings

- 21 studies in rural areas
- Only 3 studies were urban
- 1 study peri-urban community
- 1 not stated

Relationship between water use and distance

- 12 studies reported increased distance (or time) reduced water quantity
- 8 studies reported no relationship between distance (or time) and water quantity

AT-HOUSE AND OFF PLOT SUPPLIES

At-house (lpcd)	Off-plot (lpcd)	Notes
102.51	29.18	Household connections with meters and public standpipes
25.3	9.0	At-home- piped spring water, wells, protected springs and sharing with neighbors or streams
58.5	18.3	Uganda subset average
68.3	22.4	Tanzania subset average
45.4	23.2	Kenya subset average
128	11	Combined average
20-254	4-21	Range of site means
54.7	27.5 (standpipe)	At-home supplied and public standpipes
	28.3 (neighbor)	At-home supplied and households using neighbors

Evans et al, 2013

IMPACTS OF AT-HOUSE WATER SUPPLY ON HEALTH (44 STUDIES)

Within literature, at-house water supplies yield significant reductions in trachoma, hepatitis E, and helminth infections

Impact of at-house water supply on diarrhea and growth outcomes remain unclear

Mokoena et al, 2010

WATER CARRIAGE

- Quite a few papers suggesting that carrying water might be linked to some health problems
- But very few papers had good data on health impacts of carrying water
- Pickering and Davis: survey data from 26 countries
- 15 minute decrease in walking to water source associated with
  - 41% reduction in diarrhoea
  - 11% reduction in death of children <5

Mokoena et al, 2010

OUR FIELDWORK FINDINGS

Household questionnaire:

- Recruited households with private (~50%) vs. public water supply (~50%)
- Fieldwork in 3 countries Ghana, South Africa and Vietnam (n=255+206+198)

Evans et al, 2013

WATER SOURCES AND QUANTITY

Significant differences in per capita water use across sources ($p<0.0001$)

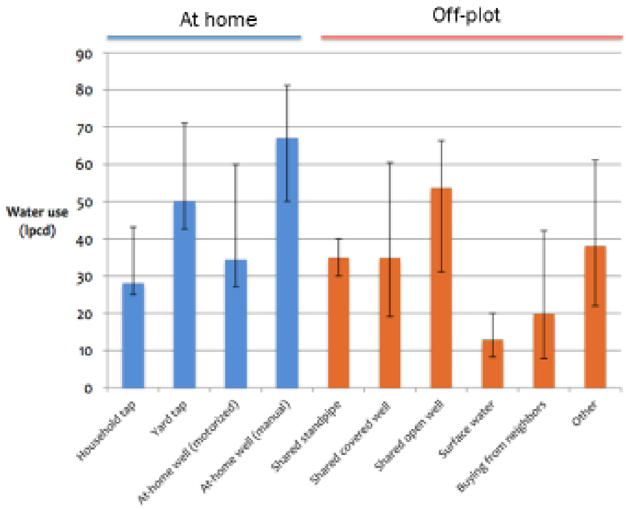
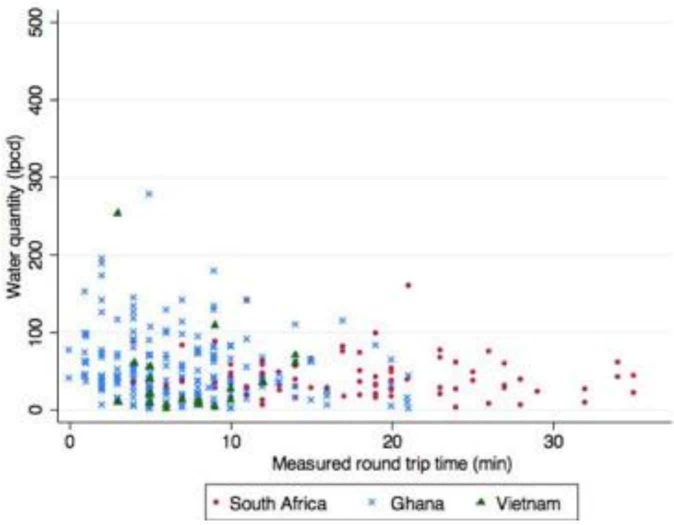


Figure – Median water quantity & water source (all countries together)

HOUSEHOLDS FETCHING WATER OFF-PLOT

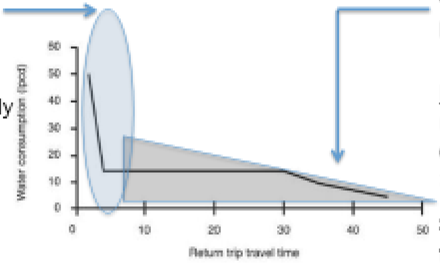


Evans et al, 2013

TIME TO WATER SOUCE & VOLUME OF WATER USED

FINDINGS INDICATE

Strong evidence of relationship between volume and at home (house/yard) supply



No evidence of relationship between distance and water volume beyond home/yard

Reliability of supply maybe more important?
(e.g. well water usage > off-plot tap water usage)

Social and geographic factors

Evans et al, 2013

RELIABILITY

Country	Number of days without water supply per week		Hours of supply per day		Time taken to repair breakdowns	
	Mean (SD)	Range	Mean (SD)	Range	Mean (SD)	Range
S. Africa	2.5 (4.2)	0-30	18.7 (8.2)	0-24	34.8 (47.2)	0-365
Ghana	3 (3.8)	0-16	18.7 (8.3)	0-24	8.5 (26.5)	0-210
Vietnam	0.8 (2.1)	0-14	22.1 (5.2)	1-24	1.2 (2.8)	0-24

Evans et al, 2013

ADEQUACY

Ability of households to meet their domestic water quantity needs

Response	Shared	Private	Total
No	64 (21.5%)	26 (7.2%)	90 (13.7%)
Less than half of the time	17 (5.7%)	10 (2.8%)	27 (4.1%)
About half of the time	9 (3.0%)	10 (2.8%)	19 (2.9%)
More than half of the time	11 (3.7%)	27 (7.5%)	38 (5.8%)
Yes	196 (66.0%)	286 (79.7%)	482 (73.5%)

Evans et al, 2013

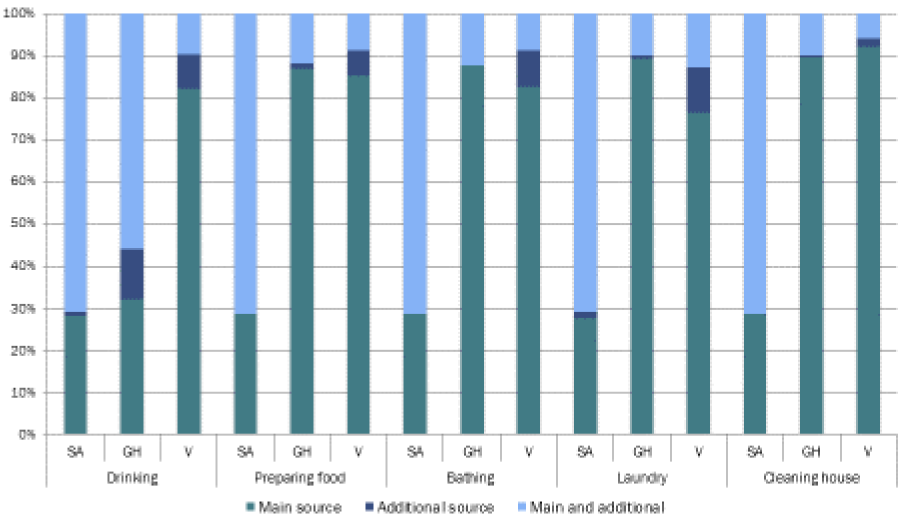
USE OF ADDITIONAL WATER SOURCES

Number of alternative sources	South Africa HH (%)	Ghana HH (%)	Vietnam HH (%)
0	56 (27.2%)	76 (73.8%)	107 (54.9%)
1	149 (72.3%)	2 (1.9%)	75 (38.5%)
2	1 (0.5%)	21 (20.4%)	10 (5.1%)
3	0 (0.0%)	4 (3.9%)	3 (1.5%)

	South Africa HH (%)	Ghana HH (%)	Vietnam HH (%)
Bottled water/sachet	0 (0.0%)	156 (61.2%)	4 (2.0%)
Total	206	255	198

Evans et al, 2013

WATER SOURCE BY ACTIVITY



Evans et al, 2013

IMPACT AT-HOUSE WATER SUPPLY ON HEALTH

Association of self-reported disease with any water obtained from out of home

Health outcome	RR	L95%CI	U95%CI	P
Skin disease	1.03	0.70	1.51	0.895
Eye disease	1.07	0.36	2.25	0.647
Diarrhoea	1.48	0.85	2.56	0.162

Evans et al, 2013

ADULTS REPORTING PAIN

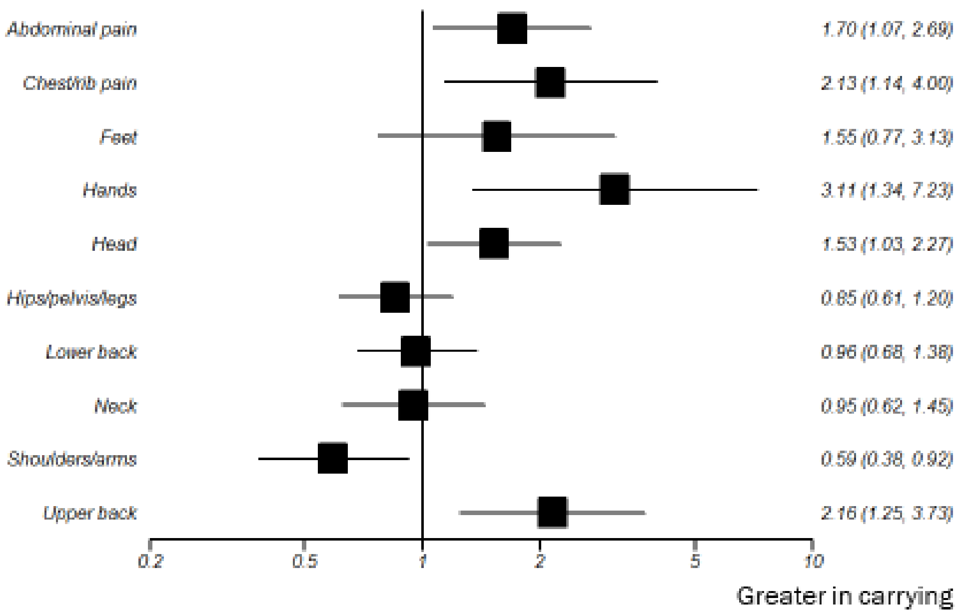
Water carrying	N	RR	L95%CI	U95%CI
No history	130	1		
Past history	145	0.97	0.77	1.23
Current	329	1.00	0.82	1.23

CHILDREN REPORTING PAIN

Water carrying	N	RR	L95%CI	U95%CI
No history	228	1		
Past history	11	ND		
Current	139	0.89	0.55	1.44

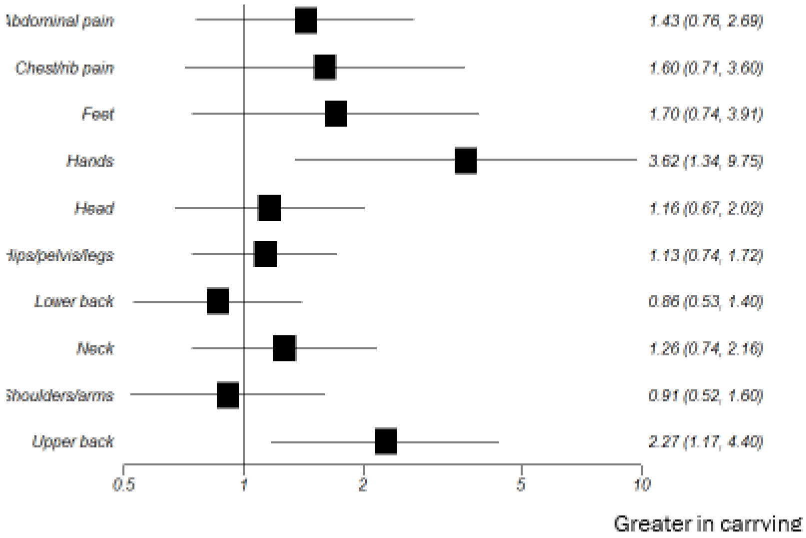
Evans et al, 2013

SITES OF REPORTED PAIN
CURRENT VS NEVER WATER CARRYING



Evans et al, 2013

SITES OF REPORTED PAIN
PAST VS NEVER WATER CARRYING



Evans et al, 2013

FACTOR OF ANALYSIS OF SITE OF PAIN

Rotated Component Matrix[a]

Explains 54% of variance

Survey q28: Pain location	Component 1	Component 2
Abdomen/stomach	.632	.131
Chest/ribs	.706	.151
Feet	.695	.221
Hands	.706	.266
Head	.616	.272
Hips/pelvis or legs	.179	.757
Lower back	.223	.750
Neck	.340	.696
Shoulders/arms	.238	.790
Upper back	.608	.347

RELATIONSHIP BETWEEN FACTOR 1 & WATER CARRYING

Factor 1= chest/ribs, hands, feet, abdomen/stomach, head and upper back

Water carrying		L95%CI	U95%CI	P
No history	0			4.5E-5
Past history	0.21	0.01	0.042	
Current	0.30	0.17	0.43	

Evans et al, 2013

RELATIONSHIP BETWEEN FACTOR 2 & WATER CARRYING

Factor 2= neck, shoulders/arms, lower back, hips/pelvis, and legs

Water carrying		L95%CI	U95%CI	P
No history	0			0.023
Past history	-0.03	-0.25	0.19	
Current	-0.18	-0.32	-0.04	

Evans et al, 2013

VOLUME OF WATER USED & SOCIAL OUTCOMES

Activities carried out by household water carriers and former household water carriers over a 24 hour period:

- Social activities
- Personal hygiene
- Domestic employed work
- Inactivity

Water collectors had 40 minutes more activity time than non-collectors

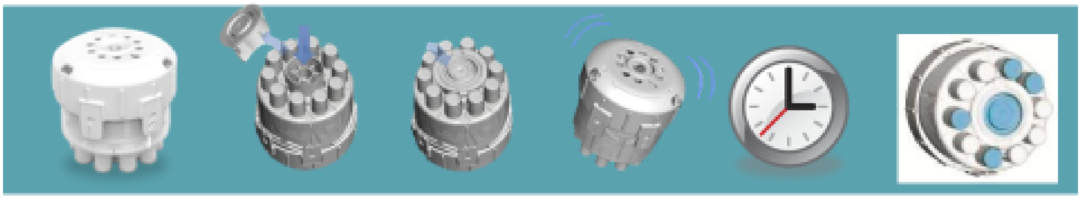
- MORE activity time ≠ increased economic activity
- REST time benefits may include family time and support child-rearing and learning

WATER QUALITY

Country	Region	Communities Visited			Source	Stored	Fieldwork Dates
Ghana	Kumasi	4	Asuofua Barakese Nkawie Abuakwa	Peri-urban Peri-urban Peri-urban Peri-urban	179	212	July 15-Sept 15, 2012
South Africa	Vhembe	3	Muraleni Ravele Tshifhire	Peri-urban Peri-urban Peri-urban	133	95	Sep 15-Nov 15, 2012
Vietnam	Lao Cai	4	Trạm Thải Lắp máy Phân Lân Lảo Lý	Rural Rural Rural Rural	0	20	July 1-Sept 1, 2012
Total		11			312	327	

Evans et al, 2013

WATER QUALITY : METHODS 'AQUATEST'

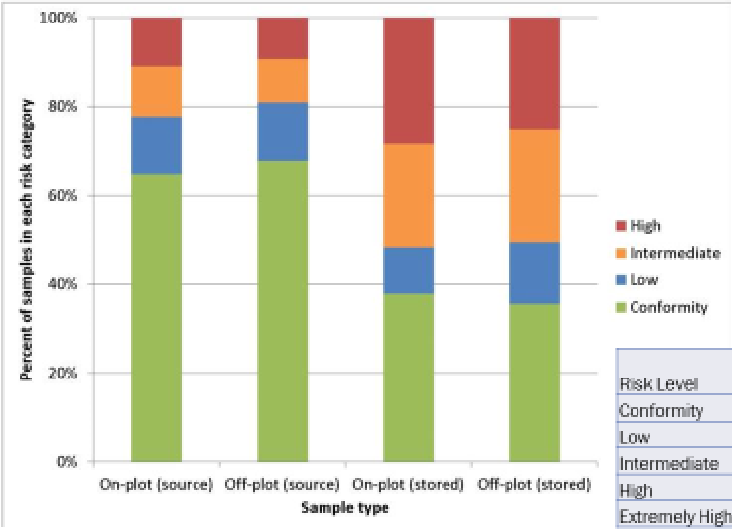


Analysis

- Excluded Vietnam data
- Source type
- On-plot vs Off-plot
- Country
- Distance to source (quintiles)
- Crude as well as adjusted regression analysis

Evans et al, 2013

WATER QUALITY: ON-PLOT VS OFF-PLOT



Risk Level	*E. coli* concentration (CFU/100 mL)
Conformity	<1
Low	1-10
Intermediate	11-100
High	101-1000
Extremely High	>1000 WHO, 1997

Evans et al, 2013

WATER QUALITY: ON-PLOT VS OFF/PLOT

Detectable *E. coli*

	Source	Stored
On-Plot	35.1%	62.1%
Off-Plot	32.2%	64.4%
OR (on-plot vs off-plot) [adjusted]	1.139 [1.086]	0.908 [0.767]
P (on-plot vs off-plot) [adjusted]	0.597 [0.859]	0.704 [0.459]

Mean *E. coli* concentrations

Source Access	Source CFU/100 mL [95% CI]	Stored CFU/100 mL [95% CI]
On-plot	24.32	62.52
	[14.33 - 34.33]	[44.42 - 80.63]
Off-plot	25.99	62.94
	[15.47 - 36.51]	[50.97 - 74.92]
P (on-plot VS off-plot)	0.8213	0.9698

Evans et al, 2013

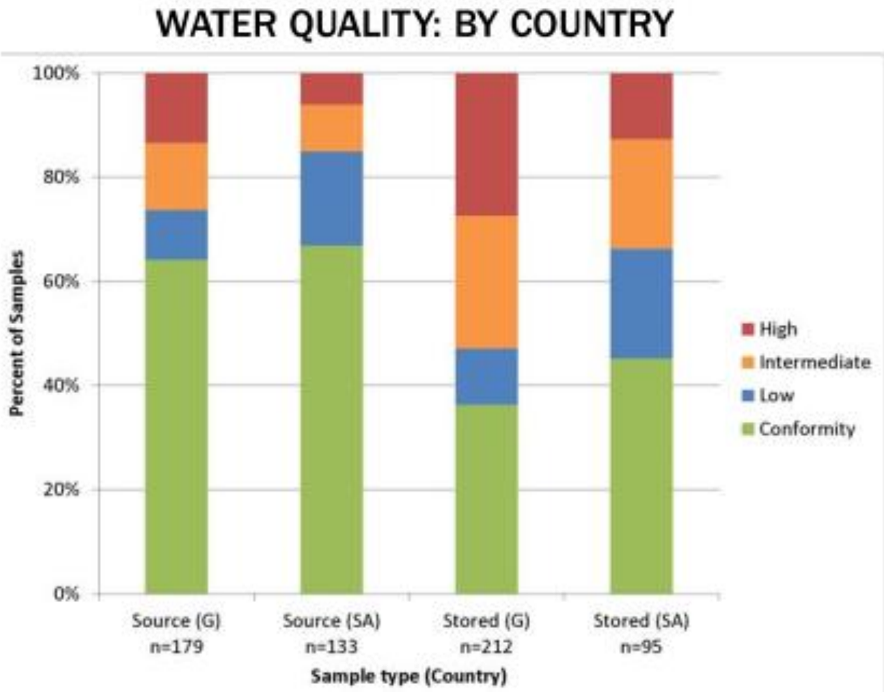
WATER QUALITY: BY COUNTRY

Detectable *E. coli*

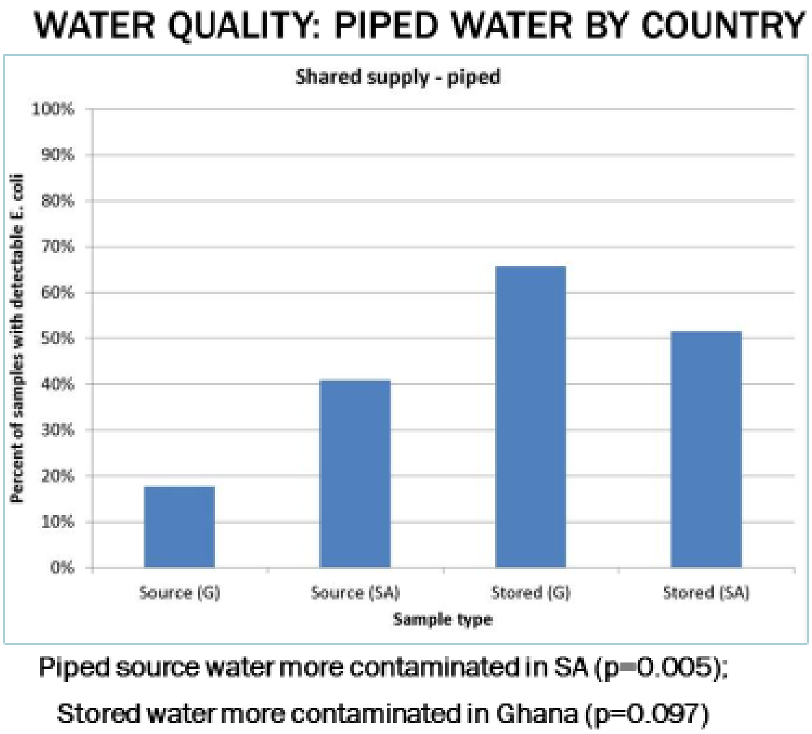
	Source	Stored
Ghana	35.8%	63.7%
South Africa	33.1%	54.7%
Vietnam (not included)	(N/A)	(100%)
OR (SA VS. G) [adjusted]	0.889 [3.270*]	0.69 [0.560]
P (SA VS. G) [adjusted]	0.624 [0.035]	0.139 [0.163]

*Significant at the 95% CI

Evans et al, 2013



Evans et al, 2013



Evans et al, 2013

WATER QUALITY: HEALTH OUTCOMES

	All		Ghana		South Africa	
	Source	Stored	Source	Stored	Source	Stored
Skin Infection	2.638 [0.81-8.55]	0.587 [0.18-1.91]	1.915 [0.53-6.91]	0.897 [0.24-3.37]	N/A	N/A
Eye Infection	0.629 [0.26-1.53]	1.066 [0.47-2.40]	0.644 [0.23-1.80]	1.583 [0.59-4.23]	0.620 [0.10-3.77]	0.306 [0.051-1.82]
Diarrhea	**2.302‡** [0.82-6.45]	1.010 [0.34-2.96]	**4.600*** [1.21-17.50]	0.704 [0.18-2.74]	0.563 [0.089-3.58]	2.061 [0.33-13.02]
Missed School or Work	**4.196*** [1.05-16.81]	2.717 [0.64-11.53]	**3.794‡** [0.82-17.65]	2.802 [0.55-14.32]	6.94 [0.25-190.91]	2.153 [0.078-59.71]

* Significant at 95% CI; ‡ Significant at 90% CI

Evans et al, 2013

WATER QUALITY: MAJOR FINDINGS

- Stored water more contaminated than source water
- No effect of on-plot access was observed
- Source water samples from piped systems more contaminated in South Africa, but stored water samples more contaminated in Ghana
- Diarrhea and missed school or work were associated with detectable *E. coli* in source water overall and in Ghana, but not in South Africa

PROJECT OUTCOME

Research project OBJECTIVE

- "test the hypothesis that an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply."

Research project OUTCOME

- Overall - the hypothesis is true when the water supply is at home and reliable (particularly in Ghana and Vietnam).

CONCLUSION

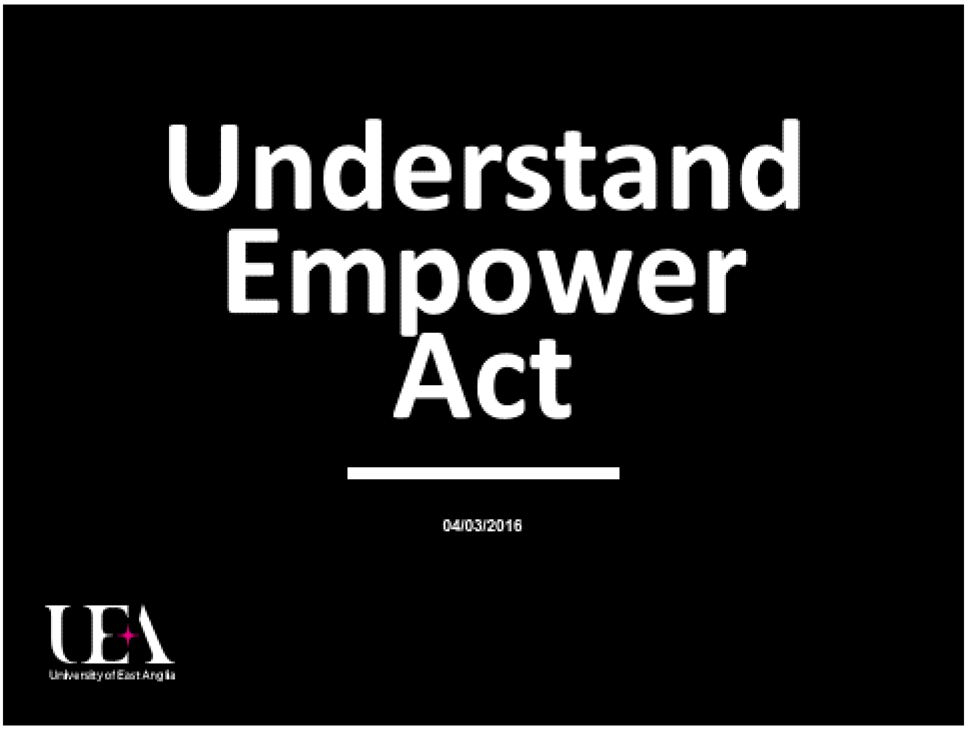
The available evidence suggests that

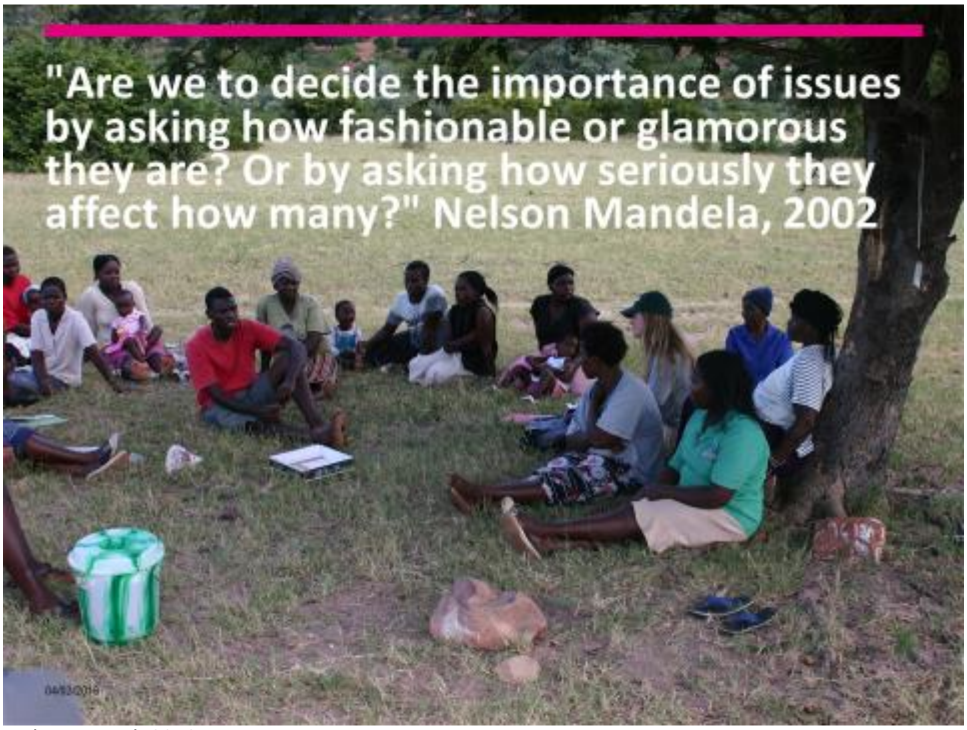
use of a reliable on plot water supply

should be the benchmark

Mokoena et al, 2010

Presentation 3. A prototype mobile phone app and new proposal for community based data collection to improve reliability of water services





Mokoena et al, 2010

WHY in Venda?

Venda people are

Resourceful and knowledgeable

Well educated and skilled

Good leadership

Venda Communities

Work together

Include many young people

Venda has

Strong traditions

A history of change

Examples of innovation

04/03/2016

Mokoena et al, 2010

Mokoena et al, 2010

Reliability might be improved with **better communication** from people using the water service to people providing the water service, to let them know

- **When** systems or parts of them break down and **where** there is a problem

- **How** people are currently coping so that service providers can **prioritize** what they must do

    - Where are they getting their water from now?
    - How far are they going to get it?
    - How difficult is it to get the water?
    - How much are they getting? Is it enough? Are there vulnerable community members?
    - What is it costing to get water?
    - What is the quality of water like?

Mokoena et al, 2010

Better communication from people providing the water service to people using the water service, to let them know

- **When** there is a problem and what will be done about it
- **When** systems or parts of them will be repaired, how long it will take and why? What must be done?
- **What** it will cost to make repairs
- **Where** are the nearest alternative sources working
- **What** type of use the quality of that water suitable for, for example drinking, washing, cooking, cleaning or gardening
- **How** people might currently cope so that they can **choose what to do**
    - Recommended household water treatment for the area
    - How to store water safely

How could better communication help?

Better relationship
Trust

Better service
Responsibility

Better health
Wellbeing

Better life!
More choice

Mokoena et al, 2010

Try to stop this

March 4,

Mokoena et al, 2010

Try supporting this

March 4,

Mokoena et al, 2010

Mobile phones and coverage networks are improving

We have developed a prototype mobile phone app

It asks questions about water access

- Source
- Carriage method if off-plot (tracks route with GPS)
- Quantity
- Effort
- Pain
- Safety


Mokoena et al, 2010

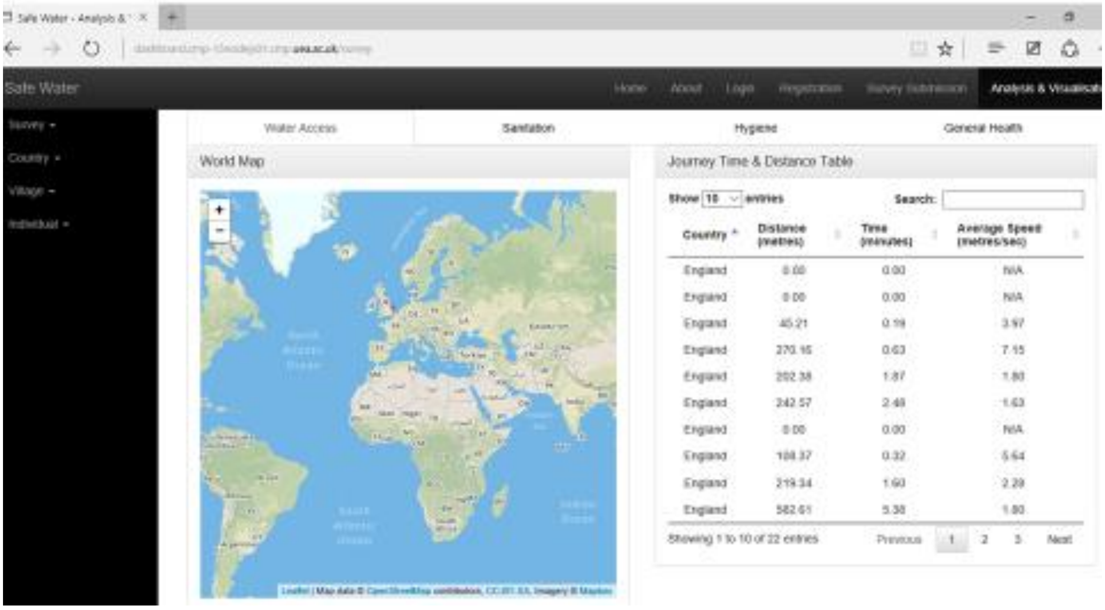
Mobile phones and coverage is improving

It also asks questions about

- Sanitation
- Hygiene
- Health
- General health
- Pain and body functioning
- Disability

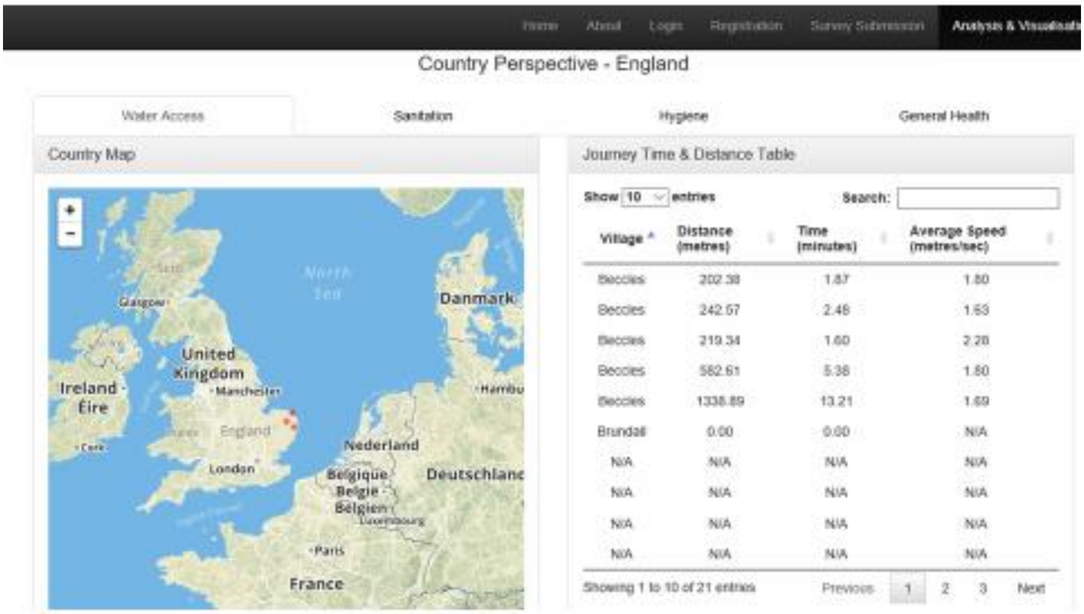

Payne et al, 2015

Prototype server for managing data



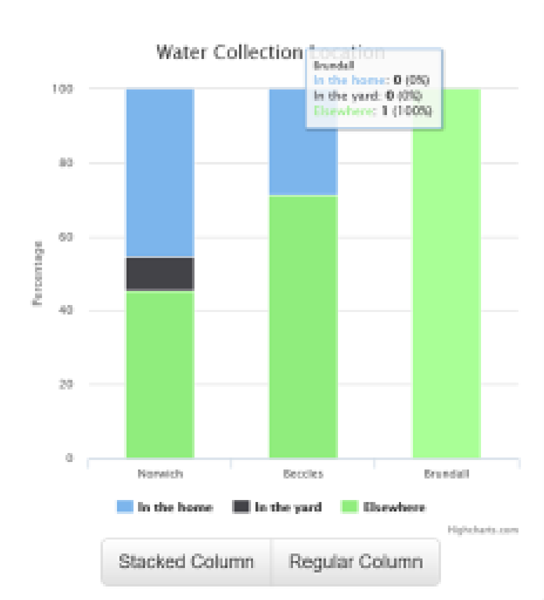
Payne et al, 2015

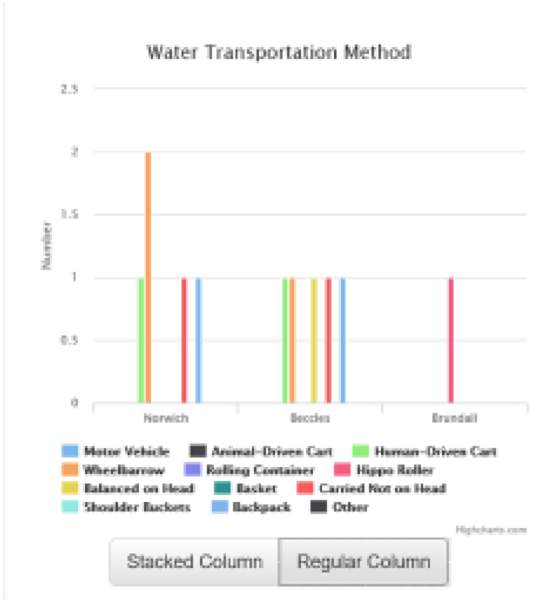
Country level information



Payne et al, 2015

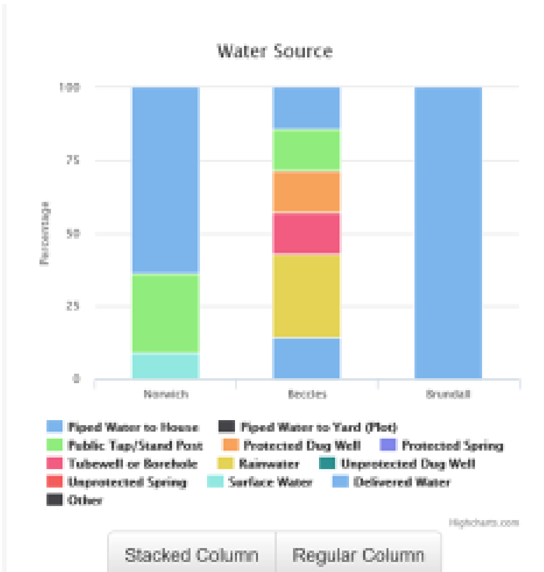
Information automatically summarised in tables: location and transport

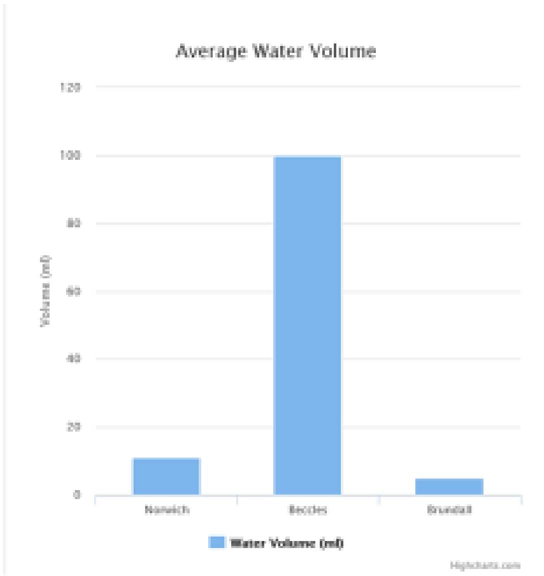




Payne et al, 2015

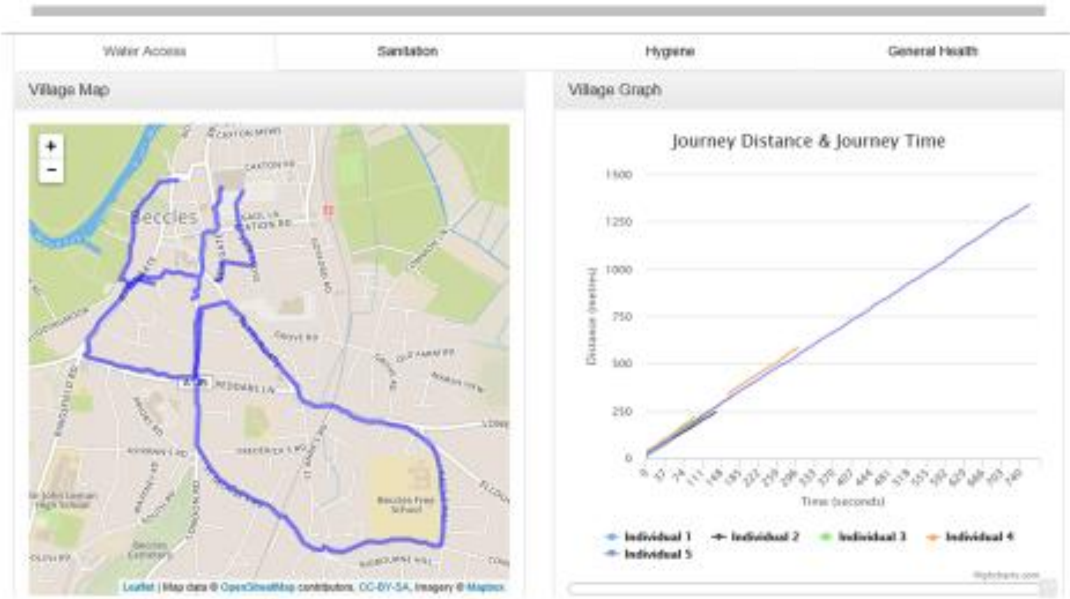
Information automatically summarised in tables: source type and mean volume compared between villages





Payne et al, 2015

Information summarised at village level: GPS function tracks water collection routes



Payne et al, 2015

Information summarised at individual level: can track change over time at country, village and household level

Payne et al, 2015

Next steps: what do you think?

- Could this work here?
- What information would service users like to get to providers?
- What information would service providers like to get to service users?

- Strengths?
- Weaknesses?
- Opportunities?
- Barriers?

THANK YOU

Public Health and Social Benefits of At-house Water Supplies

Report of 2012-13 study findings

Full Final funder report available at
http://r4d.dfid.gov.uk/pdf/outputs/water/61005-DFID_HH_water_supplies_final_report.pdf
[accessed 18/02/16]

Prepared from full report by:
University of East Anglia

Executive summary

1. Background

1.1. Research Aims and Objectives

This research project aimed to answer the following questions

1. What are the patterns of water usage including quantities used and purposes in relation to a range of source types, reliability of service and distance?
2. What health outcomes are associated with different levels of water supply provision?
3. What are the socio-economic benefits derived from different levels of water supply provision?

1.2. The team

The project team comprised researchers in water and health from eight Universities:

- the water@leeds team at the University of Leeds, U.K. and Hanoi School of Public Health (HSPH), Hanoi, Vietnam
- the Water Institute at the University of North Carolina, USA and Kwame Nkrumah University of Science and Technology (KNUST), Ghana
- the University of East Anglia, U.K. and Tshwane University of Technology, South Africa
- the London School of Hygiene and Tropical Medicine, U.K.; and
- the University College London U.K.

1.3. The approach

The project utilised several methods of research

- Reviews of published information
- A review of global data on associations between levels of water service, quality of service and health outcomes
- Field studies in Ghana, South Africa and Vietnam

1.4. This report

This report summarises the study findings and is a short version of the full report.

2. Research Methods

2.1. Literature Reviews

We reviewed information already published about five topics:

1. The relationship between distance to source and quantities of water consumed. The results are described in section 3.2.
2. Health benefits of at-house water supplies. The results are described in section 3.3.1.
3. The impacts of at-house water supplies on hygiene activities in the home, reported in sections 3.3.2.
4. The impact of water carrying on musculo-skeletal health impacts, reported in section 3.4.1.
5. The relative water quality of different facility types including at-home and off-plot supplies, reported in Section 3.5.

2.2. Field-based studies

2.2.1. Selection of field research locations

We carried out field research in South Africa, Ghana and Vietnam.

In Ghana our research was conducted in four communities near Kumasi in the Ashanti region of Ghana. All four communities were centred around a main road, stretching out densely along the road and less densely outward from the road on either side and could broadly be defined as urban or peri-urban. Water was supplied through a combination of private taps, public taps and private boreholes. The purchase of 'sachet' water was not uncommon.

In Vietnam our research was conducted in the remote rural Lao Cai province. Lao Cai is a mountainous area. The communities in Lao Cai were generally small scattered rural hamlets. Most households accessed water from several sources, some including piped water supply to the home, private boreholes and wells and public springs.

In South Africa we carried out fieldwork in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province in South Africa. Two communities were located in the dry, flat area west of Makhado town. The water sources here were communal taps or private drilled wells with either a yard tap or in-house connection. The third community was located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while some households had yard-taps or in-house taps.

2.2.2. Data collection tools

Two hundred households were recruited to participate in the study in each country. We used a household questionnaire to find out about sources of water used, water usage patterns and health outcomes.

2.2.3. Ethical approval

Ethical approval was obtained by the University of Leeds, for work in Vietnam by Leeds researchers, from UEA and TUT for work in South Africa and from the University of North Carolina for fieldwork in Ghana.

3. Results

3.1. Definitions of access and the experience of households in our field studies

3.1.1. Global definitions of “access” to water

Water supply services are commonly described according to the type of technology used, distance to water source for users, quantity of water available and the quality of the water provided. The Joint Monitoring Program (JMP) of the World Health Organisation (WHO) and UNICEF defines “access to drinking water” to mean “the source is **less than 1 km away** from its place of use and that it is possible to **reliably obtain at least 20 litres per member of a household per day**.” (WHO, 2013). The minimum per capita domestic water quantity of 20 litres is directly referenced in General comment 15 on the United Nations Human Right to Water. An ‘improved’ drinking water source include piped water into the home or yard, a public tap, tubewell, borehole, protected dug well, protected spring, and rainwater JMP (2010).

The **1 km** distance comes from studies conducted during the 1970s and 1980s in Sub-Saharan Africa (White et al. (1972), Feacham (1978) and Cairncross (1987) per capita water usage at the household levels off when the water collection time from house to source is between 5 to 30 minutes and then declines if collection time to a water source is more than 30 minutes (See **Figure 1**). A round trip time of 30 minutes is approximately equal to a distance of 1 km home to source assuming no waiting time at the tap (Cairncross (1987).

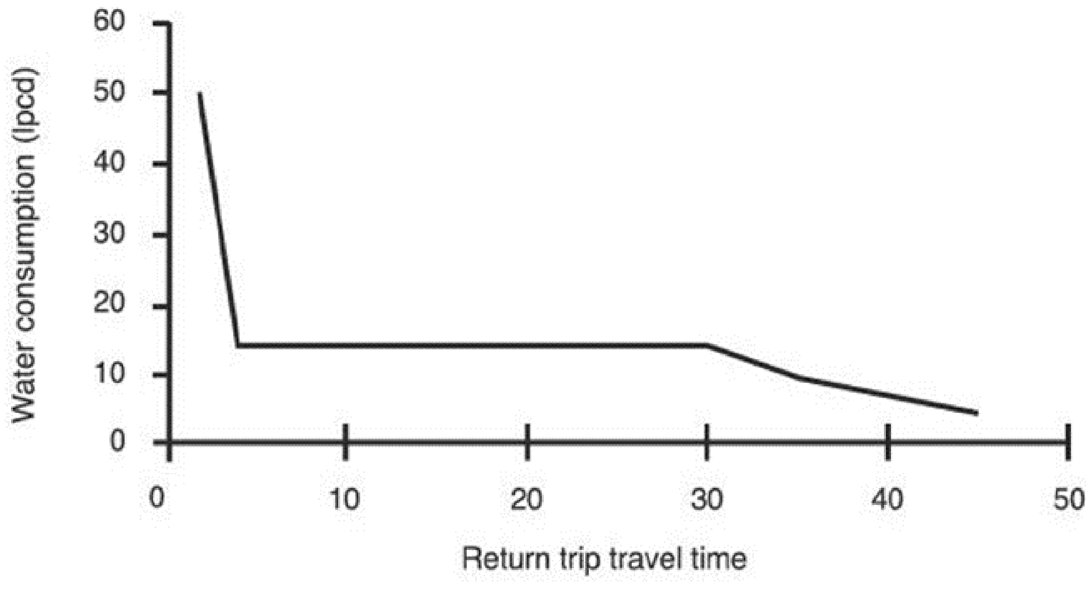


Figure 1: Graph of relationship between travel time (min) and water consumption (lpcd) Cairncross (1987)

We reviewed how different countries define 'adequate' water supplies and how this information is collected using the 2011 UN-Water GLAAS Country Survey (**Table 1**).

Table 1: Countries responding to the 2011 UN-Water GLAAS country survey

Region	**Countries providing access definitions (75 countries)**
Caucasus and Central Asia	Azerbaijan, Kyrgyzstan, Tajikistan, Uzbekistan
Eastern Asia	Mongolia
Latin America and the Caribbean	Bolivia, Brazil, Dominican Republic, El Salvador, Honduras, Panama, Paraguay
South Eastern Asia	Cambodia, Indonesia, Lao PDR, Myanmar, Philippines, Thailand, Vietnam
South Asia	Afghanistan, Bangladesh, Bhutan, India, Iran (Islamic Republic of), Maldives, Nepal, Pakistan, Sri Lanka
Sub Saharan Africa	Angola, Benin, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, DRC, Equatorial Guinea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Niger, Nigeria, Rwanda, Samoa, Senegal, Sierra Leone, South Africa, Sudan, Togo, Uganda, Zimbabwe
Western Asia	Jordan, Lebanon, Yemen

Of the 69 countries providing a definition of adequate access to water:

- 61 (88%) use type of technology as part of their definition
- The country with the most comprehensive description of access is the Philippines which describes three levels of service in terms of distance, number of users and type of technologies.
- The countries which do *not* use technology in their definition are: Ethiopia, Fiji, Maldives, Samoa, South Africa, Tajikistan, Uzbekistan and Vietnam.
- Vietnam is alone in describing allowable management arrangements for water supply rather than technology or levels of access.
- Nine countries include distance to source as part of their definition; in most cases the distance is considerably less than the 1km suggested by Cairncross while Ethiopia counts sources 1.5km from the home in rural areas (**Table 2)**.
- Only one country, Liberia, includes a measure of time to source (within 10 minutes).
- Six countries use number of users as one measure of access to services for some technologies (**Table 3**).
- Eighteen countries have water quality as part of the definition of access (**Table 4**).

Table 2: Countries using distance to source in their definition

Country	Area	Technology	Distance to source
Dominican Republic	Rural and Urban	Private tap	500m
Philippines	Rural and Urban	Point sources (Level 1)	25m
Philippines	Rural and Urban	Shared taps (Level 2)	250m
Sri Lanka	Rural and Urban	Multiple	200m
Malawi	Rural and Urban	Multiple	500m
Nigeria	Rural and Urban	Multiple	250m
South Africa	Rural and Urban	Not specified	200m
Morocco	Rural alone	Public tap	500m
Ethiopia	Rural alone	Not specified	1500m
Rwanda	Rural alone	Multiple	500m
Morocco	Urban alone	Public tap	200m
Ethiopia	Urban alone	Not specified	500m
Rwanda	Urban alone	Multiple	200m

Table 3: Countries using Number of Users in their definition

Country	Area	Type of technology	Nr of Users/Unit
Egypt	Rural and Urban	Private tap	Apartment
Bangladesh	Rural and Urban	Private tap	5
Bangladesh	Rural and Urban	Public tap	100
Mozambique	Rural and Urban	Private tap	5
Mozambique	Rural and Urban	Well/ borehole	500
Rwanda	Rural and Urban	Public tap/borehole with motor	300
Rwanda	Rural and Urban	Borehole with hand pump	350
Benin	Rural only	Public tap	250
Guinea-Bissau	Rural only	Well/ borehole	150
Benin	Urban only	Public tap	12

Table 4: Countries including water quality in the definition

Water quality standards/ commentary	Country
World Health Organisation standards	Ethiopia, Fiji, Rwanda
National standards	South Africa, Mongolia, Tajikistan, Lesotho, Jordan, India
National standards (as EU standards)	Samoa
Source more than 10m from sewage disposal point	Indonesia
Treatment	El Salvador
Treated and chlorinated	Dominican republic
Protected from fecal contamination	Honduras
Potable	Congo, Morocco

Boiled, treated, chlorinated or desalinated water	Maldives
Filtered and disinfected	Panama

Table 5: Minimum criteria for ‘basic’ water services in Ghana, South Africa and Vietnam

	Ghana	South Africa	Vietnam*
Level	‘basic’	‘basic’	-
Source	‘improved’	tap	-
Density (people per water source)	300 (hand-pump)	-	-
Distance (m)	500	200	-
Quantity (ℓ)	20	25	-
Quality	National standards	National standards	-
Flow rate (ℓ/min)	-	10	-
Reliability	95%	98%	-

*Vietnam defines access to water supplies as those provided through approved institutional arrangements

Summary Points:

- Definitions of level of service in most countries focus on technology (see also (O'Hara et al., 2008)); issues of reliability and flow rate/pressure are rarely considered and some commentators have observed that they are considered to be of secondary importance (Hope and Garrod, 2004).

- For water users however the functionality or performance of the supply may be very important (Gulyani et al., 2005). While a tap in the house may, in theory, provide a higher level of service than a yard tap or communal standpipe, low pressure or intermittent supply may affect quality or quantity water supplied, and effectively render the quality of the service low.

3.1.2. Findings from the field studies – Main water source

Households in the three countries used a range of water sources. The main water sources are shown in **Table 6**. At-house water sources included house connections to piped systems, wells in the yard and private rainwater collection in Vietnam.

Table 6: Main water sources in Ghana, South Africa and Vietnam

		Ghana (%)	South Africa (%)	Vietnam (%)
At-house water sources	Piped supply with HH tap	8 (3.1%)	43 (20.9%)	10 (5.1%)
	Piped supply with yard tap	57 (22.4%)	6 (2.9%)	87 (43.9%)
	Private well (mechanical pump)	4 (1.6%)	54 (26.2%)	40 (20.2%)
	Private well (manual pump)	36 (14.1%)		11 (5.6%)
	Private rainwater collection	-		4 (2.0%)
	Total private sources	105 (41.2 %)	103 (50 %)	152 (76.8 %)
Shared water sources	Shared piped supply with tap	112 (43.9%)	79 (38.3%)	5 (2.5%)
	Shared well (manual pump)	20 (7.8%)	-	-
	Shared well (manual lifting)	18 (7.1%)	-	2 (1.0%)
	Shared supply surface water		4 (1.9)	38 (19.2%)
	Buying water from neighbours		11 (5.3%)	-
	Other – outside of home (municipal water tanker)		9 (4.4%)	-
	Total shared sources	150 (58.8 %)	103 (50 %)	45 (22.7 %)
	Total households	255 (100 %)	206 (100 %)	197 (99.5 %)

Communal taps were the most common shared water source in both Ghana and South Africa, while surface water was more common in Vietnam. The highest proportion of households using at-house water sources was in Vietnam, with just over three quarters of the sample having access to a supply at the house or yard.

It is perhaps worth noting that although communal taps were available in all the study communities in South Africa, some households reported their main supply as neighbours' private boreholes, surface water (protecting springs) or municipal water tankers.

3.1.3. Reliability

Although the majority of main water sources used in the survey were those conventionally classified as 'improved', the reliability of the water supplies was low in Ghana and South Africa in particular. On average, water was unavailable for 3 days of the week in Ghana and South Africa, while in Vietnam it was typically unavailable for a day (**Table 7**).

On the days when it was available, water was supplied for most of the day in all three survey sites. However, breakdowns in the supply system reportedly took an average of a month to repair in South Africa, while in Vietnam repairs were within a day. In Ghana the average time for repairs was just over one week.

Table 7: Summary statistics on water supply reliability

Variable	Country	Number HH (%)	Mean (SD)	Median	Mode	Min	Max
Hours of supply	South Africa	198 (96.1%)	18.7 (8.2)	24	24	0	24
	Ghana	199 (78.0%)	18.7 (8.3)	24	24	0	24
	Vietnam	142 (71.7%)	22.1 (5.2)	24	24	1	24
Number of days without water supply in previous week	South Africa	201 (97.6%)	2.5 (4.2)	1	0	0	30
	Ghana	222 (87.1%)	3.0 (3.8)	2	0	0	16
	Vietnam	197 (99.5%)	0.8 (2.1)	0	0	0	14
Time taken to repair breakdowns (days)	South Africa	110 (53.4%)	34.8 (47.2)	30	30	0	365
	Ghana	105 (41.2%)	8.5 (26.5)	3	0	0	210
	Vietnam	101 (51.0%)	1.2 (2.8)	0	0	0	24

South Africa n = 206; Ghana n = 255; Vietnam n = 198

3.1.4. Multiple water sources

Households typically made use of a range of water sources. Of the 420 (64 %) households that reported using a secondary water source; 193 (46 %) of these were households *with* on-site supply. Essentially, only 36% of households relied exclusively on one water source. Just over a quarter of households reported that their domestic water needs were not met all the time (**Table 8**).

For households without at-house supplies, the reasons cited for inadequate water quantities were time water is available at source and accessibility to the supply, amongst others (**Table 9**). Households that had at-house water supplies cited seasonal availability of water, water pressure as well as temporal availability of water at the source amongst the reasons for having inadequate water quantities.

Table 8: Adequacy of water for domestic needs

Adequate supply	Shared	Private	Total
No	64 (21.5%)	26 (7.2%)	90 (13.7%)
Less than half of the time	17 (5.7%)	10(2.8%)	27 (4.1%)
About half of the time	9 (3.0%)	10 (2.8%)	19 (2.9%)
More than half of the time	11 (3.7%)	27 (7.5%)	38 (5.8%)
Yes	196 (66.0%)	286 (79.7%)	482 (73.5%)

Table 9: Reasons why water supply is inadequate

	Shared	Private	Total
Storage problems	3 (3.2%)	2 (3.2%)	5 (3.2%)
Number of water collectors	6 (6.5%)	1 (1.6%)	7 (4.5%)
Number of water collection containers that can be used	3 (3.2%)	0 (0%)	3 (1.9%)
Time water is available at source	23 (24.7%)*	16 (25.4%)*	39 (25.0%)*
Seasonal availability of water at source	8 (8.6%)	19 (30.2%)*	27 (17.3%)*
Power to extract water from source of water	2 (2.2%)	1 (1.6%)	3 (1.9%)
Reliability or predictability of source of water	2 (2.2%)	0 (0%)	2 (1.3%)
Price	16 (17.2%)	4 (6.3%)	20 (12.8%)
Water pressure	11 (11.8%)	16 (25.4%)*	27 (17.3%)*
Accessibility (location) of supply	19 (20.4%)*	4 (6.3%)	23 (14.7%)

3.2. Distance to source and water consumption

3.2.1. Findings from the systematic review of literature

Both existing and proposed standards for water access are based on studies dating back to the 1970s and 1980s in Sub Saharan Africa (SSA). The studies suggest that water consumption drops substantively when water sources are located at distances greater than 30 minutes (1 km return trip) away. At distances between 5 and 30 minutes, per capita water consumption remains relatively constant, but dramatically rises as water becomes available within five minutes of the household. This is an important phenomenon that has implications for providing adequate quantities of water to households.

A review of studies was conducted to assess the evidence for this and its implications for new recommended standards on distance to water sources.

Summary Points

- Current policy appears to be based on a handful of old studies: White et al. (1972), Feacham (1978) and Cairncross and Cliff (1987), performed over 30 years ago.
- More recent studies present a mixed picture of water use patterns reflecting the complex behaviour of those relying on off-plot water sources.
- Studies comparing households with at-home supplies and households using off-plot sources show a consistently greater water use.
- At-home water supplies are not available for all households with rural households less likely than urban households to enjoy this type of supply.
- Future studies should find out how best to indicate water use by households across all regions, in both rural and urban areas.

3.2.2. Summary findings from the fieldwork

At-home and off-plot supplies

Median water quantity (lpcd) was compared between households with at-home water supplies and households with off-plot water supplies. The quantile regression model was adjusted for country of study, crowding, highest level of education within the household, the number of types of assets owned, and water source type. Crowding was defined as the number of people in the household divided by the number of reported rooms within the home. Assets were defined as radios, televisions, mobile telephones, refrigerators, washing machines, cars, bicycles, motorbikes, and stoves.

Results pooled from all three countries show a significantly higher median water quantity (10.9 ± 8.0 lpcd) for those households having on-plot supplies compared to those with an off-plot supply (**Table 10**).

Table 10 Results from quantile regression of water use (lpcd) and location of water source.

Location of water source	N	Extra water use[1] (lpcd)	L95%CI	U95%CI	P
Outside house/yard	288	0	---	---	---
House/yard	221	10.9	2.9	18.8	0.007

[1] *'extra water use' refers to an increase or decrease in the median water use (lcpd) rather than the mean water use*

Water quantity by source type

To examine the relationship between median water use and water source type, a quantile regression model was adjusted for country of study, household crowding, highest level of education of any household member and number of assets owned. **Figure 2** shows the median water use (lpcd) for households using different sources with bars indicating the 25th and 75th percentile. **Table 11** shows the model results using communal standpipes as the basis for comparison. Both Figure 1 and **Table 11** show that there are significant differences in water use by source type (p<0.0001). The results from the quantile regression show the change in water use between sources, while **Figure 2** shows the actual median water use for each source.

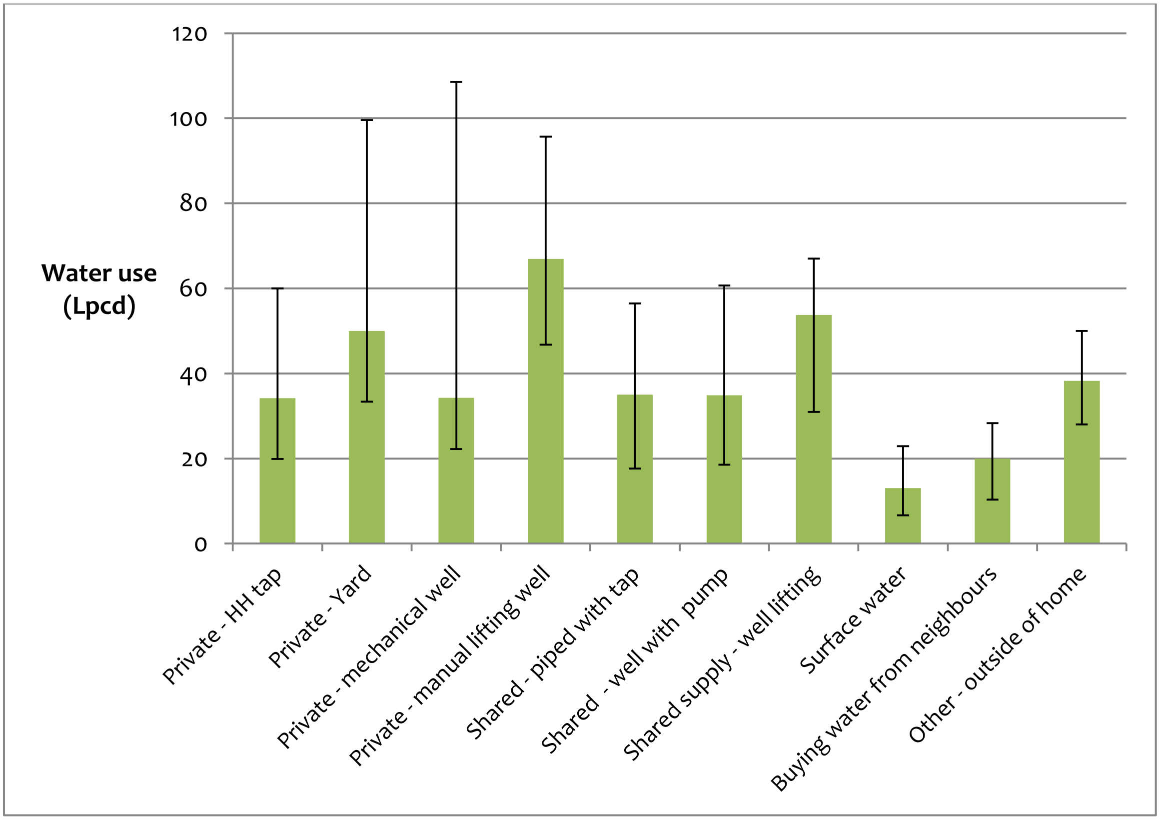


Figure 2: Median water use (lpcd) by source type (bars indicate 25th and 75th percentiles).

Table 11: Results from quantile regression of water use (lpcd) and location of water source (data from all three countries).

Water source	n	Extra water use	L95%CI	U95%CI
Shared standpipe	191	0		
Shared covered well with manual pump[1]	19	-1.3	-11.7	9.1
Shared open well with manual lifting	19	11.0	0.7	21.4
Surface water	40	-14.5	-23.6	-5.3
Buy from neighbours	11	-11.1	-23.3	1.2
Other[2]	8	9.8	-5.9	25.5
Tap in house	37	0.1	-7.5	7.7
Tap in yard	99	11.5	5.2	17.8
At-house mechanical lift	52	2.2	-6.4	10.8
At-house manual lift well	30	26.8	18.1	35.6
Rainwater collection	3	38.0	24.1	51.8

1-Most often boreholes with hand pumps
2-'other' most often tanker trucks

Extra water use' refers to an increase or decrease in the median water quantity (lcpd) rather than the mean water quantity. ($F(10, 493) = 9.91$, $p<0.0001$).

Households that identified shared manual wells as their primary source used 11.0 ± 10.4 lcpd more than households using public standpipes. Surface water users consume considerably less water (14.5 ± 9.2 lpcd) than households using public standpipes. Households relying on surface water as their primary source had the lowest median water use of 13.0 ± 5.9 lcpd.

The results from **Table 11** should be viewed in light of the sample sizes for each water source. While there were a substantial number of observations for public taps (n=191) and yard taps (n=99), some sources (shared pump well, shared manual well, rainwater collection, buying from neighbours, and other) had sample sizes less than 20 households, therefore conclusions regarding these sources cannot be made with statistical confidence.

Households fetching water off-plot

Figure 3 shows the scatterplot of water quantity and self-reported one-way time (min) to the primary water source for households in South Africa, Ghana, and Vietnam. The decreasing relationship between water quantity used and one-way travel time varies between countries. In comparison to Ghana and Vietnam, South Africa has a more uniform distribution of water quantity used for households between 0 and 30 minutes from the source. In Ghana and Vietnam, water quantity steadily declines for households located up to 15 minutes from the source.

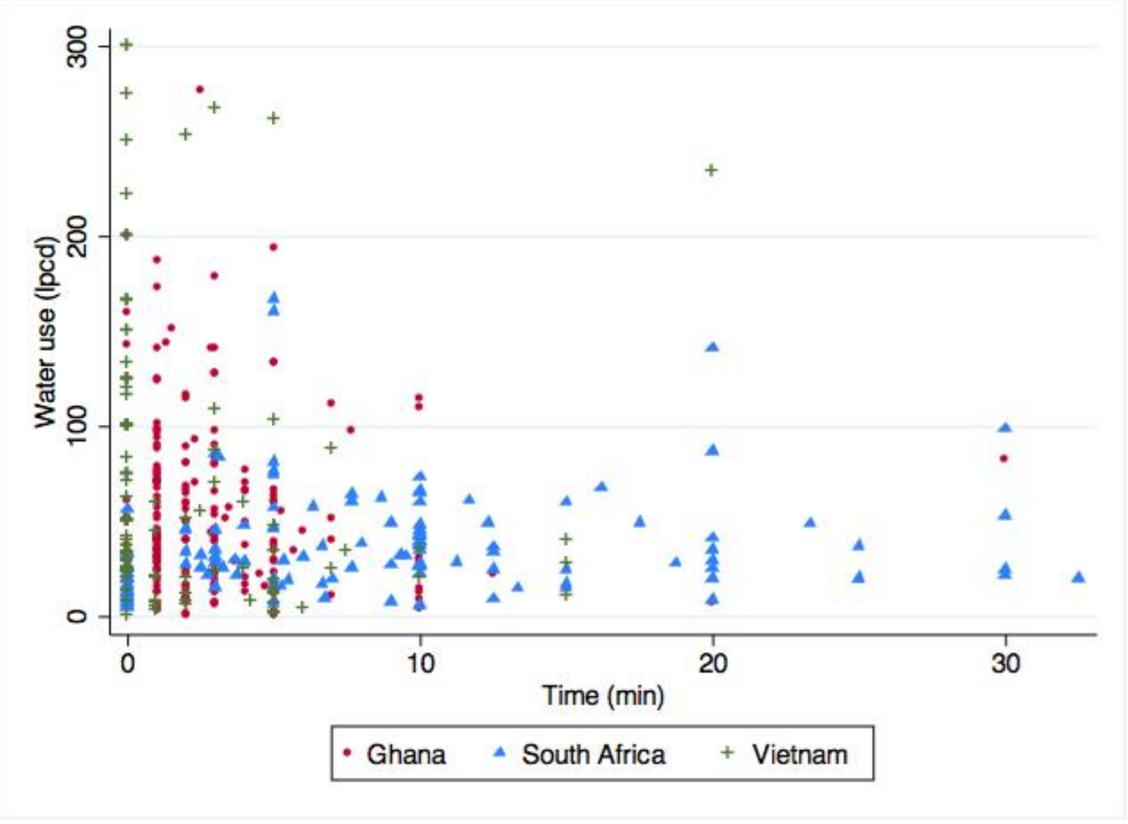


Figure 3: Scatterplot of water use (lpcd) and self-reported one-way travel time to the primary water source for households in all three countries with extreme values excluded.

To look at whether water consumption changed with collection time (self-reported and measured[1]) or distance to the water source for households using off-plot sources, a quantile regression model was adjusted for country of study, crowding, highest education level of anyone in the household, number of assets owned, and water source type.

The results from the regression using data pooled from all three countries are shown in **Table 12**. Three regression models compared different measures of time/distance from the household to the water source as the independent variable:

(a) Self-reported one way estimate of travel time (min);

(b) Measured round trip time (min);

(c) Measured round trip distance (m) to the primary water source.

None of the models showed a statistically significant relationship with water quantity. While the regression models show no relationship between collection time or distance and water quantity, there appears to be no evidence to substantiate a plateau effect.

Table 12: Results from quantile regression of water use (lpcd) and location of water source.

Independent variable	n	Extra water use[1]	L95 %CI	U95 %CI	P
(A) Self-reported time to source/10 minutes	251	0.9	-8.3	10.2	0.843
(B) Measured round trip time/10 minutes	235	-0.8	-7.9	6.3	0.823
(C) Measured round trip distance/100 metres	222	0.2	-0.7	1.1	0.699

1 *'extra water use' meaning for or every increase in X units of the independent variable (e.g. an increase in 10 minutes self-reported time to the water source) there was an increase in X lpcd (0.9 lpcd)*

Location of water using activities

Drinking water accounts for only a fraction of water used by households. Other uses can have large effect on the quantities of water used, for example laundry or bathing require more water than is used for drinking and food preparation. The location where households perform certain tasks can impact the calculated water use per person. As part of the household survey, respondents were asked to identify where they performed activities requiring water (at home, at the source, elsewhere, or in multiple locations). The results for South Africa, Ghana, and Vietnam are shown in **Table 13**.

Households in Ghana and South Africa often bathed and washed clothes at home rather than at the source. In contrast, a larger percentage of households (85% bathing, 94% laundry) using off-plot supplies in Vietnam reported performing these tasks at the source. Very few households reported using water for productive uses such as farming and commercial services. More households in Vietnam (n=16) specified using water for agricultural purposes than households in Ghana (n=6) or South Africa (n=2). Ghana had the largest number of households reporting commercial activities utilizing water (n=18),

[1] Enumerators walking with respondents measured one-way and round trip travel time from the household to the water source using stopwatches. Enumerators also recorded the distance travelled using GPS devices.

which include but are not limited to food preparation, laundry for others, and washing vehicles.

Table 13: Locations of water-using activities by households within different countries (South Africa, SA n = 206; Ghana, GH = 255; Vietnam, V = 198).

Activity	Country	n (% HH)	Location of water-using activity			
			At Home	At Source	Else where	Multiple locations
Bathing	SA	106 (100%)	103 (97.2%)	3 (2.8%)	0 (0.0%)	0 (0.0%)
	GH	148 (99.2%)	147 (99.3%)	1 (0.7%)	0 (0.0%)	0 (0.0%)
	V	46 (100%)	7 (15.2%)	39 (84.8%)	0 (0.0%)	0 (0.0%)
Laundry	SA	103 (100%)	72 (69.9%)	15 (14.6%)	10 (9.7%)	6 (5.8%)
	GH	148 (99.2%)	145 (98.0%)	3 (2.0%)	0 (0.0%)	0 (0.0%)
	V	46 (100%)	3 (6.5%)	43 (93.5%)	0 (0.0%)	0 (0.0%)
Cleaning dishes	SA	103 (100%)	103 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	148 (99.2%)	147 (99.3%)	1 (0.7%)	0 (0.0%)	0 (0.0%)
	V	46 (100%)	34 (73.9%)	12 (26.1%)	0 (0.0%)	0 (0.0%)
Gardening	SA	18 (21.8%)	12 (66.7%)	5 (27.8%)	1 (5.6%)	0 (0.0%)
	GH	6 (18.8%)	6 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	V	23 (68.7%)	14 (60.9%)	0 (0.0%)	8 (34.8%)	1 (4.3%)
Farming[1]	SA	2 (4.9%)	2 (100.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	6 (5.1%)	3 (50.0%)	1 (16.7%)	2 (33.3%)	0 (0.0%)
	V	16 (36.9%)	7 (43.8%)	0 (0.0%)	9 (56.3%)	0 (0.0%)
Commercial services[2]	SA	2 (1.0%)	2 (100%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	GH	18 (14.1%)	12 (66.7%)	2 (11.1%)	2 (11.1%)	2 (11.1%)
	V	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)

1-Includes agriculture, aquaculture, raising livestock
2-Includes preparing food, laundry for others, washing vehicles

Alternative Sources

Issues of seasonality, source reliability, cost, and convenience can lead to households choosing to use alternative sources in addition to or in place of their primary sources. Households may also chose to use different sources based on the purpose for which they are using water. For example, some households may use an improved source farther away for drinking water, but use an unimproved source next to their house for bathing. In order to better assess the extent and variation of alternative source use, households were asked to specify whether they used their primary water source or an alternative water source for different activities. The results from the three countries are presented in **Table 14**.

A large portion of households in South Africa (70.9%) and Ghana (56.0%) reported using main and alternative sources for drinking water. The large percentage of households in Ghana (61.2%) reported using bottled or sachet water, which contrasts sharply with the other countries (**Table 15**).

Table 14: Reported use of main and alternative sources for various water-using activities (South Africa, SA n = 206; Ghana, GH = 255; Vietnam, V = 198).

Activity	Country	n (% HH)	Main source	Alternative source	Main and alternative
Drinking	SA	206 (100%)	58 (28.2%)	2 (1.0%)	146 (70.9%)
	GH	252 (98.8%)	81 (32.1%)	30 (11.9%)	141 (56.0%)
	V	197 (99.5%)	162 (82.2%)	16 (8.1%)	19 (10.6%)
Preparing food	SA	205 (99.5%)	59 (28.8%)	0 (0.0%)	146 (71.2%)
	GH	252 (98.8%)	219 (86.9%)	3 (1.2%)	30 (11.9%)
	V	197 (99.5%)	168 (85.3%)	12 (6.1%)	17 (8.6%)
Bathing	SA	206 (100%)	59 (28.6%)	0 (0.0%)	147 (71.4%)
	GH	252 (98.8%)	221 (87.7%)	0 (0.0%)	31 (12.3%)
	V	197 (99.2%)	163 (82.7%)	17 (8.6%)	17 (8.6%)
Laundry	SA	205 (99.5%)	57 (27.8%)	3 (1.5%)	145 (70.7%)
	GH	252 (98.8 %)	225 (89.3%)	2 (0.8%)	25 (9.9%)
	V	196 (99.0%)	150 (76.5%)	21 (10.7%)	25 (12.8%)
Cleaning house	SA	206 (100%)	59 (28.6%)	0 (0.0%)	147 (71.4%)
	GH	251 (98.4%)	225 (89.6%)	1 (0.4%)	25 (10.0%)
	V	102 (51.5%)	94 (92.2%)	2 (2.0%)	6 (5.9%)
Gardening	SA	44 (21.4%)	29 (65.9%)	0 (0.0%)	15 (34.1%)
	GH	46 (18.0%)	24 (52.2%)	12 (26.1%)	10 (21.7%)
	V	135 (68.2%)	96(71.1%)	22 (16.3%)	17 (12.6%)

Table 15: Number of households reporting use of bottled water or sachet water.

	South Africa	Ghana	Vietnam
Bottled/sachet water	0 (0.0%)	156 (61.2%)	4 (2.0%)
Total households	206	255	198

For activities other than drinking, households in South Africa reported using their main and alternative sources. Interestingly, the reverse is seen for households in Ghana, where most households used their main water source exclusively for all activities other than drinking. Households in Vietnam predominately used only their main source for all domestic activities.

Table 16 shows the reported number of alternative sources used by sampled households. Bottled water and sachet water were separated (**Table 15**) since these alternative water sources are a unique category. More households in South Africa (72.8%) and Vietnam (59.0%) use alternative sources compared to Ghanaian households (26.2%). Table 8 breaks down the reported alternative sources by type. The results shown in Table 8 account for all reported alternative sources used by households except for sachet water and bottled water. Public standpipes were the most reported alternative source used in Ghana (30.4%). In contrast, surface water accounts for 56% and 48% in South Africa and Vietnam, respectively.

Table 16: Number of alternative sources used by households in each country.

Number of alternative sources used	South Africa HH	Ghana HH	Vietnam HH
0	56 (27.2%)	76 (73.8%)	107 (54.9%)
1	149 (72.3%)	2 (2.0%)	75 (38.5%)
2	1 (0.5%)	21 (20.4%)	10 (5.1%)
3	0 (0.0%)	4 (3.9%)	3 (1.5%)
Total HH	206	103	195

Table 17: Types of alternative sources reportedly used by households reporting at least one alternative source.

Alternative water source type	South Africa	Ghana	Vietnam
Household tap	0 (0.0%)	0 (0.0%)	1 (0.9%)
Yard tap	0 (0.0%)	4 (7.1%)	5 (4.8%)
Private well (motorized pump)	0 (0.0%)	0 (0.0%)	3 (2.8%)
Private well (manual lift)	0 (0.0%)	4 (7.1%)	1 (1.0%)
Rainwater collection	2 (1.3%)	0 (0.0%)	29 (26.9%)
Public standpipe	14 (9.3%)	17 (30.4%)	9 (8.3%)
Shared covered well (manual lift)	0 (0.0%)	6 (10.7%)	3 (2.8%)
Shared open well (manual lift)	0 (0.0%)	16 (28.6%)	1 (0.0%)
Surface water	85 (56.3%)	9 (16.1%)	52 (48.2%)
Buying from neighbors	36 (23.8%)	0 (0.0%)	0 (0.0%)
Other	14 (9.3%)	0 (0.0%)	0 (0.0%)
Total alternative sources reported	151	56	104

1- "rainwater collection" was translated as "rain" therefore rainwater collection data was excluded for Ghana.

Discussion

The field data from all three countries reveal an interesting relationship between whether water supplies are located on- or off-plot and water quantity. Households with at-home water sources used significantly more water (10.9 ± 8.0 lpcd) compared to those needing to fetch water outside their house.

The differences in water use between sources were independent of distance. Counter-intuitively, respondents using household taps had a lower median water use (28.0 ± 9.1 lcpd) compared to households with yard taps (50.0 ± 14.3 lcpd). Households with in-house taps would be expected to use more water since it is more conveniently located within the home. This result could be due to the effect of the data from all three countries being pooled together in the analysis. A systematic under-reporting by households having a tap within the home compared to those having to go out to the yard to collect water could also be the reason for this result. Another possibility for the lower water use by household taps could be the sharing of water supplies with neighbours. Households would be more prone to collect water from their neighbour's yard tap than an interior household tap. Issues of reliability or supply problems could be another reason for the discrepancy.

The data on households collecting water off-plot from all three countries reveal no significant relationship between distance and water quantity. Few households within the sample travelled further than 1 km to their water source; of those who did, the vast majority were in South Africa. This would explain why a decrease in water use was not seen in the data since households were not walking far enough to see the effect. Factors affecting water quantity for households fetching water can range from weather patterns to issues of supply or personal preference. In this study, the volume of water collected per trip was verified through the measured mass of the filled water container, however the calculation of litres per capita per day (for households relying on off-plot sources) relied on self-reported data such as number of trips per day and the number of days per week that households collected water. The observation period was also limited to one water carrier on one water collection trip. Thus, some uncertainty is introduced by the unknown accuracy of these user self-reports.

Water use patterns were different between the three countries with the majority of bathing and laundry being done at the home in Ghana and South Africa while these activities more frequently occurred at source for Vietnamese households. Although the communities within the study were not nationally representative, the results demonstrate that the location of water-using activities can vary between places.

More households in South Africa and Vietnam used at least one alternative source compared to Ghanaian households who primarily used one water source (after separating out sachet water). An interesting finding was the high percentage of households in Ghana using sachet water. The household survey did not ask respondents why they used a different source than their primary source for some activities. Multiple water sources could be used due to issues with water system services, seasonal effects, cultural habits (location of bathing and laundry), taste for drinking water or simply due to user preference.

Conclusions from field studies

- There was statistically significantly higher water use by households with at-home supplies compared to those who use off-plot supplies.

- There was no relationship between distance to the water source (or collection time) and water quantity used for households relying on off-plot water supplies. Households in the study may not have been walking far enough to collect water to see this effect.

- If international policies aim to substantially increase the amount of water used by households, then simply bringing off-plot water supplies closer to users' homes may not provide sufficient improvement for households to raise their water quantities. Rather than aiming for improved water supplies to be within 30 minutes of the household, there should be a focus on at-home water sources, which has been shown here to increase water quantity by 10.9 lpcd.

- Data collection methods for household water use should take into account cultural behaviours and seek to account for all water used by the household, whether at home or at the source.

- Further research on water quantity and water use patterns employing more detailed observation methods could aid in developing more effective policies to increase water access for households.

3.3. Health benefits of at-house water supplies

3.3.1. Systematic review of the literature on health benefits of at-house water supplies

Research evidence indicates that decreased household distance to water source reduces risk and prevalence of diarrhoea, trachoma, and other water-washed diseases. Forty four studies were found that researched at-house water sources and their impacts on diarrhoea, trachoma, child growth, and other water-washed infections.

- Reductions in trachoma, helminth infections, and Hepatitis A were significantly correlated with the use of at-house water sources.
- Results varied on the impact of at-house water sources on household diarrhoea and growth outcomes.

3.3.2. Hygiene behaviours and at-house water supplies

Personal and domestic hygiene activities are critical for household health. Safe hygiene behaviour leads to many health gains, and improved water access may facilitate hygiene improvements through greater domestic water supply and water allocation for hygiene activities. Evidence from research literature indicates that safe hygiene practices increase with household proximity to water source, presenting significant benefits and opportunities for the health and well-being of household.

3.3.3. Fieldwork findings on impact of at-house supplies on skin and eye disease and diarrhoea

Analyses for health outcomes were done using generalised estimating equations (GEE) adjusted for age and sex and accounting for clustering at the household and country level. Where the outcome variable was binary we used negative binomial regression with a log link. Where the outcome variable was scalar we used linear regression models. No significant impact was found in our field work. (**Table 18**).

Table 18: Water predictors for skin disease, eye disease and diarrhoea in previous two weeks adjusted for age and sex

Health outcomes	**Predictors**	**N**	**RR**	**L95%CI**	**U95%CI**	**P**
Skin disease	At home water source	2880	1.129	0.770	1.656	0.534
	Any water fetched from out of home	2882	1.027	0.696	1.515	0.895
	Estimated time to source/min	2215	0.977	0.941	1.015	0.231
	Estimated water used/p/d	2431	0.999	0.995	1.003	0.602
	Measured round trip distance/m	1476	0.998	0.997	0.999	0.003
	Measured round trip time/min	1532	0.949	0.904	0.996	0.032
Eye disease	At home water source	2879	1.076	0.820	1.411	0.597
	Any water fetched from out of home	2881	1.073	1.361	2.250	0.647
	Estimated time to source/min	2215	0.983	0.960	1.007	0.168
	Estimated water used/p/d	2430	0.999	0.996	1.002	0.453
	Measured round trip distance/m	1476	1.000	0.999	1.000	0.251
	Measured round trip time/min	1532	0.997	0.969	1.026	0.845
Diarrhoea	At home water source	2858	0.732	0.487	1.102	0.135
	Any water fetched from out of home	2860	1.479	0.854	2.561	0.162
	Estimated time to source/min	2197	0.998	0.971	1.026	0.909
	Estimated water used/p/d	2411	0.999	0.994	1.004	0.578
	Measured round trip distance/m	1464	1.000	0.999	1.001	0.559

Measured round trip time/min	1518	1.006	0.972	1.040	0.748

3.4. Musculoskeletal and general health impacts of carrying water

3.4.1. Literature review

Six studies met the inclusion criteria. Several studies focussed on descriptive statistics related to water carrying and access (Hemson, 2007, Geere et al., 2010a, Thompson et al., 2000); two were qualitative research reports, one on children's health perceptions (Geere et al., 2010b) and the other on gender issues (Sultana, 2009); and a final paper reported pain and rating of perceived exertion of head loading in a laboratory setting (Lloyd et al., 2010).

A common conclusion of all studies was that water carrying can impact on general health and pain, but that further research is required. No large scale epidemiological studies were found which had used an appropriate study design to scientifically analyse the association between water carrying or related risk factors and physical health outcomes such as self-report of pain, physical functioning or disability.

3.4.2. Findings from the field study

In South Africa and Ghana, substantial numbers of adults (SA 36.9%; GH 61.9%) and children (SA 19.2%; GH 43.4%) with at-house supply who were asked questions about general health, pain and disability, categorised themselves as currently carrying water. Whilst proportionately more women and children with off-plot supply in Ghana carried water by head loading, a considerable proportion of women and children with at- house supply also did so. A larger proportion of people with at-house supply in South Africa carried water by head loading compared to those with off-plot supply, as 42.4% of respondents with off-plot supply used a wheelbarrow to transport water (figure 1). In all countries, substantial numbers of women with at-house supply had previously carried water (SA 56.3%; GH 21.6%; V 26.8%). The mean number of years in which they had engaged with water carrying were 25.4 (sd19.4) for South Africa, 19.7 (sd14.5) for Ghana and 7.1 (sd10.2) for Vietnam.

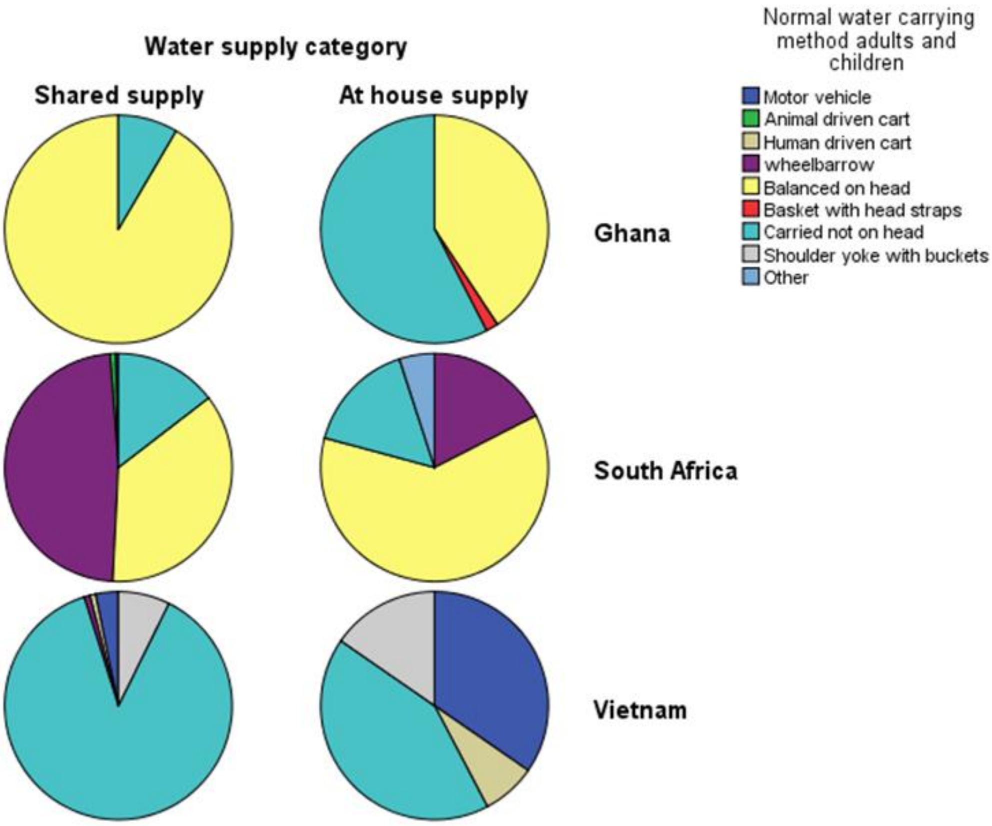


Figure 1 Water carriage method by supply type and country

Pain

Overall, comparing people with at-house versus off-plot supply within countries, there was no significant difference in reporting of pain experienced in the previous seven days. Irrespective of at-house or off-plot supply categorisation in South Africa proportionately fewer adults and children reported feeling pain in the previous seven days (SA adults 36.1%; children 4.6%) than in Ghana (adults 57.3%; children 18%) or Vietnam (adults 54.3%; children 21.7%).

Analyses of pain reported in the previous 7 days, pain location and self-rating of general health were done using Generalised estimating equations (GEE) adjusted for age and sex and accounting for clustering at the household and country level. Where the outcome variable was binary we used negative binomial regression with a log link. Where the outcome variable was scalar we used linear regression models. Personal history of carrying water (current, previous, or no history) was used as the predictor variable, as the descriptive statistics indicate that categorisation into at-house or shared supply does not distinguish between people with different levels of exposure to water carrying work.

Report of pain in the hands and upper back were statistically significant, whilst report of pain in the shoulders/arms, head, chest/ribs and abdominal area were close to statistically significant, with increasing relative risk for pain in these locations in people who previously and currently carry water (**Table 19**).

Table 19 Relative risk of pain location from personal history of water carriage

Pain location	Predictor variable	N	RR	LCI (95%)	UCI (95%)	p
Abdominal pain	No history of water carriage	364	1			0.082
	Previous history of water carriage	159	1.43	0.76	2.69	

	Currently carries water	474	1.70	1.07	2.69	
Chest/rib pain	No history of water carriage	364	1			0.054
	Previous history of water carriage	159	1.60	0.71	3.60	
	Currently carries water	474	2.13	1.14	4.00	
Feet	No history of water carriage	364	1			0.394
	Previous history of water carriage	159	1.70	0.74	3.91	
	Currently carries water	474	1.55	0.77	3.13	
Hands	No history of water carriage	364	1			0.020
	Previous history of water carriage	159	3.62	1.34	9.75	
	Currently carries water	474	3.11	1.34	7.23	
Head	No history of water carriage	364	1			0.071
	Previous history of water carriage	159	1.16	0.67	2.02	
	Currently carries water	474	1.53	1.03	2.27	
Hips/pelvis/legs	No history of water carriage	364	1			0.373
	Previous history of water carriage	159	1.13	0.74	1.72	
	Currently carries water	474	0.85	0.61	1.20	
Lower back	No history of water carriage	364	1			0.828
	Previous history of water carriage	159	0.86	0.53	1.40	
	Currently carries water	474	0.96	0.68	1.38	
Neck	No history of water carriage	364	1			0.512
	Previous history of water carriage	159	1.26	0.74	2.16	
	Currently carries water	474	0.95	0.62	1.45	
Shoulders/arms	No history of water carriage	364	1			0.053
	Previous history of water carriage	159	0.91	0.52	1.60	
	Currently carries water	474	0.59	0.38	0.92	
Upper back	No history of water carriage	364	1			0.017
	Previous history of water carriage	159	2.27	1.17	4.40	
	Currently carries water	474	2.16	1.25	3.73	

Because reporting of pain at different sites was correlated, we undertook a factor analysis of the different pain location variables. It can be seen that factor 1 is correlated to pain in the chest/ribs, hands, feet, abdomen/stomach, head and upper back, whilst factor 2 is correlated with pain in the neck, shoulders/arms, lower back and hips/pelvis or legs (**Table 20**).

Table 20 Factor Analysis of self-reported pain locations

Pain location	Factor 1: axial compression (correlation)	Factor 2: soft tissue strain (correlation)
Abdomen/stomach	.632	.131
Chest/ribs	.706	.151
Feet	.695	.221

Hands	.706	.266
Head	.616	.272
Hips/pelvis or legs	.179	.757
Lower back	.223	.750
Neck	.340	.697
Shoulders/arms	.238	.790
Upper back	.608	.347

Notes: Extraction Method: Principal components; rotation: Equamax. Variance explained: *54.8* %

GEE with linear regression was then repeated for each factor and adjusted for age and sex. Factor 1 is highly associated with currently or previously carrying water but factor 2 is marginally significantly negatively associated. There is biological plausibility in both the correlation of pain areas in each factor and the associations with water carrying. Sustained compressive loading through the neck and upper back, as occurs with carrying water filled buckets on the head, is a plausible mechanism by which intervertebral discs of the cervical and upper thoracic spine may be adversely affected over time, or deformed during loading to compress and irritate other structures (Geere et al. (2010b)) and to cause the correlation of pain locations in factor 1. The pain from cervical degenerative disc disease tends to be in the posterior paraspinal muscles and is associated with headache and inter-scapular (upper back) pain. If degenerative disc disease in the cervical spine (cervical spondylosis) progresses, it can reduce space within the spinal canal to cause irritation or compression the neural tissues (myelopathy or radiculopathy) or their connective tissue coverings. For example early myelopathy due to spinal canal stenosis may mimic carpal tunnel syndrome, causing hand pain or dysaesthesia through dural irritation or neural tissue compression and eventually dysaesthesia in the feet and gait disturbance Clark (1996).

The correlation of pain locations in factor 2 (**Table 22**), are more typical of simple non-specific musculoskeletal pain due to muscle or joint strain. Neck pain is commonly associated with referred shoulder or arm pain and back pain is commonly associated with pain in the lower quarter (hip/pelvis or legs). Non-specific spinal pain can be improved through remaining fit and active with regular physical activity, such as would occur by regularly walking to a shared water source.

Table 6 Linear regression analysis of personal history of water carriage on Factor 1 (axial compression) and Factor 2 (soft tissue strain)

Factor correlated pain locations	Predictor variable	N	B	LCI (95%)	UCI (95%)	p
Factor 1 'Axial compression'	No history of water carriage	364	0			0.000045
	Previous history of water carriage	159	0.21	0.01	0.42	
	Currently carries water	474	0.30	0.17	0.43	
	Currently carries water – no head loading	214	0			0.034
	Currently carries water – head loading	260	0.36	0.03	0.70	
Factor 2 'Soft tissue strain'	No history of water carriage	364	0			0.023
	Previous history of water carriage	159	-0.03	-0.25	0.19	
	Currently carries water	474	-0.18	-0.32	-0.04	
	Currently carries water – no head loading	214	0			0.64
	Currently carries water – head loading	260	-0.07	-0.35	0.22	

A statistically significant relative risk of better ratings of general health in those who previously or currently carry water was found (**Table 20**). This may indicate some general health benefits of water carrying, such as better heart fitness linked to being more physically active, or a greater sense of wellbeing linked to the positive social contribution or interactions associated with water carrying. It could also be because the healthier people in a household are given the job of collecting water. Such positive health benefits were reported in previous qualitative research conducted with people who carry water (Geere et al. (2010a)).

Table 8 Impact of personal history of water carriage rating of general health

General Health	Predictor variable	N	β	LCI (95%)	UCI (95%)	p
Rating of general health today (adults)	No history of water carriage	123	0			<0.000001
	Previous history of water carriage	143	-0.58	-0.80	-0.35	
	Currently carries water	325	-0.91	-1.12	-0.70	
Rating of general health today (children)	No history of water carriage	204	0			0.003
	Previous history of water carriage	10	0.39	0.02	0.75	
	Currently carries water	128	-0.20	-0.37	-0.31	

3.5. Water Quality

3.5.1. General

Water quality and its relationship to source types, distance to source and storage practices was not part of the terms of reference for this study. However, the team was able to make use of additional funding from another source to take advantage of the fieldwork being undertaken in three countries and to add additional texture to our study. We are also able to report on the findings of a review of literature undertaken by UNC with support from WaterAid.

3.5.2. Literature review

A forthcoming review concluded that improved sources had significantly lower E. coli concentrations than unimproved sources Bain et al. (2013). The literature also supposed a view that, despite being less contaminated than unimproved sources, a significant percentage of improved sources fall within higher health-based risk categories. The heterogeneity of source water quality for sources of all types supports the argument that a hierarchical “water ladder” may tend to oversimplify a complicated water safety landscape (Idem).

A few studies directly comparing water quality from water supplies on premises with those off premises were identified. These found that contamination can be more common among community sources. For example, in urban Nigeria, Ejechi and Ejechi (2008) found 18% of public water sources to be contaminated whereas 6% of private boreholes contained thermotolerant coliform (n=100 for both source types). Similarly, Genthe et al. (1996) found contamination in community standpipes whereas in house taps were free of thermotolerant coliform in a South African township (n= 153 and 24 respectively). Zuin et al. (2011) did not find significantly more frequent E. coli contamination in community taps than in-house taps in peri-urban area of Maputo, potentially due to the small sample sizes (62 and 27)

3.5.3. Results from the field

Samples were analyzed using the Aquatest method, described in detail on the Aquatest Programme website (Bristol, 2013).

Stored water and source water

When the pooled multi-country data were analysed, it was found that stored water contained significantly ($p<0.05$) higher *E. coli* concentrations than source water (**Table 23**, **Figure 4**). Mean stored water concentrations were 25.2 (95% CI 18-32) CFU/100 mL; while mean stored water concentrations were 62.8 (95% CI 53 - 73) CFU/100 mL (**Table 23**). A higher percentage of stored water samples contained concentrations of *E. coli* in excess of 100 CFU/100 mL (**Figure 4**). Interestingly, both source and stored water samples with turbidities > 1 NTU tended to have higher *E. coli* concentrations (turbidity data were available for Ghana only). These effects were significant at the 90% and 95% confidence levels for source and stored water samples, respectively.

Table 19: *E. coli* concentrations in source and stored water from on-plot and off-plot sources

Source Access	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
On-plot	24.32 (61.57) [14.33 - 34.33]	62.52 (88.87) [44.42 - 80.63]
Off-plot	25.99 (65.65) [15.47 - 36.51]	62.94 (89.27) [50.97 - 74.92]
Total	25.17 (63.57) [17.95 - 32.39]	62.82 (89.01) [52.88 - 72.75]
P	0.8213	0.9698

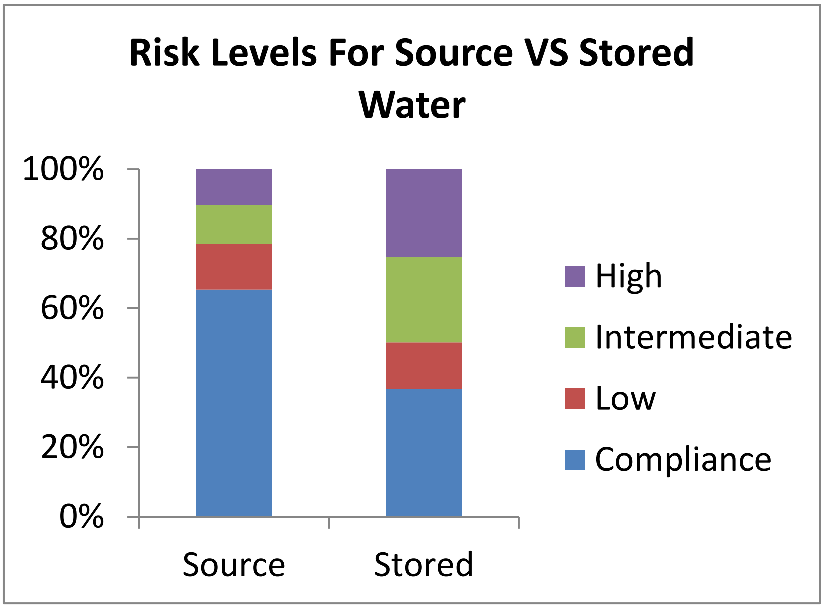


Figure 4: Health-based risk categories of source and stored water samples

Source categories

E. coli concentrations in source water from on-plot sources were not found to be significantly different from those in water from off-plot sources (**Table 23**). However, source water from improved sources was found to have significantly lower *E. coli* concentrations ($p<0.05$) than water from unimproved sources; interestingly, stored water from improved sources also had significantly less *E. coli* ($p<0.05$) than stored water from unimproved sources (**Table 24**). Similarly, it was found that source and stored water from on-plot improved sources had significantly lower *E. coli* concentrations ($p<0.05$) than source and stored water, respectively, for other sources (**Table 25**). Finally, source water samples from household taps was found to contain lower *E. coli* concentrations ($p<0.05$) than water from other sources (**Table 26**, **Figure 5**); differences for stored water were not significant.

Table 20: *E. coli* concentrations in source and stored water from improved and unimproved sources

Source Type	Source CFU/100 mL	Stored CFU/100 mL

	(S.D.) [95% CI]	(S.D.) [95% CI]
Improved	12.27 (45.61) [6.53 - 18.01]	55.44 (85.81) [44.80 - 66.09]
Unimproved	82.61 (94.12) [57.17 - 108.06]	94.31 (96.08) [69.27 - 119.35]
P	0.0000	0.0024

Table 21: *E. coli* concentrations in source and stored water from on-plot improved sources and all other sources.

Source Access	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
On-plot Improved	8.62 (39.06) [1.53 - 15.71]	37.31 (71.52) [19.86 - 54.75]
Other	36.05 (73.56) [25.26 - 46.84]	69.82 (92.14) [58.20 - 81.44]
P	0.0002	0.0079

Table 22: *E. coli* concentrations in source and stored water from on-plot piped sources and all other sources.

Source Type	Source CFU/100 mL (S.D.) [95% CI]	Stored CFU/100 mL (S.D.) [95% CI]
At-home piped water	0.31 (0.82) [0.01 - 0.61]	31.44 (89.51) [53.89 - 74.26]
All other sources	28.04 (66.55) [20.05 - 36.02]	61.07 (71.45) [-13.96 - 76.84]
P	0.0212	0.2136

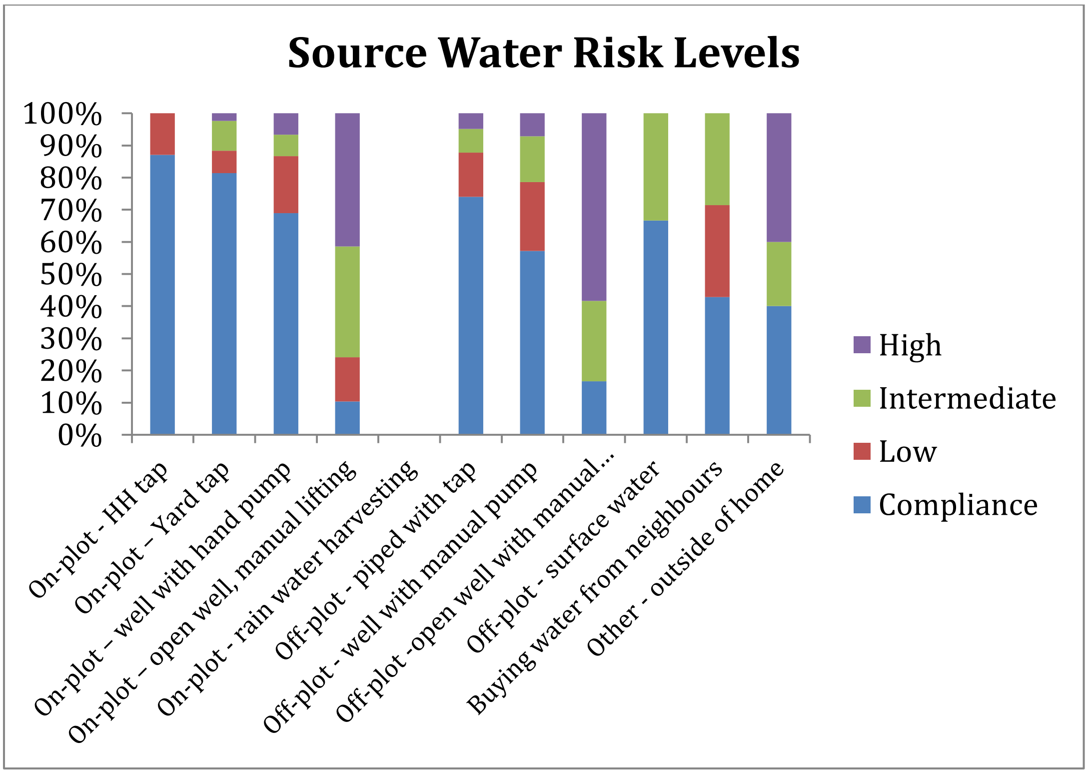


Figure 5: Health-based risk categories of *E. coli* concentrations for source and stored water from various sources.

Individual source types

A pairwise comparison of all source types showed significant differences between several different types of sources. Most notably, source water from open wells, both on-plot and off-plot, was significantly ($p<0.05$) more contaminated than water from all on-plot improved sources, as well as off-plot piped water and water purchased from neighbors (generally also piped) (**Table 27, Figure 5**). No significant differences in water quality were observed between samples of stored water from different sources (**Table 27, Figure 5**).

Table 23: *E. coli* concentrations in source and stored water from various sources

Source Type	Source Group CFU/100 mL (S.D.)	Stored Group CFU/100 mL (S.D.)
On-plot - HH tap	A 0.31 (0.82)	A 31.44 (71.45)
On-plot – Yard tap	AB 6.81 (35.19)	A 39.00 (74.77)
On-plot – well with hand pump	AB 16.08 (52.92)	A 2.23 (4.40)
On-plot – open well, manual lifting	CD 88.78 (90.10)	A 122.87 (98.16)
On-plot - rain water harvesting	. .	A 114.5 (64.35)
Off-plot - piped with tap	AB 15.69 (51.43)	A 54.92 (85.80)
Off-plot - well with manual pump	ABC 23.19 (61.72)	A 44.81 (74.51)
Off-plot -open well with manual lifting	D 137.04 (102.44)	A 93.79 (96.35)
Off-plot - surface water	ABC 17 (29.44)	A 127.82 (100.65)
Buying water from neighbors	AB 5.4 (8.29)	A 29.49 (75.57)
Other - outside of home	BCD 88.2 (102.72)	A 25.46 (59.44)

(Vertical groups sharing a letter are not significantly different at the 95% confidence level.)

Distance and time to source

There were no significant effects of distance or time to source on *E. coli* concentrations in source or stored water. Specifically, across log distance quintiles and log time quintiles, *E. coli* concentrations were not significantly different at the 95% confidence interval (**Table 28, Table 29**).

Table 24: Log travel time to source and water quality

log time quintile	Stored Group CFU/100 mL (S.D.)
1	A 68.04 (95.46)
2	A 67.25 (89.00)
3	A 67.85 (88.23)
4	A 51.98 (87.32)
5	A 49.74 (79.60)
Kruskal-Wallis p	0.662

Table 25: Log distance and water quality

log dist quintile	Stored Group CFU/100 mL (S.D.)
1	A 74.57843 (96.11415)
2	A 68.52069 (96.44541)
3	A 56.8 (87.10228)
4	A 47.32131 (73.64256)
5	A 36.45185 (73.61668)
Kruskal-Wallis p	0.3605

Health impacts

When the cross-sectional prevalence of skin infections, eye infections, and diarrhoea, as well as missed days of school or work were compared across water quality categories (by presence/absence of *E. coli*), only one significant effect was observed; detectable *E. coli* in source water samples was found to be associated with someone in the household missing school or work due to illness.

Country-specific Results

In both Ghana and South Africa, as in the multicountry analysis, stored water was significantly more contaminated than source water, while differences in *E. coli* concentrations between on-plot and off-plot sources were not significant. Source water samples from household piped sources were significantly less contaminated than samples from all other sources, while there was no significant difference among stored water samples. In Ghana, both stored and source water from improved sources was significantly less contaminated than stored and source water, respectively, from unimproved sources. Comparisons between improved and unimproved sources were not possible for South Africa, as only 5% of samples were collected from unimproved sources. Finally, in Ghana, source water from all sources except on-plot open wells with manual lifting was found to be significantly less contaminated ($p<0.05$) than source water from off-plot open wells with manual lifting. In South Africa, the only significant difference observed was that source water from at-home taps was significantly less contaminated ($p<0.05$) than samples from sources classified as “Other”—primarily tanker trucks. There were no significant differences among stored water samples in either Ghana or South Africa.

Conclusions

The results of this work suggest that on-plot improved water supplies in general, and household piped water connections in particular, result in lower rates of *E. coli* contamination than other sources, particularly unimproved sources such as open wells, both with respect to source water and stored water.

3.6. Social benefits of at-house supplies

The field research generated information about what activities were carried out by household water carriers and former household water carriers over a 24 hour period. The activities described were then clustered as follows:

- Social activities: Drink and Eat, Religious and spiritual activities, Spending time with other people, “Phone calls, letters, emails, internet, video games”, Playing, Playing sports, and Visits / meeting
- Personal hygiene: Dressing, getting ready, Bathing and Going to the toilet
- Domestic: Washing (dishes and / or clothes), Preparing to eat, Other domestic activities, Purchases (at the market, etc.), Taking care of other members of the household
- Employed work: Work and activities related to work (going to work, finding a job etc) and Professional training
- Inactivity: Sleep, Resting, Watching television

When we looked at the predictors of these activities the only significant association was between carrying water and ‘inactivity’. People who collect water had about 40 minutes less inactivity time than those who did not. The finding that reduced time carrying water is not significantly correlated with increased economic activity supports similar recent findings. However there is a case to be made for the benefits of increased ‘rest’ time which may also be in part time spent with the family and time spent by parents with children in non-work activities. Children who can spend more time with their parents may have improved opportunities for learning and this may have knock-on effects in their adult lives. This intergenerational impact of reduced time for children or parents spent collecting water merits further investigation.

4. Discussion

We carried out a mix of secondary and primary research to examine the hypothesis that "access to an at-house water supply will deliver significantly greater health, social and economic benefits than those derived from a shared public water supply."

The relationship between water source, water usage and health and social outcomes is complex and mitigated by range of contextual and intermediate factors. A recent review of global data sets for example suggests that time spent walking to the household's main water source was a strong determinant of under-five child health ((Pickering and Davis, 2012). However a review of this analysis suggests that alternative interpretations would be possible if the data were to be adjusted for other water- and sanitation-related variables or for a broader set of determinants of these multiple child health outcomes. In general it is likely that households experience a clustering of risk factors so that simply looking at water fetching time in the analysis without adjusting for type of water source, type of sanitation facility, type of cooking fuel masks specific effects and the outcome is more likely to be a measure of general "environmental deprivation" rather than the specific effect of water fetching time. A fundamental challenge in comparing outcomes of at-house supplies with shared supplies lies with wealth as confounder. In our analysis we were able to tease out wealth effects to some extend because of the detailed household information we were able to collect. Nonetheless these challenges are significant.

In our research therefore we focused on a two-step approach, looking at the relationship between distance to source and volumes of water consumed followed by an analysis of volumes of water carried/ consumed and health and social outcomes including hygiene practices. In this way we hoped to reduce the effect of wealth and other broader social contextual factors in the analysis. This was supplemented by the analysis of the relationship between source-type and water quality.

From our field data a strong theme was the heterogeneity of water sources used by many households. This dimension of water usage is poorly researched and little understood. The diversity of multiple use strategies is much greater that has previously been identified. It is likely that the use of multiple sources of water for different activities is a significant confounder and one of the reasons why research into the relationships between health outcomes and use of specific water sources has been inconclusive.

We found a strong link between volumes of water consumption and the at-home/ off-plot break point in services but limited evidence of a distance/ volume relationship once households were using off-plot supplies. Similarly we found strong evidence of a 'break point' in health outcomes between those who currently carried water from outside the house compared to those who previously or had never carried water particularly relating to musculo-skeletal effects. Water quality was also significantly better for those with piped water at home that those who carried water from elsewhere and stored it at home. The evidence on social benefits was limited but points to possible advantages to families who do not have to spend time carrying water but can spend time in leisure activities.

Overall the results from our research indicate that evidence for the detailed 'Bradley' curve is tenuous. The conclusion that at-house supplies are associated with higher consumption and health and social benefits is supported but there is no evidence for the secondary drop in consumption at a fixed distance from home. In reality it seems most likely that the relationship between distance to source and volumes of consumption is likely to be highly mediated by social and geographical factors, with the curve likely to be 'displaced' upwards or downwards in different contexts.

5. Conclusion

The headline conclusion from our research is that at-home water supply has significant, measurable benefits when compared with shared water supply outside the home. It results in higher volumes of water consumption, greater practice of key hygiene behaviours, improved water quality and has great potential to reduce adverse impacts on musculoskeletal tissues associated with carrying water from outside the home..

The strong evidence that household access is better than shared can be compared with the weaker evidence that access to shared supplies is better than access to ‘unimproved’ supplies. This suggests a logical policy shift towards the promotion of household access as the international benchmark for water supply.

For many governments, the implications of this are relatively simple. Where most people have access to reasonable quantities of water close to the home, there is a strong and compelling argument to focus investment in getting piped water supplies into the home. In such cases, the outstanding challenges relate to improving our understanding of the relative risks associated with dimensions of levels of service. For example, under what circumstances does a tap in the house have significant benefits over a tap in the yard? What is the relative risk associated with intermittent supply or low pressure of at-house piped supplies compared with shared supplies if the latter can provide a more reliable service? A pressing gap in the literature relates to the water resources and cost implications of providing 24 hour supply in piped systems.

For some countries however, the challenge of moving to household supply as the benchmark level of service is more significant and will take time. In these locations (typically arid regions with limited water resources and limited access to capital funds) the policy emphasis may change more slowly, but the clear message is that developments should be designed to enable a progressive move towards provision of household supplies in the end rather than aiming for ‘intermediate’ levels of access as the ultimate goal.

In the post-2015 era, the available evidence suggests that access to water supply at-home should be the benchmark for water supply.

Appendix A: Field work report: Ghana

Study Area and Communities

Four communities (Table A-1) near Kumasi in the Ashanti region of Ghana were included in the DFID field study. All four communities were centred around a main road, stretching out densely along the road and less densely outward from the road on either side.

Table A-1. Ghana study community characteristics.

Town Name	Density	Population 2012	No. of registered users (GWC)	No. of HHs in Survey
Nkawie (a town)	Urban	9, 054	528	67
Asuofua (a town)	Peri-urban	8, 373	132	61
Barekese (a town)	Peri-urban	10, 544	---	63
Abuakwa (a small city)	Urban	23, 634	---	64
Total				255

Household Characteristics

The definition of "household" in the Ghanaian context is also distinct from the definitions applicable in other countries. Households in the study communities lived almost exclusively in compounds comprised of 3-6 nuclear family units living in adjacent rooms that formed a larger structure with a shared courtyard. These family units were often but not always biologically related to each other. Enumerators were trained to collect data from a single family unit within each compound to avoid confusion. For the purpose of this study, a single water source used exclusively by the households within a single compound was classified as a private source. Since only one household was interviewed in each compound, respondents with private sources were asked to report the total number of individuals sharing the source. If a water bill was available for that source, the previous month's consumption was divided by the total number of users reported to calculate the average per-capita consumption.

In addition, it was observed during training that Ghanaians often use the words for "sister" and "brother" figuratively for close friends and familiar cousins, and often use "husband" and "wife" figuratively to refer to their husband's brothers or their wife's sisters. Thus, enumerators were instructed to clarify the actual biological relationships among household members when administrating questionnaires.

Water Points and Water Collection

Some households in the study area were served by private connections provided and maintained by the Ghana Water Company Limited (GWCL, responsible for water supply in urban areas and some small towns in Ghana), while others used public water sources, largely provided by local government (District Assemblies), with support from the Community Water and Sanitation Agency (CWSA). Other households used private boreholes and piped sources that may have been installed by local government or by the users, and some used hand-dug wells, presumably installed by the users. Households included in the study that were serviced by GWCL were asked to share their previous month's water bill, and the previous month's water usage was recorded. Consumption by non-GWCL users was estimated based on observed container volume and self-reported collection frequency. All four communities contained a mixture of private and public supplies shown in Table A-2.

Table A-2. Primary water sources used by households in study communities.

	Number of Households				
	Nkawie	Asuofua	Barekese	Abuakwa	Total (%)
Household tap	2	2	1	3	8 (3%)
Yard tap	6	15	21	15	57 (22%)
Private well, motorized pump	0	0	0	4	4 (2%)
Private well, manual lift	16	5	7	8	36 (14%)
Total Private Sources	24 (36%)	22 (36%)	29 (46%)	30 (47%)	105 (41%)
Communal tap	22	36	30	24	112 (44%)
Communal covered well, manual lift	8	0	3	9	20 (8%)
Communal open well, manual lift	13	3	1	1	18 (7%)
Total Public Sources	43 (64%)	39 (64%)	34 (54%)	34 (53%)	150 (59%)

No households reported using rainwater for drinking and domestic purposes. A mistranslation in the survey questionnaire resulted in “rainwater collection” bring translated as simply “rain” in the local language, but field observations of the communities did not reveal evidence of any households using rainwater collection methods of any kind.

A substantial number of respondents also reported obtaining drinking water in the form of “sachets,” or 500-mL plastic water bags produced by commercial manufacturers and sold in most shops and by ubiquitous street vendors for 0.10 GHS (equivalent to USD $0.05). While these were not the primary source of water for domestic purposes, they provided a convenient and readily accessible drinking water source.

Household interviews also revealed the sharing of some private supplies amongst households, creating an added level of complexity in determining ownership of and access to water supplies. In cases where a respondent used a neighbours’ “private” source (usually for a fee comparable to that for public sources), that respondent was considered to be fetching water from a public supply. In cases where a respondent shared their own “private” source with neighbours, however, the respondent was considered to be accessing her own private supply when she fetched water. These decisions were made based on the relative proximity, access, and control users had to their own “private” source vs. their neighbours’ source. The notion of “public” and “private” sources was further complicated in a small minority of households, where respondents with water sources on their properties reported that the government had given them “private” supplies to be used by their communities.

Some respondents were also unsure as to the type of primary drinking water source they used, as they hired other women in the community to fetch water for them. These respondents were similarly unable to show enumerators where they fetched the water, preventing measurement of the distance travelled and time spent fetching water. This finding was of interest, as delivery of water from public sources by others had not been considered in the study design. This mode of water collection is unique because the physical and time burden of water collection shifts from the household to an outside water carrier. A properly controlled comparison of domestic and professional water carriers in relation to musculoskeletal outcomes could be of interest with respect to the health impacts of water carriage.

Most respondents reported paying to access water. Users of public and shared private sources typically paid a small fee to fetch water, typically ranging from GHS 0.05 (USD $0.025) to GHS

0.10 (USD $0.05) per trip, with users typically being allowed to fetch 20-60 L of water per trip. Users fetched water in a large variety of containers, but the most commonly used vessels were 20, 30, or 40-L round plastic or metal basins, followed by 20-L jerricans and 15 or 20-L buckets. Most adult water carriers were observed to fetch between 15 and 40 L per trip, while most children fetched 10-30 L. Professional water carriers typically fetched 40-60 L per trip in large basins. Most users transported water by balancing one container on their head, cushioned by a ring of folded cloth. Users fetching water from a well with a manual pump or manual lifting would fill a container, then lift it onto their head, usually with the help of another user waiting to collect water. Where piped water was available from public standpipes, community members often modified these standpipes with an additional length of pipe, so that water could be dispensed from the original faucet to fill a narrow-mouthed jerrican on the ground, or from the extension pipe, at a height of approximately 2 m, allowing the user to fill a basin or bucket while it was balanced on the head.

Wealth Data

In Ghana, it was observed that many households reported extremely low or non-existent incomes when asked directly about their earnings, in contrast with significant water costs and the ownership of mobile phones, etc. Anecdotally, one Ghanaian colleague mentioned that rural Ghanaians are often very circumspect about their finances, and will frequently under-report income and possessions to avoid provoking envy or discomfort among their neighbours. Thus, it is possible that the apparent disparity between reported incomes and consumption patterns may be related to this cultural bias.

Appendix B: Fieldwork report – Vietnam

Study area and communities

Four villages in the province of Lao Cai were included in the field study. The villages are in a remote rural area close to the border with China in the north of Vietnam. The area is mountainous and experiences a cold dry season from October to April and a tropical monsoon season from April to September. The province is one of the poorest in the country, with an estimated expenditure and income poverty incidence of 54% (REF).

Four communities were included in the study (**Table B-1**)

Table B-1: Vietnam study community characteristics

	Number of households	Number of HHs in the survey
Trạm Thải	72	50
Lắp máy	67	43
Phân Lân	68	55
Láo Lý	57	51

Sampling of households was hampered by the fact that available local records, provided by the district health posts, were unreliable. Local village leaders felt that more than half the data provided by the district was out of date or otherwise inaccurate. Sampling in any community therefore had to be based on a revised household list prepared in consultation with local leaders.

Láo Lý was reportedly a much poorer environment than the other three communities, with evidence of widespread open defecation and indiscriminate solid waste dumping. The quality of housing was reportedly poorer, with more common use of low cost materials such as masonry breeze blocks or thatch rather than bricks and tiles. The other three communities were reportedly clean with only minor evidence of littering.

Household characteristics

The average household size was 4.1 and the maximum number of people in any study household was 11. The area is highly ethnically diverse, with at least five ethnic groups represented in the survey. These were Day, Tay, Dao, Mong and Kinh. The Kinh group are reportedly the 'senior' community and generally live lower down the mountainside with other groups higher up.

Water use

Most of the study area has been provided with gravity piped water supply systems through the Government of Vietnam's 'Programme 135'. These systems generally draw water from springs or streams higher up the mountain and deliver it to individual households. The water is often stored in a concrete tank in the house or yard. Households widely reported that this water is 'not clean' or 'not enough'. During the rainy season the water is reportedly 'dirty' and this was confirmed by our enumerators who observed high rates of suspended solids in the gravity scheme water. An inspection of the source for some of these schemes confirmed that the protection of springs and surface sources is rudimentary. Many households who had connections to these systems supplemented their supply with shallow wells, 2-3m deep, located within the yard, and this was often reportedly preferred as a source of water for drinking and cooking. Unusually for Vietnam rainwater harvesting systems were not prevalent in the area; households reported that rainwater is scarce.

Most of the gravity piped supplies in the area have been installed relatively recently. In village Phân Lân a system was installed during the period of the research. Households appeared to have good knowledge of the location of the source. The sources were often fairly distant from the households and access was via steep narrow paths.

Overall 43.9% of the respondents reported piped water to the house or yard as their main source of supply, 25.8% reported a well as the main source and 19.2% a shared supply of surface water. The latter may include water piped into the house from a distant source. Overall 76.8% of households reported that their main supply was outside the house but this often referred to water from elsewhere that was piped into the house or yard. Since most households used multiple sources of water for different uses it was difficult for many households to say with confidence which was their 'main' supply.

31.3% of households reported carrying water from outside the home and this was usually carried manually but not on the head.

Piped water supply is supposedly metered although we were not able to confirm the presence of meters during the fieldwork. In focus group discussions the general impression was that there was a willingness to pay for piped water but that the quality and quantity of the water was inadequate. Households reported that in the new scheme in Phân Lân water would be free up to 3,000 l per month per household. It was observed by participants in focus group discussions that this amount was quite low, particularly for rural households with livestock.

In Phân Lân, Lắp máy and Trạm Thải water was reportedly boiled before drinking although not in Láo Lý. This result could not be confirmed during household interviews.

Appendix C: Fieldwork report - South Africa

The study was conducted over a period of 10 weeks (late September to early December, 2012) in three peri-urban communities in Vhembe District in the northern parts of Limpopo Province in South Africa. Three communities were selected from a sample frame of ten, that represented water service levels in the area (**Table C-1**).

Table C-1: Private and shared water supplies in the study communities

Community	Households with shared supply	Households with private supply	Total number of households
1	406	56	462
2	741	84	825
3	467	359	826

Communities 1 and 2 (C1 and C2) are located in the dry, flat area west of Makhado / Louis Trichardt town. The water sources in Communities 1 and 2 (C1 and C2) are communal taps or private drilled wells with either a yard tap or in-house connection. Community 3 (C3) is located in the foothills of the Soutpansberg mountain range. Shared water sources in the area are protected springs and communal taps, while private supplies are yard taps or in-house connections.

Although all three communities had problems reliability of water supply, the supplies C1 and C2 seemed to be particularly unreliable. Most of the households using communal taps as their main source reported their alternative source as buying from neighbours with private drilled wells, and a few more relied on a municipal tanker that delivered water to the area once a week.

Although the households in C1 and C2 bought water from neighbours with drilled wells, a common complaint was that the water from these wells was very salty. This is not surprising, as the two communities are located at the base of the Soutpansperg ("salt pan mountain") mountain range. Because the water was so salty, some households with private supplies reported using communal taps or a municipal tanker that delivered water once a week as alternative sources, mainly for their drinking water.

Thus the 'private' supplies in C1 and C2 were private in the sense that they were wholly managed by the households themselves. By drilling their own wells and setting up yard or house connections and in some cases subsequently selling water to their neighbours, these households performed the role 'service' roles of abstraction and distribution roles themselves.

The relatively wealthier households in C3 did not drill wells, but paid for a municipal connection to the yard / house, or privately connected pipes from the protected springs in the area to the yard / house. Some households with municipal connections still collected drinking water from springs, as they preferred the taste of the water from there. During water supply failures, households using communal taps collected water from either the nearest springs, or from neighbours with connections from the spring. Unlike in C1 and C2, water collected from neighbours in C3 was obtained for free.

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