# Understanding and promoting walking for transport in adults

**by**

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# Abstract

**Background**

The benefits of physical activity for physical and mental health and well-being are well evidenced. Despite this, a substantial proportion of the adult population in England do not meet current recommended guidelines for physical activity leading to a significant burden on individuals, health services and the economy. Strategies are needed which lead to sustainable increases in physical activity at the population level. Walking is a free and accessible behaviour which is acceptable to most people and can be incorporated into everyday activities. Walking for transport is a type of walking which is undertaken specifically to travel from one point to another to reach a destination. Gaining an understanding of behavioural and contextual influences on walking for transport is important to facilitate specificity in designing effective interventions. Evaluating both the implementation and effectiveness of interventions to promote walking for transport in real-world settings may help to improve interventions and determine how they can be implemented at scale to impact population levels of physical activity.

The research in this thesis aimed to contribute to the evidence base relating to understanding the factors influencing and the promotion of walking for transport in adults to address the problem of how to increase population levels of physical activity to improve health and well-being. Eight research articles are presented which used data collected as part of three research projects: Impact of COnstructing Non-motorised Networks and Evaluating Changes in Travel (iConnect), Walking Works and Fitter for Walking.

**Results**

The Transport and Physical Activity Questionnaire (TPAQ) was developed and its measurement properties for assessing different domains of physical activity were tested. It was found to be suitable for use in comprehensively assessing transport and physical activity behaviour with comparable reliability and validity to other similar measures. A new 13-item scale was developed to assess adults' perceptions of the environment in the neighbourhood (PENS) in the UK context. This was found to have comparable reliability to other similar scales.

Using PENS and TPAQ, walking for transport was found to be positively associated with perceptions of supportive infrastructure, availability of local amenities, and general environment quality in the residential neighbourhood. Walking to and from work was found to be positively associated with the perceived presence of convenient walking routes, suitable pavements, maintained pavements or

convenient public transport in the workplace neighbourhood. Walking to and from work was also positively associated with employees who were aged <30 years, did not have a car, had no free car parking at work, were confident of including some walking or intended to walk to or from work on a regular basis, and had support from colleagues for walking. It was negatively associated with employees' perceptions that they lived too far away from work to walk, walking was less convenient than using a car for commuting, they did not have time to walk, they needed a car for work, or they had always travelled the same way.

In a community-based intervention to promote walking for transport, a wide variety of small-scale environmental changes were made which were led by local authorities (e.g. removal of encroaching vegetation, new/improved pedestrian signage, new dropped kerbs/kerb improvements, and new, repaired or improved footpaths) or by communities (e.g. planting bulbs, shrubs or bedding plants, clean-up days and litter pick-ups). Additional activities were undertaken to help increase awareness of the benefits of walking and promote the newly improved routes (e.g. led walks, themed walks, development of maps/resources and community events). After 12 months, there was a decrease in pedestrian route use overall and in four out of the five case studies where data collection took place. However, after 14-20 months there was an increase in pedestrian route use overall and in all case studies. Participants in the intervention perceived the main impacts to be improved physical and social environments. Implementing the intervention was found to be complex and required considerable resource and time. Processes required for implementation of the intervention were identified which included planning, preparation and delivery phases. Adaptability of the intervention to fit the local context was highlighted as being critical for successful programme delivery.

In a whole-workplace walking to work intervention, no changes in walking behaviour were observed which may have resulted from barriers in using volunteer employee walking champions to deliver activities, the programme components not being delivered as originally intended, the types of activities which were delivered, and lack of awareness and participation by employees.

**Conclusions**

A range of factors operating at different levels which influence walking for transport behaviour in adults were identified, confirming the need for specificity in studying both the behaviour and the contexts in which the behaviour is undertaken. Evidence is provided of the barriers and facilitators for implementing community-based and workplace interventions which aim to promote the behaviour. These should be addressed to maximise the effectiveness of interventions. Researchers,

practitioners and policy-makers should take these research findings into consideration in the future design, planning and implementation of co-produced, multi-level interventions which aim to promote walking for transport. Future research should identify causal factors influencing walking for transport, improve intervention content and optimise intervention implementation. Researchers should address methodological limitations of work in this area, including the application of more rigorous study designs and the use of more reliable and valid measures of walking for transport and overall physical activity. Together this will maximise the potential impact of walking for transport interventions for promoting physical activity and improving health and well-being at the population level.

***Key words:*** walking for transport; physical activity; health; physical environment; measurement; correlates; implementation; intervention; adults

# Acknowledgements and dedication

I am proud to have worked at Loughborough University for nearly 14 years and am grateful for the opportunity to undertake my PhD by publication as a member of staff.

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# List of abbreviations

| | |
|---|---|
| ALPHA | Assessing Levels of Physical Activity and Fitness |
| FFW | Fitter for Walking |
| GIS | Geographical Information System |
| GPS | Global Positioning System |
| iConnect | Impact of COnstructing Non-motorised Networks and Evaluating Changes in Travel |
| IPAQ | International Physical Activity Questionnaire |
| NTS | National Travel Survey |
| PASIM | Single item measure of physical activity |
| PENS | Perceptions of the environment in the neighbourhood scale |
| NEWS | Neighbourhood Environment Walkability Scale |
| TPAQ | Transport and Physical Activity Questionnaire |
| WW | Walking Works |

# Chapter 1. Introduction

## 1.1 Physical activity and health

The benefits of being physically active for promoting physical and mental health and well-being, and preventing non-communicable disease, have been well evidenced (Department of Health, 2011; Physical Activity Guidelines Advisory Committee, 2008; Physical Activity Guidelines Advisory Committee, 2018; US Department of Health and Human Services, 1996). Guidelines for the amount and frequency of aerobic physical activity which should be undertaken to obtain health benefits have been established based on the scientific evidence. In the UK, it is currently recommended that adults (aged 19-64 years old) should accumulate at least 150 minutes of moderate intensity physical activity in bouts of 10 minutes or more throughout the week, or at least 75 minutes of vigorous intensity physical activity, or an equivalent combination of moderate and vigorous intensity activity (Department of Health, 2011). Similar global recommendations have been established (World Health Organisation, 2010).

Despite the known benefits to health, and existence of physical activity guidelines, it is estimated that worldwide, 31.1% of adults are inactive (do not meet minimum recommended levels of physical activity) (Hallal et al., 2012) costing healthcare systems approximately $53.8 billion per year (Ding et al., 2016). A similar pattern can be seen in adults in England with 38% of those aged over 19 (34% males and 42% females) not meeting recommended guidelines for physical activity (Health and Social Care Information Centre, 2017), and an estimated cost for the National Health Service of at least £450 million per year (Public Health England, 2016). Strategies to increase participation in physical activity are therefore urgently needed to reduce the individual, health and economic burden of disease associated with low levels of physical activity. Identifying interventions which increase physical activity participation and can be implemented in real-world settings and scaled up to reach a large proportion of the population is currently a priority for research, practice and policy (Public Health England, 2014; Reis et al., 2016).

## 1.2 The role of walking in physical activity promotion

Walking is an example of an activity that can be undertaken at moderate intensity and can contribute to meeting physical activity recommendations (Pate et al., 1995). There is growing evidence of the benefits of walking for physical and mental health (Hamer & Chida, 2008; Kelly et al., 2014; Lee et al., 2010; Murtagh et al., 2015; Robertson et al., 2012). Walking has been described as 'near perfect exercise' as it is free, acceptable to most people, requires no special equipment and

can be incorporated into everyday activities (Morris & Hardman, 1997); it could thus be targeted in interventions which aim to increase physical activity in the adult population.

Walking can be undertaken for a variety of different purposes including for transport, recreation, exercise, dog walking, or for incidental purposes such as stair climbing or walking around shops. It can also be undertaken in a variety of different contexts, for example in local neighbourhoods, to public transport stops and to/from or at destinations, such as workplaces. In England, recreational walking is one of the most popular forms of physical activity (Sport England, 2018). In contrast, levels of walking for transport purposes are much lower and are declining. Currently, only 25% of journeys are undertaken on foot, with most undertaken by car, either as a driver or passenger (62%) (Department for Transport, 2017a). In addition, there has been a 19% reduction in the average number of walking trips per week between 2005 and 2015 (Department for Transport, 2018). There are also low levels of walking for specific journey purposes, such as commuting to work. Currently, only 11% of commuting trips in England are made by walking, with 60-67% made by car or van (Department for Transport, 2017a; Goodman, 2013).

Evidence is emerging that individuals who walk for transport, including for general transportation or for specific journeys, such as to and from work, have higher overall levels of physical activity (measured objectively or using self-report instruments, or a combination of both) (Audrey et al., 2014; Kang et al., 2018; Sahlqvist et al., 2012; Yang et al., 2012). Therefore, promoting walking for transport provides a potential strategy to increase physical activity levels and improve health. In addition, promoting walking for transport has the potential to address other goals such as reducing air pollution, traffic congestion and road traffic collisions by reducing the use of motor vehicles (National Institute for Health and Care Excellence, 2012). Additional co-benefits for environmental sustainability and the economy have also been identified (Sallis et al., 2015). Promoting walking for transport is therefore of interest to a variety of stakeholders from a multi-disciplinary field including the health, transport, urban planning and environment sectors.

## 1.3 Walking for transport as a discrete behaviour

Walking for transport is a complex behaviour and may involve journeys which include walking as a single mode, walking in combination with other modes of transport (multi-mode trips), walking to a single destination or walking to multiple destinations as part of one journey. Regardless, most journeys, including multi-mode trips, start and end on foot and it is therefore an important area of research for physical activity promotion. In the field of public health, walking for transport has often

been combined with walking for recreation or exercise and studied as 'total walking'. However, walking for transport may be undertaken at different intensities, duration and volume, and for different distances, compared to walking for recreation (Merom & Korycinski, 2017), and therefore a different dose may be required to obtain health benefits. This needs to be understood for the purposes of developing and testing interventions. Walking for transport is also often combined with cycling for transport under the umbrella of 'active transport', 'active travel' or 'active commuting'. Given the functional differences between walking and cycling and different requirements in interventions (Krizek et al., 2009), this may not be appropriate. In addition, the need to study specific behaviours in specific contexts to identify behaviour-specific influences has previously been highlighted (Giles-Corti et al., 2005). It is therefore important that walking for transport is studied as a discrete behaviour to provide specificity in understanding its relationship with health outcomes, the factors influencing the behaviour and how to effectively deliver interventions to promote the behaviour, and ultimately increase physical activity levels to promote health and well-being.

## 1.4 Summary of current evidence for walking for transport

The behavioural epidemiological framework provides a systematic approach for the development of the evidence base related to health behaviours. It includes: 1) establishing links between the behaviour and health outcomes; 2) developing measures of the behaviour; 3) identifying the factors influencing the behaviour; 4) evaluating interventions to change the behaviour; and 5) translating research evidence into practice leading to population level interventions (Sallis et al., 2000). Research to develop the evidence base for walking for transport and its impact on increasing physical activity levels and improving health is emerging. However, it is still at a relatively early stage of development when studied as a discrete behaviour.

### 1.4.1 Walking for transport and health outcomes

There is growing evidence of the links between walking for transport and health outcomes, however research still frequently includes the study of total walking (walking for transport and recreation) (Kelly et al., 2014) or active transport (walking and cycling combined) (Saunders et al., 2013). Further work is required to establish the dose-response relationship specifically for walking for transport which will help to inform intervention development with regards to the volume, frequency and intensity of transport walking required to obtain health benefits.

### 1.4.2 Measurement of walking for transport

Tools are required which enable walking for transport to be measured as a discrete behaviour, as well as providing a wider and more comprehensive assessment of other domains of transport and physical activity. These need to account for different methodological approaches used by the transport and health sectors who have a common interest in understanding and promoting these behaviours (Krizek et al., 2009). Self-report and objective measures have been used to assess transport and physical activity behaviours, both having methodological challenges and limitations. For example, most self-report instruments have not enabled walking and cycling behaviours being undertaken for different purposes (e.g. for transport or for recreation) to be assessed separately; whilst using objective methods, such as combing accelerometery and Global Positioning Systems (GPS) with the use of Geographical Information Systems (GIS), has presented challenges in identifying walking for transport trips requiring labour intensive and costly analytical processes. The development of reliable and valid instruments along with using consistent methods and outcomes for assessing walking for transport behaviour is a priority to support epidemiological health-related research, surveillance and evaluation of interventions (Merom & Korycinski, 2017).

### 1.4.3 Factors influencing walking for transport

Understanding the factors influencing behaviours, and how they interact, is important for the development and improvement of interventions (Bauman et al., 2012). There are a large range of potential influences on behaviour, therefore theoretical models are often used to identify and understand relationships between different factors. Socio-ecological models suggest there are multiple levels of influence on behaviours including individual, intra- and inter-personal, organisational, environmental and policy-related factors (Mcleroy et al., 1988; Sallis et al., 1998). Specifically related to walking for transport, the most substantial evidence is available for associations with the physical environment in the residential neighbourhood. Review level evidence suggests that residential density, land use mix, street connectivity, pedestrian infrastructure and having destinations to walk to are associated with walking for transport (Cerin, 2006; Cerin, 2007; Sugiyama, 2012; Van Dyck et al., 2012; Van Holle et al., 2012). However, few studies have been conducted in the UK where contexts may differ to those in other countries, and there has been little research examining the relationship of physical environmental attributes with different behaviours being undertaken for different purposes, such as walking for transport. Evidence is emerging of associations between individual factors, psychological factors, organisational factors and social environmental factors and walking for transport (Bopp et al., 2012; Laverty et al., 2013; Panter & Jones, 2010; Panter et al., 2011; Panter et al., 2013), though these have been much less widely

studied. Further research is needed to understand the associations of perceived barriers, psychological factors (such as attitudes, self-efficacy and intention), social norms and the social environment, with walking for transport for general transportation purposes and for specific journey purposes, such as walking to and from work.

### 1.4.4 Walking for transport interventions

Understanding the factors influencing behaviours can enable modifiable elements to be identified which can be targeted to provide tailored interventions, as well as identifying target groups. Developing theory-based interventions, targeting specific groups who are most sedentary or motivated to change their behaviour and tailoring walking interventions have been identified as being important for intervention effectiveness (Ogilvie et al., 2007; Williams et al., 2008). Most interventions to promote walking for transport to date have focussed on individual or household approaches, or on modifying the physical environment. Individual approaches (such as using individualised marketing) have been shown to be effective in increasing the proportion of trips made on foot and increasing time spent walking for transport. Overall, walking for transport interventions have been found to increase time spent walking by 15-30 minutes per week on average (Ogilvie et al., 2007). Other strategies have been used to effectively promote walking more generally, such as telephone prompts or counselling, but have not specifically targeted walking for transport (Williams et al., 2008). Behaviour change techniques which are most effective in increasing walking behaviour include “prompt self-monitoring of behaviour” and “prompt intention formation” (Bird et al., 2013). These approaches and techniques should therefore be considered for inclusion in future interventions.

Interventions to modify the physical environment to promote walking for transport are attractive as they have the potential to reach a larger proportion of the population compared to individually focussed interventions. This is due to the numbers of individuals exposed to the environment which enables whole populations to be impacted in a sustained manner (Giles-Corti et al., 2005; Heath et al., 2006). To date, only a few studies have been reported in the literature which assess the effectiveness of changing the physical environment to promote walking (or cycling) for transport. These have typically focussed on interventions which involve: relocating to a new neighbourhood where residents are exposed to a different type of environment, e.g. the RESIDE study (Giles-Corti et al., 2013; Knuiman et al., 2014); installing or improving large-scale walking and cycling infrastructure, e.g. the iConnect study (Goodman et al., 2014; Ogilvie et al., 2012); and the development of new or improved public transport or road systems (Boarnet et al., 2013; Brown & Werner, 2009; Foley et al.,

2017; Heinen et al., 2015). Whilst increases in walking for transport have been observed, these have typically taken a long period of time (greater than 2 years) to become evident. Some interventions targeting smaller street scale interventions have been reported to be effective in increasing walking (Heath et al., 2006; Heath et al., 2012). However, few have been implemented in the UK therefore this is an area requiring further research.

Using community consultation and engagement is recommended for implementing environmental changes (National Institute for Health and Care Excellence, 2008; National Institute for Health and Care Excellence, 2018). The author is aware of only one published study which has used community consultation and engagement to inform and deliver intervention activities to improve the local walking environment (Krieger et al., 2009). This study was found to be effective in increasing walking, however it was only measured in walking group participants rather than in the wider community. These types of intervention warrant further investigation both in terms of how they can be implemented and their effectiveness.

In addition to the positive impacts resulting from increasing walking for transport, the potential adverse effects of interventions also need to be taken into consideration. These include increased exposure to air pollution (negatively affecting health) and a rise in pedestrian injuries (de Nazelle et al., 2011). Research to date suggests that the benefits of increasing physical activity through increasing walking for transport outweigh the harm caused by air pollution, except in areas with the most highly concentrated levels (Tainio et al., 2016), but that increases in the number of people walking (or cycling) may lead to increased injuries (Woodcock et al., 2009). Therefore, interventions to promote walking for transport should consider health, transport and environmental factors and should be carefully planned and implemented to avoid potential negative consequences.

### 1.4.5 Translating research evidence into practice and policy

Despite the existence of research evidence for effective interventions for promoting physical activity (Dunn et al., 1998; Global Advocacy for Physical Activity Council of the International Society of Physical Activity and Health, 2012; Heath et al., 2012; Kahn et al., 2002), population levels of participation remain largely unchanged (Health and Social Care Information Centre, 2017). One of the reasons for this could be the knowledge translation gap between research and practice, with few effective interventions being translated, implemented and tested in real-world settings, embedded into practice on a sustainable basis or scaled up to impact whole populations (Reis et al., 2016). Translating research evidence into practice and policy is challenging (Giles-Corti et al., 2015). In the

field of walking for transport, co-production of interventions involving researchers, practitioners and policy-makers from a variety of disciplines is needed to ensure practice and policy relevant research is undertaken. In addition, incorporating the relatively new field of implementation science (Peters, 2013) into intervention development and testing offers new opportunities for improving knowledge translation.

Promoting walking for transport offers a potential solution for increasing physical activity levels in adults. It will, however, require input from a variety of stakeholders from a multi-disciplinary field including health, transport, urban design and the environment to design and implement interventions, and evaluation of interventions in real-world settings. Further research is needed in this area to optimise the implementation, effectiveness and scaling up of walking for transport interventions to impact the whole population and increase overall physical activity levels.

## 1.5 Overview of thesis

The research in this thesis focusses on walking for transport, which is defined as walking for the purposes of travelling from one point to another on foot to reach a destination where the individual stops to undertake an activity (e.g. shopping or work) or to change mode of transport. This is based on Handy's definition of active travel, which is 'destination-orientated physical activity' and 'not simply a loop from starting point back to starting point' (such as going for a walk for recreation or exercise) (Handy, 2005). For the purpose of this thesis, the definition includes travel where walking is undertaken for the whole journey (single-mode journeys), or for some of the journey, in combination with other modes of transport, e.g. the car, bus or train (multi-mode journeys). It focusses on understanding and promoting walking for transport in adults (aged 19-64) as a target population who may benefit from increased participation in physical activity to improve health and prevent disease.

### 1.5.1 Thesis aims and objectives

This thesis aimed to contribute to the evidence base relating to understanding and promoting walking for transport in adults to address the problem of how to increase population levels of physical activity to improve health and well-being. The objectives of the research were:

Objective 1: To develop a self-report measure of transport and physical activity behaviour which enables specific domains of physical activity being undertaken for different purposes (including

walking for transport) to be assessed separately, and to test the reliability and validity of the physical activity items in this measure

Objective 2: To identify individual, psychosocial and environmental factors influencing walking for transport in adults

Objective 3: To evaluate the implementation and impact of interventions promoting walking for transport in community and workplace settings and make recommendations for research, policy and practice.

### 1.5.2 Research articles

This thesis comprises eight peer reviewed research articles with a common theme of understanding and promoting walking for transport in adults. Emma Jane Adams (EJA) was lead author on all the articles. Full details of the articles and EJA's contribution are presented in Chapter 2. The articles map on to the research objectives outlined in section 1.5.1 as follows:

- Objective 1: Paper 1
- Objective 2: Papers 2, 3 and 4
- Objective 3: Papers 5, 6, 7 and 8

The articles presented used data collected in three completed research projects: iConnect (Impact of COnstructing Non-motorised Networks and Evaluating Changes in Travel) (Papers 1 and 2), Walking Works (Papers 3, 4 and 8) and Fitter for Walking (Papers 5, 6 and 7). A mixed methods approach was used in each of the projects including collection of quantitative and qualitative data. Full details of the methodology are provided in each research article and discussed further in Chapter 3.

### 1.5.3 Original contribution to research

The research presented in this thesis has made a novel contribution to the field because it:

1) studied walking for transport as a discrete behaviour, separately from walking for recreation, and separately from cycling which is functionally different (Krizek et al., 2009), taking into account specific contexts (Giles-Corti et al., 2005) (all papers).
2) developed a new self-report instrument for comprehensively assessing transport and physical activity behaviour, the Transport and Physical Activity Questionnaire (TPAQ), providing a tool for

use in multi-disciplinary studies and enabling discrete behaviours, such as walking for transport, to be measured separately. Such comprehensive instruments did not previously exist (Paper 1).

3) developed a reliable short instrument for use in studying perceptions of the neighbourhood environment: Perceptions of the Environment in the Neighbourhood Scale (PENS). Most previous instruments such as the Assessing Levels of Physical Activity and Fitness (ALPHA) Environmental questionnaire (Spittaels et al., 2009, 2010) and the Neighbourhood Environment Walkability Scale (NEWS) (Cerin et al., 2006) were too long for inclusion in wider surveys or were not specific to the UK context (Paper 2).
4) used TPAQ and PENS to investigate the associations of attributes of the residential neighbourhood physical environment with walking for transport, walking for recreation and cycling for transport and cycling for recreation. These have typically not been studied as four separate behaviours and this was the first study to investigate these relationships in the UK context (Paper 2).
5) assessed attributes of the physical environment at a destination (the workplace) and their association with walking for transport (specifically walking to and from work) thus aiding understanding of behaviour- and context-specific environmental correlates. This contrasts with previous research which has typically assessed attributes of the physical environment in the residential neighbourhood. Only two similar studies have been conducted but these did not consider walking to and from work as a unique behaviour and were not conducted in the UK (Adlakha et al., 2015; Schwartz et al., 2009) (Paper 3).
6) examined individual, psychosocial and employment-related factors associated with walking to and from work; previous research in this area has been limited (Bopp et al., 2012; Laverty et al., 2013; Panter et al., 2011; Panter et al., 2013) and no studies have examined associations between social support and walking to and from work (Paper 4).
7) evaluated two interventions (community- and workplace-based) which aimed to promote walking for transport and were delivered in real-world settings. To date there has been limited reporting of real-world interventions in the literature and a need has been identified to develop the evidence base in this area (Reis et al., 2016) (Papers 5, 6, 7 and 8).
8) assessed the implementation and impact of a project which aimed to change small-scale attributes of the physical environment using community engagement approaches to promote walking for transport. Previous interventions have mainly focussed on changing large-scale infrastructure or transport systems which are costly and take considerable time to implement (Boarnet et al., 2013; Brown & Werner, 2009; Brown et al., 2016; Foley et al., 2017; Goodman et al., 2014; Heinen et al., 2015). The author is aware of only one previously published study which

used a community engagement approach to improve the walking environment (Krieger et al., 2009). In addition, there has been limited investigation of the implementation of these types of interventions to date. Through this research several processes were identified for planning and delivering future interventions and recommendations made for research, practice and policy (Papers 5, 6 and 7).

9) evaluated the implementation and impact of a whole-workplace project which aimed to increase walking to and from work and during the working day. The author is not aware of any other whole-workplace walking programmes which have previously been published, and there has been limited consideration of the effectiveness of implementing interventions using volunteer employees. Barriers and facilitators for this approach were identified and recommendations made for future intervention design and implementation (Paper 8).

# Chapter 2. Research articles, abstracts and contribution

## 2.1 Paper 1

Emma J Adams, Mary Goad, Shannon Sahlqvist, Fiona C Bull, Ashley R Cooper and David Ogilvie (2014) Reliability and validity of the Transport and Physical Activity Questionnaire (TPAQ) for assessing physical activity behaviour. *PLoS ONE*, *9*(9): e107039. doi:10.1371/journal.pone.0107039

### 2.1.1 Abstract

**Background**

No current validated survey instrument allows a comprehensive assessment of both physical activity and travel behaviours for use in interdisciplinary research on walking and cycling. This study reports on the test-retest reliability and validity of physical activity measures in the transport and physical activity questionnaire (TPAQ).

**Methods**

The TPAQ assesses time spent in different domains of physical activity and using different modes of transport for five journey purposes. Test-retest reliability of eight physical activity summary variables was assessed using intra-class correlation coefficients (ICC) and Kappa scores for continuous and categorical variables respectively. In a separate study, the validity of three survey-reported physical activity summary variables was assessed by computing Spearman correlation coefficients using accelerometer-derived reference measures. The Bland-Altman technique was used to determine the absolute validity of survey-reported time spent in moderate-to-vigorous physical activity (MVPA).

**Results**

In the reliability study, ICC for time spent in different domains of physical activity ranged from fair to substantial for walking for transport (ICC=0.59), cycling for transport (ICC=0.61), walking for recreation (ICC=0.48), cycling for recreation (ICC=0.35), moderate leisure-time physical activity (ICC=0.47), vigorous leisure-time physical activity (ICC=0.63) and total physical activity (ICC=0.56). The proportion of participants estimated to meet physical activity guidelines showed acceptable reliability (k=0.60). In the validity study, comparison of survey-reported and accelerometer-derived time spent in physical activity showed strong agreement for vigorous physical activity (r=0.72, p<0.001), fair but non-significant agreement for moderate physical activity (r=0.24, p=0.09) and fair agreement for MVPA (r=0.27, p=0.05). Bland-Altman analysis showed a mean overestimation of MVPA of 87.6 min/week (p=0.02) (95% limits of agreement -447.1 to +622.3 min/week).

**Conclusions**

The TPAQ provides a more comprehensive assessment of physical activity and travel behaviours and may be suitable for wider use. Its physical activity summary measures have comparable reliability and validity to those of similar existing questionnaires.

### 2.1.2 Contribution

This paper was an output of the iConnect project on which EJA was a Research Associate (2008-2013). EJA contributed to the research by: co-ordinating and contributing to the development of the iConnect core survey; jointly contributing to the development of the TPAQ; jointly conceiving and designing the reliability and validity studies; developing study materials; co-ordinating and undertaking data collection activities for the reliability and validity studies; analysing the data and interpreting the results for the reliability study; and writing and editing the manuscript.

## 2.2 Paper 2

Emma J Adams, Anna Goodman, Shannon Sahlqvist, Fiona C Bull, David Ogilvie (2013) Correlates of walking and cycling for transport and recreation: factor structure, reliability and associations of the perceptions of the environment in the neighbourhood scale (PENS). *International Journal of Behavioural Nutrition and Physical Activity*, *10*(87). doi:10.1186/1479-5868-10-87

### 2.2.1 Abstract

**Background**

Emerging evidence suggests that walking and cycling for different purposes such as transport or recreation may be associated with different attributes of the physical environment. Few studies to date have examined these behaviour-specific associations, particularly in the UK. This paper reports on the development, factor structure and test-retest reliability of a new scale assessing perceptions of the environment in the neighbourhood (PENS) and the associations between perceptions of the environment and walking and cycling for transport and recreation.

**Methods**

A new 13-item scale was developed for assessing adults' perceptions of the environment in the neighbourhood (PENS). Three sets of analyses were conducted using data from two sources. Exploratory and confirmatory factor analyses were used to identify a set of summary environmental variables using data from the iConnect baseline survey (n=3494); test-retest reliability of the individual and summary environmental items was established using data collected in a separate reliability study (n=166); and multivariable logistic regression was used to determine the associations of the environmental variables with walking for transport, walking for recreation, cycling for transport and cycling for recreation, using iConnect baseline survey data (n=2937).

**Results**

Four summary environmental variables (traffic safety, supportive infrastructure, availability of local amenities and social order), one individual environmental item (street connectivity) and a variable encapsulating general environment quality were identified for use in further analyses. Intraclass correlations of these environmental variables ranged from 0.44 to 0.77 and were comparable to those seen in other similar scales. After adjustment for demographic and other environmental factors, walking for transport was associated with supportive infrastructure, availability of local amenities and general environment quality; walking for recreation was associated with supportive

infrastructure; and cycling for transport was associated only with street connectivity. There was limited evidence of any associations between environmental attributes and cycling for recreation.

**Conclusions**

PENS is acceptable as a short instrument for assessing perceptions of the urban environment. Previous findings that different attributes of the environment may be associated with different behaviours are confirmed. Policy action to create supportive environments may require a combination of environmental improvements to promote walking and cycling for different purposes.

### 2.2.2 Contribution

This paper was an output of the iConnect project on which EJA was a Research Associate (2008-2013). EJA contributed to the research by: co-ordinating and contributing to the development of the iConnect core survey; jointly contributing to the development of the PENS; jointly conceiving and designing the reliability study; developing study materials; co-ordinating and undertaking data collection for the reliability study; analysing the data and interpreting the results of the reliability study; analysing the environmental correlates data, using data collected in the iConnect baseline survey; jointly interpreting the results; and writing and editing the manuscript, except for the sections related to the factor analysis.

## 2.3 Paper 3

Emma J Adams, Fiona C Bull and Charlie E Foster. (2016) Are perceptions of the environment in the workplace 'neighbourhood' associated with commuter walking? *Journal of Transport and Health, 3*(4), 479-484. doi:10.1016/j.jth.2016.01.001

### 2.3.1 Abstract

**Background**

Walking for the daily commute is one potential strategy for increasing physical activity levels. Understanding the behaviour-specific environmental correlates associated with commuter walking will help effective interventions to be identified and developed. The aim of this study was to examine the associations of perceptions of the environment in the workplace 'neighbourhood' and commuter walking.

**Methods**

Participants in the baseline survey of the Walking Works intervention study reported perceptions of ten environmental attributes in their workplace neighbourhood, availability of public transport, time spent walking to and from work in the last seven days, their participation in physical activity and socio-demographic characteristics (n=676). We built a series of multivariate logistic regression models to examine associations between each environmental item, public transport availability and commuter walking.

**Results**

Half (52%) of respondents were classified as commuter walkers (n=352) (66% female; 47% aged <30 years). Respondents were significantly more likely to walk for their daily commute if they reported there to be convenient walking routes (OR (odds ratio) 2.05, 95% CI (confidence interval) 1.23-3.42), suitable pavements (OR 2.23, 95% CI 1.23-4.04), maintained pavements (OR 1.64, 95% CI 1.02-2.62) or convenient public transport (OR 4.98, 95% CI 3.34-7.44) after adjusting for socio-demographic characteristics, free car parking at work and distance lived from work.

**Conclusions**

Creating 'pedestrian friendly' environments in workplace surroundings may be important for encouraging walking for the daily commute to work. Such environments would include convenient routes, suitable and maintained pedestrian infrastructure and convenient access to public transport. Improving and maintaining the walking environment around existing workplaces and ensuring

infrastructure around new workplaces is designed to support commuter walking should be considered a priority area for investment.

### 2.3.2 Contribution

This paper was an output of the Walking Works project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods including the baseline survey; undertaking data collection; conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

## 2.4 Paper 4

Emma J Adams, Dale W Esliger, Ian M Taylor and Lauren B Sherar. (2017) Individual, Employment and Psychosocial Factors Influencing Walking to Work: Implications for Intervention Design, *PLoS ONE, 12*(2): e0171374. doi:10.1371/journal.pone.0171374

### 2.4.1 Abstract

**Background**

Promoting walking for the journey to and from work (commuter walking) is a potential strategy for increasing physical activity. Understanding the factors influencing commuter walking is important for identifying target groups and designing effective interventions. This study aimed to examine individual, employment-related and psychosocial factors associated with commuter walking and to discuss the implications for targeting and future design of interventions.

**Methods**

1,544 employees completed a baseline survey as part of the 'Walking Works' intervention project (33.4% male; 36.3% aged <30 years). Multivariate logistic regression was used to examine the associations of individual (age, ethnic group, educational qualifications, number of children <16 and car ownership), employment-related (distance lived from work, free car parking at work, working hours, working pattern and occupation) and psychosocial factors (perceived behavioural control, intention, social norms and social support from work colleagues) with commuter walking.

**Results**

Almost half of respondents (n=587, 49%) were classified as commuter walkers. Those who were aged <30 years, did not have a car, had no free car parking at work, were confident of including some walking or intended to walk to or from work on a regular basis, and had support from colleagues for walking were more likely to be commuter walkers. Those who perceived they lived too far away from work to walk, thought walking was less convenient than using a car for commuting, did not have time to walk, needed a car for work or had always travelled the same way were less likely to be commuter walkers.

**Conclusions**

A number of individual, employment-related and psychosocial factors were associated with commuter walking. Target groups for interventions to promote walking to and from work may include those in older age groups and those who own or have access to a car. Multi-level

interventions targeting individual level behaviour change, social support within the workplace and organisational level travel policies may be required in order to promote commuter walking.

### 2.4.2 Contribution

This paper was an output of the Walking Works project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods including the baseline survey; undertaking data collection; conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

## 2.5 Paper 5

Emma J Adams and Nick Cavill. (2015) Engaging communities in changing the environment to promote transport-related walking: evaluation of route use in the 'Fitter for Walking' project. *Journal of Transport and Health, 2*(4), 580-594. doi:10.1016/j.jth.2015.09.002

### 2.5.1 Abstract

**Background**

Promoting walking for transport may help to increase physical activity levels. Associations between the built environment and walking for transport have been well reported. Engaging communities in making small-scale changes to local routes is one potential low-cost strategy to improve neighbourhood environments. The purpose of this study was to evaluate changes in pedestrian use of local routes following environmental changes made by communities and local authorities (LAs) in the 'Fitter for Walking' (FFW) project, to assess route users' awareness of the environmental improvements which were implemented and to make recommendations for future evaluation.

**Methods**

FFW targeted deprived communities in twelve LA areas in England. Coordinators worked with communities and LA partners to improve local route environments based on identified barriers to walking. Route user counts and intercept surveys were conducted in five FFW case studies at baseline, 12 months and 14-20 months after the project activities had commenced.

**Results**

A wide range of environmental improvements were undertaken. After 12 months, there was a decrease in pedestrian route use overall (-19.4%) and in four case studies (range -42.1% to -10.4%). However, after 14-20 months, an increase in pedestrian route user overall (14.9%) and in all case studies (range 5.4% to 58.9%) was observed compared to baseline. Route users' awareness of environmental improvements made to routes varied across case studies and was very low for some of the improvements which had been made.

**Conclusions**

Engaging communities in making small-scale environmental improvements to key routes in local neighbourhoods may be an effective, low-cost strategy for increasing walking for transport. Increasing the number of people walking on newly improved routes may take a long time and require additional promotional initiatives. Evaluating these types of initiatives is challenging. These

factors should be considered by health and transport professionals developing initiatives and by researchers interested in measuring behaviour change.

### 2.5.2 Contribution

This paper was an output of the Fitter for Walking project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods including the route user survey; conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

## 2.6 Paper 6

Emma J Adams, Nick Cavill and Lauren B Sherar (2017) Evaluation of the implementation of an intervention to improve the street environment and promote walking for transport in deprived neighbourhoods. *BMC Public Health, 17*(655). doi:10.1186/s12889-017-4637-5

### 2.6.1 Abstract

**Background**

Levels of physical activity remain low, particularly in deprived areas. Improving the street environment to promote walking for transport using a community engagement approach is a potential strategy to increase physical activity. An understanding of the implementation of this intervention approach is needed to facilitate further research, replication and scale-up. The aim of this study was to evaluate the implementation of the Fitter for Walking (FFW) intervention in deprived neighbourhoods.

**Methods**

FFW was delivered in five regions of England between August 2008 and March 2012 and aimed to use a community engagement approach to improve the street environment to promote walking for transport. Implementation was assessed in relation to reach; dosage; implementation processes and adaptation; and factors influencing implementation. Three data sources were used: focus groups and face-to-face interviews with coordinators; implementation logs; and participation records.

**Results**

*Reach:* 155 community groups participated in FFW engaging 30,230 local residents. *Dosage:* A wide variety of environmental improvements were implemented by local authorities (LAs) (42 projects) and by communities (46 projects). Examples of LA-led improvements included removal of encroaching vegetation, new/improved pedestrian signage, new dropped kerbs/kerb improvements and new, repaired or improved footpaths. Examples of community-led improvements included planting bulbs, shrubs or bedding plants, clean-up days and litter pick-ups. In 32 projects, no environmental improvements were implemented. Promotional and awareness-raising activities were undertaken in 81 projects. Examples included led walks, themed walks, development of maps/resources to promote improved routes and community events. *Processes and adaptation:* The need for a planning phase, a preparatory phase, and a delivery phase with a four-step process were identified. Adaptability to local context was important. *Factors influencing implementation:* Five key themes were identified in relation to the barriers and facilitators of implementing FFW: local

knowledge and contacts; intervention delivery; coordinator role; working with LAs and other partners; and working with communities.

**Conclusions**

FFW is one of few reported interventions which have used a community engagement approach to change the street environment to promote walking for transport in deprived neighbourhoods. Delivering these types of interventions is complex and requires considerable resource and time. A set of recommendations and an implementation framework are proposed for future delivery of this and similar types of programme.

### 2.6.2 Contribution

This paper was an output of the Fitter for Walking project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods including the implementation logs and focus group and interview schedules; undertaking data collection (except for the final focus groups/interviews with the coordinators); conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

## 2.7 Paper 7

Emma J Adams and Lauren Sherar (2018). Community perceptions of the implementation and impact of an intervention to improve the neighbourhood physical environment to promote walking for transport: a qualitative study. *BMC Public Health, 18*(714). doi:10.1186/s12889-018-5619-y

### 2.7.1 Abstract

**Background**

Using community engagement approaches to develop and deliver interventions targeting small-scale physical environmental improvements in neighbourhoods is a potential strategy for increasing walking for transport. This study aimed to qualitatively assess community perceptions of the implementation and impact of the Fitter for Walking (FFW) intervention, which encouraged communities to work together to improve the street environment on local routes and promote walking for transport.

**Methods**

From 155 FFW community projects, nineteen were selected to take part in a focus group/interview using specified criteria: geographical area; level of community involvement; intervention activities; and project progress. Participants were invited to take part via the project coordinator or lead member of the community group. A written guide was used to initiate and direct discussions through key topics. Deductive and inductive approaches were used to analyse the data and identify key themes relating to the barriers and facilitators for implementation and the perceived impact of the intervention.

**Results**

Fourteen focus groups and five interviews were conducted with 86 community members. Themes were identified in relation to barriers (poor area reputation and regeneration areas; engaging the local community; and working with local authorities) and facilitators (provision of a coordinator/facilitator; strong local partnerships; and using a range of communication and engagement activities) for programme implementation. Participants perceived the main impacts to be improved physical and social environments. Increases in walking for transport were rarely specifically commented on, but participants did report increased street use.

**Conclusions**

Community perspectives provided important insights into the barriers and facilitators for the implementation of the FFW intervention and its' potential impacts. Using community engagement approaches can lead to perceived improvements in the physical and social environment resulting in increased street use, which may lead to increases in walking for transport in the longer-term. Recommendations are provided for researchers, practitioners and policy makers in planning and delivering future interventions. Future research should determine optimal implementation strategies, investigate the relative importance of improving physical environments, social environments and using individual behaviour change strategies, and determine how physical and social environments interact to maximise intervention impact on walking for transport.

### 2.7.2 Contribution

This paper was an output of the Fitter for Walking project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods including the focus group and interview schedule; undertaking data collection; conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

## 2.8 Paper 8

Emma J Adams, Anna E Chalkley, Dale W Esliger and Lauren B Sherar. (2017) Evaluation of the implementation of a whole-workplace walking programme using the RE-AIM framework. *BMC Public Health, 17*(466). doi:10.1186/s12889-017-4376-7

### 2.8.1 Abstract

**Background**

Promoting walking for the journey to/from work and during the working day is one potential approach to increase physical activity in adults. Walking Works was a practice-led, whole-workplace walking programme delivered by employees (walking champions). This study aimed to evaluate the implementation of Walking Works using the RE-AIM framework and provide recommendations for future delivery of whole-workplace walking programmes.

**Methods**

Two cross sectional surveys were conducted; 1,544 (28%) employees completed the baseline survey and 918 employees (21%) completed the follow-up survey. Effectiveness was assessed using baseline and follow-up data; reach, implementation and maintenance were assessed using follow-up data only. For categorical data, Chi square tests were conducted to assess differences between surveys or groups. Continuous data were analysed to test for significant differences using a Mann-Whitney U test. Telephone interviews were conducted with the lead organisation co-ordinator, eight walking champions and three business representatives at follow-up. Interviews were transcribed verbatim and analysed to identify key themes related to adoption, implementation and maintenance.

**Results**

*Adoption*: Five workplaces participated in Walking Works. *Reach*: 480 (52.3%) employees were aware of activities and 221 (24.1%) participated. *Implementation*: A variety of walking activities were delivered. Some programme components were not delivered as planned which was partly due to barriers in using walking champions to deliver activities. These included the walking champions' capacity, skills, support needs, ability to engage senior management, and the number and type of activities they could deliver. Other barriers included lack of management support, difficulties communicating information about activities and challenges embedding the programme into normal business activities. *Effectiveness*: No significant changes in walking to/from work or walking during the working day were observed. *Maintenance*: Plans to continue activities were mainly dependent on identifying continued funding.

**Conclusions**

RE-AIM provided a useful framework for evaluating Walking Works. No changes in walking behaviour were observed. This may have been due to barriers in using walking champions to deliver activities, programme components not being delivered as intended, the types of activities delivered, or lack of awareness and participation by employees. Recommendations are provided for researchers and practitioners implementing future whole-workplace walking programmes.

### 2.8.2 Contribution

This paper was an output of the Walking Works project on which EJA was the Principal Investigator and main researcher (2009-2011). EJA contributed to the research by: designing the data collection methods, including the baseline and follow-up surveys and focus group and interview schedules; undertaking data collection for the surveys; conceiving the idea for the manuscript; analysing the data and interpreting the results; and writing and editing the manuscript.

# Chapter 3. Strengths and limitations of research methods

The articles in this thesis used data collected as part of three research projects: iConnect (Impact of COnstructing Non-motorised Networks and Evaluating Changes in Travel); Walking Works; and Fitter for Walking. This chapter outlines the strengths and limitations of the study design, recruitment methods, measurement methods, and data analysis undertaken for each project. Strengths and limitations are also discussed in each research article.

## 3.1 iConnect

iConnect was a five-year natural experiment which aimed to assess the impact of improving walking and cycling infrastructure on travel, physical activity and carbon emissions. A conceptual framework was developed to guide the overall study design (Ogilvie et al., 2011). This comprised a longitudinal cohort study of residents living within 5km of three case study projects (Cardiff, Kenilworth and Southampton) including repeated surveys before and after the opening of new infrastructure (Ogilvie et al., 2012). The findings from the evaluation of the intervention were not part of this thesis and are reported elsewhere (Goodman et al., 2014; Sahlqvist et al., 2013). EJA contributed to work package 2: measurement and evaluation techniques (Paper 1) and led the analysis of the associations between the perceived neighbourhood environment and walking and cycling for different purposes (Paper 2).

### 3.1.1 Study design

The iConnect baseline survey was used to assess associations between perceptions of the environment in the neighbourhood and the four separate behaviours of walking for transport, walking for recreation, cycling for transport and cycling for recreation (Paper 2), thus the study used a cross-sectional design. Using cross-sectional studies such as this is relatively quick and easy to undertake as there is no long-term follow-up, therefore they are inexpensive with low participant burden (Mann, 2003). However, cross-sectional data does not allow for any temporal relationships between variables to be inferred, only statistical associations (Bauman et al., 2012). This is because measurements are taken at a single time point, which means it is not possible to identify the causes of a behaviour which might be modified to effect the behaviour (Mann, 2003). Collecting data at a single time point also has implications for the measurement of physical activity behaviours, such as walking for transport, as participation may vary by season and weather (Tucker & Gilliland, 2007). Therefore, walking levels may be higher in the summer than in the winter which could affect study findings in terms of the strength of the observed relationship between variables. Despite this, cross-

sectional studies are useful for identifying associations between variables and generating hypotheses that can be explored using more rigorous longitudinal study designs.

### 3.1.2 Recruitment methods

The edited electoral register for the three case study sites was used to randomly select 22,500 adults who were sent the iConnect baseline survey. Randomly selecting participants is a strength of the study. However, the edited electoral register may not be representative of the general population as it is possible to 'opt out' (Mann, 2003; Sahlqvist et al., 2011). This may create a selection bias in the study population which will reduce generalisability of the findings.

The response rate to the survey was low (n=3,516; 15.6%) which is a limitation of the study. However, this is a challenge faced by many researchers in this and other fields of research (McCluskey & Topping, 2011). A similar response rate (15.9%) was observed in another natural experiment using postal surveys (Ogilvie et al., 2008b). Participants in the iConnect baseline survey tended to be older than the local population, had a higher level of educational attainment and were in better health, suggesting there was some non-response bias. These sample characteristics are a common occurrence in surveys of this type (MCcoll et al., 2001) and may limit the generalisability of the findings. Improving response rates to surveys and representativeness of samples is important for future research in this area to reduce bias.

### 3.1.3 Measurement methods

A postal self-report survey was used in this study. This was selected due to the large population being sampled (N=22,500 adults) in the main intervention. Self-report surveys are suitable for use in large free living populations as they are practical to deliver and cost-effective (Dishman et al., 2001). The iConnect survey was developed by the research consortium over a period of 15 months using a robust process. Key development steps included: 1) creating a master list of potential variables based on the iConnect conceptual framework; 2) refining this to a shortlist of key variables; 3) identifying potential existing instruments which could be used and gaps where existing instruments did not meet the needs of the project; 4) iterative development, review and revision of the survey; 5) peer review of the survey by physical activity and transport experts; 6) adaptation of the survey based on feedback (particularly concerns regarding the survey being too long); 7) reliability and validity testing of a long and short version of the survey; 8) further revisions to the survey based on reliability and validity results; 9) second phase of reliability and validity testing of the final version of the survey. The robust process used and the development of the survey by a multi-disciplinary team

was a strength of the project. However, there were some challenges in survey development due to existing instruments not meeting the needs of the project and differences in data collection methods typically used by each of the disciplines (e.g. physical activity researchers often use self-report questionnaires or telephone surveys, whereas transport researchers use trip diaries and intercept surveys (Krizek et al., 2009)). Even though a short version of the survey was developed, it was still long (12 pages with 41 questions, taking approximately 30 minutes to complete) due to the collection of data for multiple different constructs in the conceptual framework. This may have resulted in the low participant response (see section 3.1.2) and non-response to items in the survey. A feasibility study using the iConnect survey showed that item non-response was low, but it was significantly higher in a longer version of the survey compared to a shorter version (Sahlqvist et al., 2011).

The final iConnect survey is available in Ogilvie et al., 2012. It included a new instrument for comprehensively assessing physical activity and transport behaviours (TPAQ), and a new instrument for assessing environmental attributes, the perceptions of the environment in the neighbourhood scale (PENS). The test-retest reliability and validity of the physical activity items in TPAQ, and the test-retest reliability of items in the PENS were reported as part of this thesis (Papers 1 and 2, respectively) which is a strength of the research. Standardised methodologies and data analyses were used in these studies. A limitation of this research is that the reliability and validity studies were not completed before data collection for the main intervention started. Therefore, it was not possible to make further adjustments to the survey, such as reduce the number of environmental attributes assessed, based on the findings.

Whilst comprehensive measures were developed, relying on self-report measures for assessing attributes of the neighbourhood environment and participation in physical activity and transport behaviours may have resulted in measurement error and bias. Specifically, it is known that self-report physical activity questionnaires have poor reliability and validity, recall of activities is poor, social desirability may lead to over-reporting of activity levels and seasonal variations can affect responses (Shephard, 2003). Perceptions of environmental attributes may have depended on individual awareness and use of the local neighbourhood which may have led to a bias in perceptions by those who walk (or cycle) as they may be more aware of the walking (and cycling) environment (Koohsari et al., 2015). In addition, researcher-defined neighbourhoods, typically referred to as the neighbourhood within a 10-15 minute walk of a person' home, are known to have poor correspondence with the neighbourhood considered by an individual (Smith et al., 2010) which

is a limitation of this study. Using objective measures of the environment and the behaviours can help to overcome these issues. However, whilst it may have been desirable to use these to improve the accuracy of findings, it was not feasible to use them for the large cohort being studied in the iConnect intervention due to practical reasons, cost and challenges with analysing these types of data (Brownson et al., 2009; Oliver et al., 2010).

### 3.1.4 Data analysis

This study used factor analysis to identify environmental items in the PENS that were correlated and therefore potentially measuring similar constructs (Paper 2). Both exploratory and confirmatory factor analysis were conducted in this study as there was no a priori hypothesis regarding which factors may be related. A strength of using factor analysis is the identification of a reduced set of summary variables for use in analysis. However, this approach can only be based on the questions asked, therefore other important environmental attributes may have been excluded. In addition, using the factors identified in factor analysis for analyses can reduce the effect of individual environmental attributes and may result in unintuitive findings. For example, in this study, 'pavements for walking' was included in the local amenities factor rather than the supportive infrastructure factor. A further limitation of this approach is that it was more difficult to compare the findings to other studies as the four factors identified in this study (traffic safety, supportive infrastructure, availability of local amenities and social order) did not map on to environmental constructs reported in other studies (e.g. walkability indices including residential density, diversity of land use mix and street connectivity (Van Holle et al., 2012)).

The relationships between the identified environmental factors and the four behaviours (walking for transport, walking for recreation, cycling for transport and cycling for recreation) were examined using logistic regression. Logistic regression was used in this study because the total minutes per week of walking for transport, walking for recreation, cycling for transport and cycling for recreation (dependent variables) were highly skewed, even after log transformation. Thus, the data failed the assumptions required for linear regression. The strengths of logistic regression are that it does not require the dependent variable to be normally distributed and can be used with categorical dependent variables, it can be used with categorical or continuous independent variables and it is relatively easy to interpret (Field, 2009). However, converting continuous dependent variables into categorical variables reduces the sensitivity of the data, which is a limitation. In addition, using logistic regression does not enable us to determine any dose response relationship, i.e. the 'amount' of the behaviour which might change based on a unit change in the perceived environmental

exposures. For this study, a simple complete case analysis was undertaken in the logistic regression analysis, rather than using a method to account for missing data, which reduced the size of the sample available for analysis and may have created further selection bias (Wood et al., 2005).

The logistic regression analysis was adjusted for several potential individual and household co-variates which is a strength of the study. These were selected based on whether they were statistically important (by conducting a series of univariate logistic regression analysis which explored the association between the co-variate and the dependent variable). This may however have excluded other theoretically important variables. Specifically, neighbourhood self-selection (i.e. where active individuals may choose to live in neighbourhoods which support walking) was not accounted for in this study, which is a limitation. This was not measured due to constraints on survey length. Excluding this may have affected the strength of the associations observed as research has shown that associations between the built environment and physical activity may be attenuated after adjustment for neighbourhood self-selection (McCormack & Shiell, 2011). Future studies should include empirically and theoretically important variables in addition to those which are statistically important (Giles-Corti & Donovan, 2002). One final limitation of this study is that only environmental factors were considered. There may be other predictors of walking and cycling for transport and recreation such as psychological factors (e.g. intention, perceived behavioural control, habit) and social environmental factors (e.g. social support, social norms) which should be considered in future studies (Ball, 2006; Giles-Corti & Donovan, 2002; Panter & Jones, 2010).

## 3.2 Walking Works

Walking Works (WW) was a practice-led intervention delivered in five workplaces in England. The overall aim of the project was to increase walking to and from work and walking during the working day using volunteer workplace champions to deliver intervention activities. EJA was appointed as the independent evaluator for this project and did not have any role in intervention design or delivery. This was a strength in providing an independent assessment of the project, however the timing and content of intervention activities, and practical considerations, created challenges for developing and implementing a robust study design. Baseline data collected in WW were used to assess the associations between perceptions of the environment in the workplace neighbourhood and walking to and from work (commuter walking) (Paper 3) and to identify individual, employment and psychosocial factors associated with commuter walking (Paper 4). All data collected were used to evaluate the implementation of the intervention (Paper 8).

### 3.2.1 Study design

A pragmatic approach (Glasgow & Riley, 2013) was utilised to evaluate the WW intervention due to the real-world delivery of the programme. A pre-/post- mixed methods study design was used which included: 1) two online surveys with employees in each workplace pre-intervention (baseline) and post-intervention (follow-up) (approximately 18-22 months apart depending on when the project started); and 2) telephone interviews with the overall project manager, volunteer employee champions and business representatives (project end). A strength of this study was the use of identical data collection methods and consistency in measures across the five workplaces. The use of a mixed methods study design was also a strength. This approach involves quantitative and qualitative data collection using different strategies, approaches and methods which helps to combine the strengths and overcome the weaknesses of each study design (Johnson & Onwuegbuzie, 2004). In WW, qualitative interviews enabled evaluation of intervention implementation and supported the interpretation of quantitative survey findings. The main limitations of the study design were the lack of any control or comparison workplaces, and the lack of randomisation to the intervention, which was mainly due to financial and practical constraints of evaluating a real-world intervention. This meant it was not possible to directly attribute any observed changes in walking for transport between baseline and follow-up to the intervention delivered, as other factors may have affected the outcomes which it was not possible to control for in the analysis (Craig et al., 2008).

Baseline data only was used for assessing the association between individual, psychosocial, employment-related and environmental factors and commuter walking (Papers 3 and 4). As noted previously, using cross-sectional studies is quick, easy and therefore inexpensive with low participant burden (Mann, 2003). However, it only allows for statistical associations to be identified rather than causal relationships (Bauman et al., 2012). This meant it was only possible to identify potential correlates of walking to and from work rather than factors which cause the behaviour (determinants). A limitation of this work is that it was completed after the intervention had been delivered, therefore it was not possible to use the findings to inform intervention design and delivery.

The RE-AIM framework (Glasgow et al., 1999) was used to evaluate the implementation of WW (Paper 8). It was selected for use in the evaluation of WW because it is relevant for evaluating real-world interventions addressing aspects of both internal and external validity and considering implementation, replicability and generalisability. Using an established framework to report evaluation findings is a strength of this study. In contrast, RE-AIM also has limitations in that it is not

known how the five dimensions interact to influence successful implementation of interventions. Furthermore, the recent growth in implementation research may mean the implementation dimension in RE-AIM needs to be expanded to consider a wider range of implementation outcomes. Alternative frameworks (Tabak et al., 2012) might also be considered for assessing implementation in future.

### 3.2.2 Recruitment methods

3.2.2.1 Employee surveys

The target population for the intervention was all employees in each of the five workplaces recruited to take part in the intervention. Therefore, all employees were invited to take part in the surveys at baseline and follow-up. A relatively large number of employees completed the baseline (n=1,544; 28%) and follow-up surveys (n=918; 21%) which is a strength. However, despite reminder invitations which can help to increase survey completion (Sahlqvist et al., 2011), and guidance provided to workplaces as to how to gain the best response rate, survey response rate was low. The low response is a limitation of this study but also presents a challenge for this field of research (McCluskey & Topping, 2011). Comparable response rates (18%-26%) have been observed in similar workplace-wide travel surveys (Petrunoff et al, 2016). The low response rate may have been due to the length of the survey which collected data on many constructs and included 44 questions. Survey length resulting in participant burden is known to reduce participant response rate and increase item non-response (Sahlqvist et al., 2011) which may have affected study findings. There may also have been selection bias with those who were more interested in the topic of walking and physical activity completing the survey leading to higher reported levels of these behaviours compared to the wider employee population.

There were no significant differences between the baseline and follow-up samples for individual or employment-related characteristics except for distance lived from work, with more employees living >2 miles from work at follow-up. This may have had implications for the findings as it is known that employees who live further away are less likely to walk to work (Panter et al., 2011). It was not possible to assess the representativeness of the samples compared to the overall workplace population as these data were not available. The issues outlined above would be considered if the study were to be repeated with efforts made to reduce survey length, increase response rates and promote survey completion in representative samples.

3.2.2.2 Telephone interviews

All the workplace champions agreed to take part in telephone interviews therefore experiences in all participating workplaces were represented. In contrast, business representatives from only three of the workplaces agreed to take part, leading to a possible bias in findings with these individuals' potentially having more positive views of the intervention or their organisations being more supportive of the intervention.

### 3.3.3 Measurement methods

3.3.3.1 Employee survey

Self-report surveys were used at baseline and follow-up as these are practical to use with large study populations (Dishman et al., 2001). No unique identifying information was collected on the surveys due to challenges in identifying a suitable mechanism to do this whilst retaining employee anonymity. This is a limitation of the study and meant it was not possible to match data from the two surveys to enable comparisons within subjects between baseline and follow-up. Thus, it was not possible to identify changes in individual behaviours and associated outcomes. The survey collected data on a range of behavioural, psychosocial, environmental, employment-related and individual constructs.

*Psychosocial and environmental outcomes*

Validated measures were used to assess psychosocial (attitude, perceived behavioural control, intention, social norms, social support from colleagues) and environmental (perceived environment in the workplace neighbourhood) constructs wherever possible. However, for the psychological measurements single items were selected and adapted from a longer questionnaire (Fishbein & Ajzen, 2010) which may have altered the validity of the instrument and is a limitation of the study. A 10-item question asking about perceptions of the environment in the workplace neighbourhood was included. These items were also selected from existing questionnaires which have been tested for reliability (Cerin et al., 2006; Ogilvie et al., 2008; Spittaels et al., 2010). Although the selection of a sub-set of questions was desirable for reducing the length of the questionnaire and minimising participant burden, again the reliability and validity of questions may have been altered by not using the full instruments, which is a limitation.

*Physical activity participation*

Two different physical activity instruments, the single item measure for physical activity (PASIM) (Milton, Bull, & Bauman, 2011) and short international physical activity questionnaire (IPAQ) (Craig et al., 2003)) were used in WW. The PASIM was a measure required by the funder of the Active Travel Consortium of projects, of which WW was one, to enable comparisons across projects. The IPAQ was included as a short measure of physical activity providing more detailed data about different domains of physical activity including walking. Including both measures highlighted the challenges of accurately measuring physical activity levels using self-report surveys, as different estimates of participation were obtained using each measure. For example, using baseline data (reported in Paper 3), the PASIM indicated that only 24.6% of participants met the current physical activity guideline of at least 150 minutes of moderative-to-vigorous intensity physical activity per week (Department of Health, 2011). In contrast, using IPAQ, the mean total moderate-vigorous physical activity was estimated to be 648.6 ±530.5 minutes per week, suggesting participants had very high levels of activity exceeding current guidelines by on average over 8 hours per week. In addition, as discussed previously, self-report physical activity questionnaires are known to have poor reliability and validity, recall of activities is poor, and social desirability may lead to over-reporting of physical activity levels (Shephard, 2003). This particularly applies to short IPAQ, which has been shown to overestimate physical activity by on average 106% (range 36-173%) compared to objective measures (Lee et al., 2011). There was evidence of over-reporting in this study; the use of the short IPAQ is therefore a limitation. In future studies, it would be preferable to use objective measures, such as accelerometers, in at least a sub-sample of the study population, to gain more reliable and valid estimates of physical activity. However, there are challenges with measuring some types of activity with accelerometers (such as cycling) and identifying activities being undertaken for different purposes (e.g. walking for transport vs walking for recreation). Further advances in technology and analytical processing are needed to facilitate this type of objective measurement. This is discussed further in Chapter 5.

*Travel to work behaviour*

A 7 day travel diary which has been tested for reliability (Shannon et al., 2006) and the walking to work question from the TPAQ (Paper 1) were used to assess travel to work behaviour. In WW, the usual mode of transport used to travel to and from work and the time spent walking to and from work (including single and multi-mode trips) were measured separately and reported for baseline and follow-up. Although not directly comparable due to differences in methods of calculation, usage rates of motorised transport, cycling and walking only (single mode trip) were broadly similar to

rates observed in the 2011 National Travel Survey (NTS) (Department for Transport, 2011). Walking in combination with other modes (multi-mode trips) were also reported in WW which may have included some public transport trips. Multi-mode trips are excluded from the NTS which usually only reports the main trip mode (mode used for the longest stage of the trip by distance). The NTS may therefore underestimate the amount of walking for transport being undertaken by only reporting single mode walking journeys. Indeed, in WW, when time spent walking to and from work per week (including single and multi-mode journeys) was reported, over 50% of the sample did some walking as part of their journey to work (Papers 3, 4 and 8). Assessing and reporting walking undertaken for single and multi-mode journeys is a strength of the WW study. In contrast, there may have been some over-reporting due to the self-report nature of the survey (Shephard, 2003).

#### 3.2.3.2 Telephone interviews

Telephone interviews were used to collect information on the experiences and views of those involved in implementing the intervention (overall project manager, workplace champions and business representatives). The advantages of telephone interviews are that they are low cost and were suitable for use in WW due to financial restrictions and the geographical spread of workplaces (Oltmann, 2016). Disadvantages are that telephone interviews tend to be shorter due to the lack of interaction and verbal cues between the interviewer and interviewee, therefore less detailed data may be collected (Oltmann, 2016). A strength of the study was that the rigour and trustworthiness of the data was ensured by considering four criteria: dependability, confirmability, credibility and transferability (Guba, 1982; Shenton, 2004). This included using recognised research methods, using strategies to encourage participants to answer honestly, highlighting the independent nature of the interviewer and using probes to obtain more detailed and confirmatory information.

### 3.2.4 Data analysis

Research in this thesis aimed to examine the association of commuter walking with perceptions of the environment in the neighbourhood (Paper 3) and individual, psychosocial and employment-related factors (Paper 4). In paper 3, a complete case analysis approach was used which resulted in a smaller sample (n=676) and may have led to selection bias (Wood et al., 2005). In contrast in paper 4, cases were included in the analysis if they had data for the dependent variable (n=1,189) resulting in a larger sample. However, in this study there were some differences in characteristics between those included and excluded from the analyses suggesting there was selection bias which may have affected the findings. For example, those excluded were more likely to have a car and have free car parking at work. In both studies, logistic regression was used to assess associations between the

independent variables and the dependent variable (commuter walking). The strengths and limitations of this approach have been discussed previously. As time spent walking to walk was positively skewed, even after log transformation, a dichotomous categorical variable was created for use in analysis. Those who walked for at least 10 minutes on one trip to or from work were categorised as commuter walkers, meaning the threshold for being a walker was quite low. This may have weakened the observed associations. However, dose-response analysis has shown that health benefits can be gained from even small amounts of walking justifying the use of this low threshold (Kelly et al., 2014). The relatively homogeneous sample included in the analyses, which were similar on highest educational qualification, ethnic group and occupation, may have resulted in limited variability weakening associations between independent and dependent variables.

A large number of individual, employment and psychosocial factors were assessed to explore those which could potentially be associated with commuter walking (Paper 4). A strength of the study was the use of a series of univariate logistic regression models to identify variables to include in further analyses. A limitation was that wider empirically or theoretically important variables were not considered. Entering the variables in blocks to enable their contribution to be assessed using Nagelkerke $R^2$ was also a strength. However, there may have been multicollinearity between some of the variables. For example, distance lived from work and the perceived barrier for walking 'I live too far away from work' may have measured the same constructs, affecting the findings of the study by weakening the relationships between variables. The large number of independent variables included in the analyses may have led to over fitting of the statistical models. Observed increases in $R^2$ may have been due to increases in the number of variables in the model, rather than a true relationship between the independent and dependent variables (Altman, 1999) which is a limitation of this study. A backward stepwise regression model was presented which aimed to maximise the predictive power of the independent variables and identify those variables most strongly associated with commuter walking. However, this may also have been affected by multicollinearity and over fitting of statistical models. Future studies may benefit from stratifying the sample by distance lived from work to increase the predictive power and specificity of the models for those who walk for the whole journey to work compared to those who only walk for some of the journey.

The RE-AIM framework (Glasgow et al., 1999) guided the analysis of data collected in the evaluation of the WW intervention (Paper 8). A variety of standard statistical methods were used to assess data relevant to each domain of the framework including chi square tests to assess differences between surveys or groups and non-parametric analysis (Mann-Whitney U Test) to test for significant

differences in continuous data (where data was not normally distributed). Baseline and follow-up survey data were treated as independent samples as it was not possible to match data at the two time points, which is a limitation of this study. Other limitations of the analysis were that it was not possible to fully assess each dimension of the RE-AIM framework. This was due to some data not being collected in the intervention, for example, the characteristics of the workplaces who declined to participate in the intervention (adoption), accurate measures of participation which could only be assessed using the follow-up survey rather than actual participation in activities (reach), costs of the intervention (implementation), and long-term implementation and impact of the intervention due to the short-term nature of the project (maintenance). In addition, it was not possible to robustly assess effectiveness due to weaknesses in the study design used (no control or comparison group; and the use of two cross-sectional surveys).

## 3.3 Fitter for Walking

Fitter for Walking (FFW) was a practice-led intervention delivered in 155 communities located in 12 different local authorities from five different areas of England. The overall aims of the project were to improve the local neighbourhood walking environment, increase the number of people walking on a specific route targeted for environmental improvements and encourage communities and residents to work together to promote walking. Five regional project co-ordinators were appointed to lead the delivery of the intervention. EJA was appointed as the independent evaluator for this project and did not have any role in intervention design or delivery. As for WW, this was a strength in providing an independent assessment of the project, however the timing and content of intervention activities, and practical considerations, created challenges for developing and implementing a robust study design. Data collected were used to assess changes in the number of people walking on a local route after environmental improvements were made (Paper 5), to examine implementation reach, dosage, processes and adaptation of the intervention along with coordinators' perspectives of implementation barriers and facilitators (Paper 6) and to explore communities' perceptions of the implementation and impact of the intervention (Paper 7).

### 3.3.1 Study design

A pragmatic evaluation approach (Glasgow & Riley, 2013) was taken in FFW due to the real-world delivery of the programme. A mixed methods study design was used which included: 1) pre- and post- route user counts (five case study sites); 2) pre- and post- route user intercept surveys (five case study sites); 3) annual focus groups and/or interviews with project co-ordinators; and 4) focus groups or interviews with community members (mid-end project) (19 community projects). In

addition, an implementation log (developed and tested in consultation with coordinators) was used to record real time information on project status and intervention activities delivered, including environmental improvements made. Coordinators also kept records of the numbers of people attending each activity.

Practical and financial constraints limited the scope and scale of the evaluation including the study design, measurement methods used and the number of communities where evaluation could be undertaken. A strength of this study was the use of identical data collection methods and consistency in measures in a sub-set of communities. As for WW, the use of a mixed methods approach was also a strength of the study combining strengths and overcoming weaknesses of each study design (Johnson & Onwuegbuzie, 2004). Route user counts and surveys were utilised to explore changes in pedestrian route use and qualitative interviews with different stakeholders (coordinators and community members) enabled evaluation of intervention implementation. The intervention was delivered at the community level, rather than targeting and recruiting individuals, making assessment of the impact of the intervention challenging. The main limitations were that no control or comparison communities were used, meaning it was not possible to directly attribute changes in route use to the environmental improvements. Any changes observed in route use could have been due to season, weather or natural variation in travel behaviour, rather than environmental improvements.

### 3.3.2 Recruitment methods

There was no individual recruitment to the FFW intervention as the aim of the evaluation was to assess the impact of the intervention at the community level. However, route users were interviewed using an intercept survey. The response rate was low (baseline: 16%; follow-up: 30%) and responses were likely to be biased to those who had time to stop to be interviewed. The sample may therefore not be representative of the population in the community, however it was not possible to assess this due to the lack of population level data in the small-scale area being studied. Although the response rate was low, there was considerable variation in the individual characteristics of route users who participated in the survey within and across case study sites (Paper 5) reflecting diverse local contexts and providing heterogeneous samples. This may have improved the generalisability of the findings.

All coordinators took part in focus groups and interviews providing good representation across the different project areas (Paper 6). Focus groups and interviews were conducted with 86 community

members from 19 projects (Paper 7). Therefore, a large number of individuals provided information about their experiences, which is a strength of the study. There are few directly comparable projects, however another similar study only recruited 31 participants (Kaczynski & Sharratt, 2010). Projects and participants were recruited from diverse geographical areas to ensure representation from different contexts. Due to financial constraints, it was only possible to conduct focus groups/interviews with 19 of the 155 projects undertaken, therefore the findings may not have been representative of the experiences of all projects. In addition, due to the pragmatic nature of the evaluation, most projects which were represented had been involved with FFW for some time and made progress with intervention activities, therefore there may have been some bias in the findings towards those who had successfully participated in the intervention.

### 3.3.3 Measurement methods

The main outcome for FFW was to assess changes in numbers of individuals walking on routes targeted for improvements. Therefore, route user counts and surveys were selected to gain some insight into the level of route use, and the purposes routes were used for, before and after improvements to the route were made (Paper 5). This approach has been advocated for measuring changes in behaviour due to environmental improvements (Krizek et al., 2009) and has been used in interventions similar to FFW (Morrison et al., 2004). However, route user counts and surveys are limited in that they only include those actually using the route, only basic information about route users can be collected and they do not allow any assessment of the volume of walking for transport an individual is doing, or their overall physical activity behaviour (Krizek et al., 2009). Due to these issues, and the cross-sectional nature of route user counts and surveys, it was not possible to assess individual behaviour change which is a limitation of the study. In addition, unvalidated route user surveys were used and counts and surveys were only conducted on one weekday and one weekend day at each time point, therefore any variability across the week was not assessed. The counts and survey responses may have been strongly influenced by the weather and variations in the season in which data was collected as these can affect walking for transport (Clark et al., 2013). However, the weather on each count day was recorded at regular intervals and reported with the findings to enable readers to make some judgement as to whether it may have affected the results (Paper 5). Financial constraints limited the number of times the counts and surveys could be conducted, thereby potentially missing changes in route use. Future interventions might conduct route user counts and surveys on a three-monthly basis to capture changes over time. Alternatively, automatic counters or video cameras might be installed to allow for continuous monitoring and to provide

more robust data (Krizek et al., 2009). Additional alternative study designs and measurement methods are discussed in Chapter 5.

Implementation was comprehensively assessed in FFW, which is a strength of the study. Regularly collecting data from coordinators, by using focus groups and interviews along with the implementation logs, provided valuable data on changes that occurred in implementation as the project progressed. As previously, a strength of the study was that the rigour and trustworthiness of the data was ensured by considering four criteria: dependability, confirmability, credibility and transferability (Guba, 1982; Shenton, 2004). A limitation of the study is that it was not possible to quantitively evaluate the level of intervention delivered in each area with the methods utilised, therefore no robust comparison of intervention activities between different community projects was possible. Improving data collection of the level, or 'dose' or intervention delivered and received is an area for future research to help more fully understand implementation. However, this may be challenging in community-wide interventions. Using comprehensive process evaluation methods along with a focus on implementation research will help to improve the evidence in this area (Moore et al., 2015; Peters et al., 2013).

### 3.3.4 Data analysis

Due to the nature of the numerical data collected (raw count data), for which the limitations are described above, it was not possible to use inferential statistics to analyse the findings from route user counts. Thus, only descriptive data are reported and proportion of change between time points, which is a limitation of the study. A similar approach was used elsewhere (Morrison et al., 2004). Deductive and inductive approaches were used to thematically analyse qualitative data from focus groups and interviews with coordinators and community representatives providing detailed insight into intervention implementation. Using both deductive and inductive approaches is a strength of this study allowing hypotheses to be tested and the development of new theory and explanations (Jones, 2015). The findings from coordinator focus groups and interviews were reported using a recognised framework for implementation research including assessment of implementation outcomes such as reach, dosage and adaptation (Durlak & DuPre, 2008) which is a strength of the study (Paper 6).

# Chapter 4. General discussion

The aim of this thesis was to undertake research on walking for transport in adults to address the problem of how to increase population levels of physical activity to improve health and well-being. This chapter summarises the key findings reported in the eight published articles in relation to the research objectives of the thesis and discusses the findings in the context of the wider literature. Where possible findings across multiple papers are integrated and the text is cross-referenced to the relevant paper(s).

## 4.1 Summary of key findings

The key findings from the research articles presented in this thesis are summarised below in relation to each of the research objectives.

**Objective 1: To develop a self-report measure of transport and physical activity behaviour which enables specific domains of physical activity being undertaken for different purposes (including walking for transport) to be assessed separately, and to test the reliability and validity of the physical activity items in this measure**

- The Transport and Physical Activity Questionnaire (TPAQ) was developed for use in multi-disciplinary studies. TPAQ assesses time spent using six different modes of transport (walking, cycling, bus, train, car as a driver, car as a passenger and other) for five journey purposes (to and from work; for business purposes; to and from a place of study; for shopping and personal business; and to visit friends or family, or for other social activities) and time spent in four different domains of physical activity (vigorous physical activity, moderate physical activity, walking for recreation, cycling for recreation) (Paper 1).
- The reliability and validity of the TPAQ for measuring total physical activity and specific domains of physical activity were found to be comparable to those of existing physical activity questionnaires (Paper 1).

**Objective 2: To identify individual, psychosocial and environmental factors influencing walking for transport in adults**

- A new 13-item scale was developed to assess adult's perceptions of the environment in the neighbourhood (PENS) in the UK context. This was found to have comparable reliability to other similar scales and thus was considered acceptable for use (Paper 2). Using this scale and TPAQ (Paper 1), walking for transport was found to be positively associated with the following perceived neighbourhood environmental attributes: supportive infrastructure,

availability of local amenities, and general environment quality; in contrast walking for recreation was only associated with supportive infrastructure. The environmental attributes for cycling for transport and cycling for recreation also differed to walking for transport (Paper 2).

- Walking to and from work was positively associated with the perceived presence of convenient walking routes, suitable pavements, maintained pavements or convenient public transport in the workplace neighbourhood (Paper 3).
- Walking to and from work was positively associated with employees who were aged <30 years, did not have a car, had no free car parking at work, were confident of including some walking or intended to walk to or from work on a regular basis, and had support from colleagues for walking. It was negatively associated with employees' perceptions that: they lived too far away from work to walk; walking was less convenient than using a car for commuting; they did not have time to walk; they needed a car for work; or they had always travelled the same way (Paper 4).

**Objective 3: To evaluate the implementation and impact of interventions promoting walking for transport in community and workplace settings and make recommendations for research, policy and practice**

**Communities:**

- The Fitter for Walking (FFW) intervention worked with 155 local communities across England to make small-scale improvements to the local neighbourhood physical environment and promote walking for transport, reaching 30,230 residents. A wide variety of environmental changes were made which were led by local authorities (e.g. removal of encroaching vegetation, new/improved pedestrian signage, new dropped kerbs/kerb improvements, and new, repaired or improved footpaths) or by communities (e.g. planting bulbs, shrubs or bedding plants, clean-up days and litter pick-ups). Additional activities were undertaken to help increase awareness of the benefits of walking and promote the newly improved routes (e.g. led walks, themed walks, development of maps/resources and community events) (Papers 5 and 6).
- After 12 months, there was a decrease in pedestrian route use overall and in four out of the five case studies where data collection took place. However, after 14-20 months there was a 14.9% increase in pedestrian route use overall and in all case studies (range 5.4-58.9%).

Route users' awareness of environmental improvements which had been made was low (Paper 5).

- Participants in the FFW intervention perceived the main impacts to be improved physical and social environments. Increases in walking for transport were rarely reported, though participants did refer to increases in walking as part of intervention activities and increased street use (Paper 7).
- Using community engagement approaches and working with local authorities to improve the physical environment on local routes to key destinations, such as shops, public transport, workplaces, schools, leisure facilities and entertainment venues, is complex and requires considerable investment, staff resource and time. Processes required for implementation of the intervention were identified which included planning, preparation and delivery phases. Adaptability of the intervention to fit the local context was highlighted as being critical for successful programme delivery. Coordinators and community members highlighted barriers and facilitators for implementation related to working with and engaging communities, the critical role of the coordinator, and working with local authorities and other partners. Recommendations were provided for future design, planning and implementation of interventions (Papers 6 and 7).
- The challenges of using robust study designs to evaluate the impact of interventions which aim to change the physical environment to promote walking for transport were highlighted, along with recommendations for future evaluation design and working with those implementing interventions in practice (paper 5).

**Workplaces:**

- A whole-workplace walking intervention, Walking Works (WW), which aimed to increase walking to and from work and during the working day was evaluated using the RE-AIM framework. No changes in walking behaviour were observed which may have resulted from barriers in using volunteer employee walking champions to deliver activities, the programme components not being delivered as originally intended, the types of activities which were delivered, and lack of awareness and participation by employees (Paper 8).
- Recommendations were provided for the implementation of future whole-workplace walking programmes regarding: recruitment of workplaces; workplace buy-in and commitment; using employees as implementers; recruiting and engaging employees; planning and delivering activities; facilitating sustainability; and monitoring and evaluation (Paper 8).

## 4.2 Discussion of key findings

### 4.2.1 Specificity in physical environment influences on walking for transport

Findings from this thesis contribute evidence that perceived attributes of the residential neighbourhood physical environment are associated with walking for transport in the UK, and that these differ from physical environmental attributes associated with other behaviours (walking for recreation and cycling for recreation or transport) (Paper 2). The findings support similar evidence from other countries (Kerr et al., 2016; Saelens & Handy, 2008; Van Dyck et al., 2012; Van Holle et al., 2012). However, direct comparisons to these studies are not possible due to heterogeneity in study design and measurement methods. For example, there are differences in: the environmental constructs assessed and reported (e.g. individual items or factors identified from individual items vs walkability indices); the methods and instruments used for assessing the environment (e.g. perceptions of the environment instruments such as NEWS (Cerin et al., 2006) or ALPHA (Spittaels et al., 2009) vs GIS measures); and the methods and instruments used for assessing walking for transport (self-report surveys such as IPAQ long (Craig et al., 2003) vs objective measures such as accelerometers). Despite this, the findings provide evidence of associations of environmental attributes with walking for transport which can be explored in longitudinal studies and further support the need for specificity in understanding and promoting different behaviours, congruent with previous research (Giles-Corti et al., 2005; Owen et al., 2004; Pikora et al., 2003).

Most studies to date have assessed perceptions of physical environment attributes in residential neighbourhoods and associations with walking for transport (Kerr et al., 2016; Van Dyck et al., 2012). This may be relevant for short journeys from home where walking is the only mode of transport used. However, it does not consider that walking may be part of longer multi-modal journeys and that the physical environment at destinations, such as workplaces, may differ from that in the residential neighbourhood and may also be an important influence. Recent research has demonstrated that individuals may undertake a large proportion of their physical activity outside of the residential neighbourhood (Hillsdon et al., 2015). Therefore, considering only the environment in the residential neighbourhood may neglect wider environmental influences. This thesis includes one of the first studies to directly investigate the relationship between walking to and from work and the workplace neighbourhood environment (Paper 3). Previous studies (Adlakha et al., 2015; Schwartz et al., 2009) have not investigated walking to work as a discrete behaviour in relation to the workplace neighbourhood environment, and they were conducted outside of the UK where contexts may differ. A small number of studies (Panter et al., 2011; Panter et al., 2014) have assessed perceptions of the route environment on the journey to work, rather than specifically in the workplace neighbourhood.

However, these studies do not enable changes in the environment that may occur along the route, particularly on longer journeys, to be recorded. Therefore, this may not accurately capture perceptions of the environment in different contexts (residential neighbourhood vs workplace neighbourhood), reducing specificity. In the study reported in this thesis, perceived attributes of the physical environment in the workplace neighbourhood were found to be associated with walking for transport for the journey to and from work, including the perceived presence of convenient walking routes and suitable or maintained pavements. In contrast, another study (Panter et al., 2011) found the perceived presence of convenient walking routes was not a strong predictor of walking to work, whilst perceiving it was pleasant to walk and there being little traffic were significantly associated with walking to work. Differences in the instruments used in these studies, the environmental attributes assessed, and the area of reference studied (workplace neighbourhood vs. commuting route) limits comparison of specific findings.

A study included in this thesis (Paper 3) also showed strong associations between perceived availability of public transport and walking to and from work. There was evidence that this may be more important than environmental attributes in promoting this behaviour. The association between perceived convenient public transport and higher levels of walking to work has also been reported elsewhere (Panter et al., 2011). This requires further investigation given growing evidence that using public transport leads to higher levels of walking for transport, making a significant contribution to overall physical activity levels (Besser & Dannenberg, 2010; Freeland et al., 2013; Lachapelle & Noland, 2012; Lachapelle & Pinto, 2016; Morency et al., 2011; Rissel et al., 2012).

Together the findings from the studies in papers 2 and 3 of this thesis confirm the need for specificity in studying behaviours and environments. The findings suggest that walking for transport may be influenced by environmental attributes, albeit some of the associations are relatively weak and other factors, such as the availability of public transport, may be stronger predictors. Additional research is needed to examine the relationship between walking for transport and the physical environment at specific destinations, such as workplaces. More specifically, evidence is needed as to the relative importance of the physical environment for promoting walking for transport in comparison to other factors, such as the provision of public transport. Interventions which aim to modify the physical environment may be needed in residential neighbourhoods and potentially at destinations, such as workplaces, but the importance and effectiveness of improving the environment to promote walking for transport requires further investigation in intervention studies. Ultimately, a comprehensive and cohesive network of walking routes to all destinations and services

including workplaces, along with provision of public transport, may be required to fully support walking for transport for single mode, or as part of multi-mode, journeys.

### 4.2.2 Is changing the physical environment enough to increase walking for transport?

Physical environmental interventions have the potential to reach and influence a large proportion of the population and have been hypothesised to increase physical activity by promoting walking and cycling (Heath et al., 2006). However, it is not yet clear whether changing the physical environment is needed, or is sufficient in isolation, to encourage new individuals to change their travel behaviour and take up walking for transport. Environmental improvements may simply encourage existing users to increase their use of the improved routes (National Institute for Health and Care Excellence, 2018). Preliminary evidence suggests that physical environment changes may be needed to support walking for transport, but may not be sufficient alone to instigate behaviour change and increase walking for transport (Song et al., 2017). Therefore, other potential influences and how they interact needs to be considered. Ecological models provide a useful framework for research in this area highlighting multiple individual, intra- and inter-personal, organisational, environmental and policy-related factors which may influence behaviour (Mcleroy et al., 1988; Sallis et al., 1998).

The findings in this thesis suggest that, in addition to the physical environment, a range of individual, psychological, organisational and social environmental factors may be important influences on walking for transport (Papers 4 and 7), which is consistent with previous research (Giles-Corti & Donovan, 2003; Panter & Jones, 2010). These findings extend the evidence base in this area, particularly in relation to walking to and from work, confirming previous findings with regards to age, car ownership, distance lived from work, availability of free car parking at work and perceived behavioural control (Bopp et al., 2012; Laverty et al., 2013; Panter et al., 2011; Panter et al., 2013) and add new evidence regarding the role of social support from colleagues. Furthermore, as noted previously, other environment-related factors may be important, such the availability and convenience of public transport (Paper 3). Specifically, this may be a significant influence on walking for transport for those who live too far from certain destinations to be able to walk the entire journey.

The social environment is also postulated in ecological models to influence behaviour (Mcleroy et al., 1988; Sallis et al., 1998). However, the role of the social environment in promoting walking for transport has been understudied (Hunter et al., 2018). A small number of studies have investigated the relationship between social support from family and friends and active travel (walking and

cycling), but findings have been mixed (Panter & Jones, 2010). Some research has explored the relationship between social capital and walkability, finding living in walkable neighbourhoods is related to higher levels of social capital (Leyden, 2003), but limited research has been undertaken to examine the relationship between social capital and walking for transport behaviour. Qualitative investigation in this thesis contributes evidence which suggests that using community engagement approaches to consult communities regarding their local walking environment, and encouraging them to participate and work together to undertake environmental improvements, may lead to substantive perceived changes in social capital (Paper 7). This in turn appeared to result in changes in perceptions of the local area related to improved safety from crime and anti-social behaviour, leading to a perceived increase in street use and by proxy, an increase in walking for transport (though this could not be verified due to limitations of the study design). This suggests that increasing social capital, in addition to providing a supportive physical environment, may be important in promoting walking for transport and warrants further investigation in quantitative studies. Indeed, one study in Canada has reported that neighbourhood social cohesion (a key component of social capital) positively influenced time spent walking for transport (Clark & Scott, 2013).

Overall, based on findings in this thesis and evidence to date, changing the physical environment alone may not be sufficient to increase walking for transport. In order to maximise the effectiveness of interventions and increase walking for transport and overall physical activity at the population level, future interventions are needed which include components addressing multiple individual, social and physical environmental factors. These types of multi-level interventions have previously been advocated (Ball, 2006; Sallis et al., 2006). Determining the relative importance of different levels of influence for changing walking for transport behaviour continues to be a challenging but important area for research. Theoretical and statistical models need to be developed to identify and understand the complex interactions between variables and potential mediators and moderators of the behaviour (Panter & Jones, 2010).

### 4.2.3 Can small-scale changes to the physical environment increase walking for transport?

Most published research studies evaluating the effectiveness of environmental improvements for increasing walking for transport have assessed interventions which have involved relocating to a new neighbourhood where residents are exposed to a different type of environment, installing or improving large-scale walking and cycling infrastructure, or the development of new or improved public transport or road systems (Boarnet et al., 2013; Brown & Werner, 2009; Foley et al., 2017;

Giles-Corti et al., 2013; Goodman et al., 2014; Heinen et al., 2015; Knuiman et al., 2014). These types of improvements require substantial changes to the urban landscape, significant investment, can take a long time to implement and even longer to instigate changes in walking for transport behaviour. This thesis presents an alternative strategy to improving the neighbourhood environment by using a community engagement approach to make small-scale changes such that more rapid, relevant improvements can be made at a lower cost. Only one similar study has been identified (Krieger et al., 2009) which found increases in walking following the intervention, but this was only measured in walking group members rather than at the community level. The findings from the work in this thesis showed that making small-scale changes to key routes in the neighbourhood, with community consultation and action, is feasible (Papers 5 and 6) and thus this approach could be used in future interventions. However, it should be noted that this can take time and effort (Heath et al., 2006). This was confirmed in the research this thesis along with the need for substantial support and resource (Paper 6).

Increases in pedestrian route use (walking for transport) were observed in five case study sites where small-scale environmental improvements were made to a local route (Paper 5). However, these increases were not observed until 14-20 months after baseline, thus supporting previous findings that it may take considerable time before environmental changes lead to a detectable change in walking for transport levels. The findings should be interpreted with caution as weaknesses in study design mean the changes observed cannot be directly attributed to the environmental changes. Furthermore, there was low awareness of environmental improvements in route users suggesting the changes might not have directly impacted on individual decisions to walk. Further research is needed to investigate whether changing the environment influences behaviour, and how, and the types and scale of environmental changes needed to instigate behaviour change. More robust study designs are needed to assess the effectiveness of environmental interventions. However, this is a challenge which applies to the work in this thesis and for the wider field of research (Ogilvie et al., 2010). This is discussed further in Chapter 5.

### 4.2.4 Targeting specific journeys and contexts in walking for transport interventions

Targeting certain journey purposes may help to further increase specificity in understanding and promoting walking for transport. For example, the journey to and from work, which is a relatively stable behaviour with 72.3% of adults in England travelling to the same workplace each day (Department for Transport, 2015), provides an opportunity to intervene. Understanding specific factors influencing walking to and from work can help to target and tailor interventions, which is

known to be important in designing interventions which are effective in promoting walking (Ogilvie et al., 2007). As discussed previously, findings from the research in this thesis confirmed and extended knowledge of the behaviour-specific associations between individual, psychosocial and employment-related factors and walking to and from work (Paper 4). It also contributed evidence of potential associations between the physical environment and the availability of public transport in workplace neighbourhoods with walking to and from work (Paper 3). These multi-level factors should be taken into consideration in intervention planning and design (Sallis et al., 2006).

The author is not aware of any previously published interventions which have used multi-level approaches or a whole-workplace approach to specifically promote walking to and from work. An evaluation of the implementation of a whole-workplace walking intervention, organised by volunteer employee champions, is included in this thesis (Paper 8). This research contributes new evidence related to the challenges of delivering whole-workplace walking to work interventions in real-world settings. Although the components which were suggested as part of this intervention included a range of activities addressing multi-level factors, the practice-led nature of the intervention resulted in mostly short-term, one-off challenges and campaigns being delivered due to challenges with implementation. This meant activities were not based on evidence or theory, which is known to be important for delivering effective interventions (Glanz & Bishop, 2010), limiting the potential of the intervention to change behaviour. Future interventions would benefit from researcher input into designing and developing intervention activities using co-production and frameworks for guiding intervention development (Hawkins et al., 2017).

Research in this thesis (Paper 8) confirmed the intervention activities were not sufficient to change walking to work behaviour. No changes in transport mode or time spent walking on the journey to and from work were observed. However, due to practical and financial considerations, a pre-/post-study design was used with no control or comparison group, limiting interpretation of the findings. Similar cross-sectional approaches have been used to evaluate the impact of workplace travel policy on walking (and cycling) to work (Brockman & Fox, 2011; Petrunoff et al., 2016) and the impact of a national walk to work day campaign (Merom et al., 2005). Small but significant increases in walking to work were observed in all three studies, however the findings were also limited by weak study designs similar to those used in this thesis. A limited number of other published studies have promoted and evaluated walking to work interventions using more robust study designs. One study tested a self-help intervention which included written interactive materials based on the transtheoretical model of behaviour change in a randomised controlled trial (Mutrie et al., 2002).

Another pilot study tested a 10 week individually targeted intervention delivered by trained walk to work promoters in a cluster randomised controlled trial (Audrey et al., 2015). These interventions had a positive impact on walking for work and thus offer potential intervention strategies. However, behaviour change was only measured in the short-term (less than 12 months), therefore it is not known whether the changes in behaviour were sustained in the longer-term. Furthermore, both studies used only individually targeted interventions and therefore may have had limited reach. More comprehensive workplace-wide interventions may be needed to maximise effectiveness and sustainability of intervention delivery in the longer-term, and to support changes in travel to work behaviour across whole employee populations.

The findings in this thesis (Papers, 3, 4 and 8) suggest that multi-level interventions based on ecological models (Sallis et al., 1998) are needed in workplace settings to promote walking to work. Determining feasible and optimal implementation strategies for delivering interventions in real-world settings to promote long-term sustainability and ensuring practice-led interventions are designed using appropriate theory, evidence and guidance, is a priority. Further research is needed to identify effective interventions for promoting walking to work using more rigorous study designs. Lessons may be learnt from research into interventions promoting walking to school, both in terms of intervention content and research methodology, which have been much more extensively studied (Larouche et al., 2018; Pang et al., 2017). Identifying effective walking to work interventions which can be embedded into daily workplace practice and sustained in the long-term is a substantial area for future work.

### 4.2.5 Implementing walking for transport interventions

Despite the evidence of effectiveness for some types of intervention (Dunn et al., 1998; Global Advocacy for Physical Activity Council of the International Society of Physical Activity and Health, 2012; Heath et al., 2012; Kahn et al., 2002) and policy support for the implementation of interventions (Public Health England, 2014), population levels of participation remain largely unchanged (Health and Social Care Information Centre, 2017). Some of the reasons for this could be the failure to translate research knowledge into policy and practice, failure to develop evidence-based policy and practice (Giles-Corti et al., 2015), and challenges in implementing and scaling up interventions in real world settings (Reis et al., 2016). Inadequate resources and lack of incentives may also affect how completely and appropriately interventions are implemented and evaluated (Heath et al., 2006).

Evaluating the implementation of walking for transport interventions is an understudied area of research. A small number of studies have reported the implementation of community-based walking interventions (Hanson et al., 2016; National Institute for Health and Care Excellence, 2012). However, these have mainly focussed on recreational walking, sometimes in groups, rather than walking for transport. The author is not aware of any published studies reporting the implementation of workplace-based walking for transport interventions. This thesis therefore contributed new evidence to demonstrate the challenges stakeholders face in implementing interventions promoting walking for transport and made recommendations for how to overcome them (Papers 6, 7 and 8). The findings revealed that working with local authorities and communities to make environmental changes, and implementing interventions in workplaces using employees as champions, is complex, challenging and resource intensive. These findings are highly relevant to current policy (Department for Transport, 2017a; National Institute for Health and Care Excellence, 2008b, 2012, 2018) which advocates action by multiple stakeholders to deliver recommended guidelines and policy actions. The extent to which these guidelines and policies are adopted and implemented in practice requires further investigation using implementation science methodology (Peters et al., 2013) and is an area for future research.

# 5. Implications and conclusions

This chapter discusses the challenges and opportunities for current walking for transport research considering the overall findings in this thesis and the strengths and limitations of the research undertaken. It highlights the implications of these along with gaps in the literature and makes recommendations for future research, practice and policy.

## 5.1 Implications for research

### 5.1.1 Measurement of walking for transport and the physical environment

Defining walking for transport is challenging due to the complex nature of travel behaviour and difficulties in distinguishing walking for transport from walking for other purposes such as leisure and exercise (Merom & Korycinski, 2017). As a result, disaggregating walking for transport from other types of walking presents challenges for measurement of the behaviour for research purposes. Furthermore, the multi-disciplinary nature of walking for transport research creates challenges for measurement, with different approaches being used by the public health and transport sectors (Krizek et al., 2009). The availability of tools which meet the needs of both sectors, by enabling transport mode shift to be assessed as well as time spent in different domains of physical activity, has previously been limited. This thesis presents a new self-report instrument (TPAQ) which allows a comprehensive assessment of transport and physical activity behaviour to be undertaken (Paper 1). Whilst the instrument was found to have comparable reliability and validity for assessing physical activity constructs to other similar instruments, the limitations of using self-report instruments to measure physical activity related constructs remain. This includes poor reliability and validity, poor recall of activities, over-reporting of activity due to social desirability, and response variation due to seasonal changes (Shephard, 2003). A limitation of paper 1 is that the validity of the individual transport items (i.e. time spent travelling and distance travelled using six different modes of transport for five journey purposes) was not reported. This was due to a lack of resource to undertake the intensive manual processes and complex analytical techniques required to analyse the accelerometer and GPS data to identify different modes of transport being used. The newly developed questionnaire may therefore have limited utility as a comprehensive measure of physical activity and travel behaviour, simply adding another similar physical activity questionnaire to the already extensive number available (van Poppel et al., 2010).

Use of self-report measures of physical activity with poor reliability and validity is a limitation of the work in this thesis, which also applies to the overall body of research in this area and across the

wider physical activity and public health field (Shephard, 2003). This and low response rates to surveys, as seen in the studies in this thesis and elsewhere, presents a major challenge for research. Future studies would benefit from the use of objective measures of the behaviour, such as accelerometers, which may be less intrusive for participants and result in lower participant burden for data collection (Berlin et al., 2006). The use of these types of measure would be desirable for all future studies in this field instead of using self-report measures. However, whilst objective measures, such as using accelerometers combined with GPS, may provide a solution for measuring physical activity, identifying walking for transport trips using these measures is still challenging and labour intensive. Advancements in technology for objectively measuring physical activity, and the development of analytical processes such as machine learning (Ellis et al., 2014), will help to progress this field of research. This will require working with other disciplines, such as computer scientists and mathematicians. A promising new technology includes ecological momentary assessment (EMA) (Dunton, 2017) which will aid the collection of real-time contextual data currently lacking in objective measurement. Specifically, this will help to address a gap in the evidence by enabling patterns of walking for transport overall and for different journey purposes (e.g. to public transport stops, to work) to be determined (including time spent walking, intensity and context). This will facilitate the identification of opportunities for intervention and potentially offer new intervention approaches.

In addition to a measure for assessing physical activity and transport behaviour, a new self-report instrument was presented in this thesis for assessing perceptions of the neighbourhood environment for supporting walking (and cycling) (Paper 2). This contributed a new short tool with similar reliability to other measures relevant for use in UK neighbourhoods. There are several challenges of using instruments for assessing perceptions of the environment, including that they are likely to be biased to those who walk (or cycle) and have more awareness of the environment (Koohsari et al., 2015) and that researcher-defined neighbourhoods (usually 10-15 minutes from a person's home) do not correspond with those considered by participants responding to questionnaires (Smith et al., 2010). An alternative to this is to use objective measures, such as GIS. This provides a more direct assessment of environmental attributes which can be evaluated in the researcher-defined area of interest (Butler et al., 2011). However, mismatches between the perceived and objectively-measured environment have been reported, whereby those living in objectively-measured highly supportive walking environments perceive the walking environment to be poor (Koohsari et al., 2015). Therefore, individual perceptions of the environment may be as important as objectively measured attributes of the environment in influencing walking for transport

and one should not necessarily replace the other (Ogilvie et al., 2008b). Understanding the differences between the associations of walking for transport with perceptions of, and objectively measured, environments is a gap in research. Using both measurement approaches simultaneously is warranted in future studies to account for this and further research is needed to investigate this mismatch.

### 5.1.2 Determinants of walking for transport

Understanding the factors influencing walking for transport is important for identifying target groups and designing interventions. Several individual, psychosocial, employment-related and environmental factors associated with walking for transport (or specifically walking to work) were identified in this thesis (Papers 2, 3 and 4) extending the evidence base in this area. However, the use of cross-sectional study designs to establish these relationships is a limitation of this research, and of the overall evidence in this field. This prevents any assessment of causality, thus the factors identified in this thesis and in much of the wider research are correlates rather than determinants (Bauman et al., 2012).

There is now an extensive body of evidence identifying the correlates of walking for transport, particularly in relation to the physical environment (Van Holle et al., 2012; Van Dyck et al., 2012). Future research needs to move towards identifying determinants of the behaviour to help with understanding of the causes of walking for transport. This will require the use of longitudinal studies to assess how changes in different factors affect changes in the behaviour. For example, conducting a longitudinal prospective cohort study with a larger, more diverse group of participants living or working in more varied environments, would enable a more robust examination of how these factors affect the outcome of interest. An example is reported by Bentley et al., 2018. Careful consideration should be given to collecting data on potential confounding variables, such as choice of residential neighbourhood and whether individual's move to a new house during the study period, as this may affect study findings.

### 5.1.3 Implementation and effectiveness of walking for transport interventions

Evaluating interventions in real-world settings is a priority for research (Reis et al., 2016). The work in this thesis contributes new evidence in relation to two intervention studies which targeted small scale environmental changes in neighbourhoods (Papers 5, 6 and 7) and interventions for promoting walking to and from work (Paper 8). The two interventions were practice-led with no researcher input into intervention design or implementation. Failure to use evidence- or theory-based

strategies may have reduced the potential impact of the interventions for changing behaviour (Glanz & Bishop, 2010). This needs to be addressed in future interventions by encouraging the development of research-practice partnerships to promote co-production of research and intervention content (Hawkins et al., 2017). There was limited funding available for evaluation, or time to develop evaluation methodologies prior to interventions commencing, which is common in practice-led real-world interventions. This presented challenges for using robust research methodology to assess implementation and effectiveness. The lack of funding, and timing of practitioners engaging with researchers, needs to be addressed if robust evaluation of these types of interventions is to be undertaken. In the two interventions described above, pre- / post- study designs were used to assess changes in walking for transport, with no control or comparison groups. Both are a limitation of these studies, but not dissimilar to other studies conducted in the field (Brockman & Fox, 2011; Krieger et al., 2009; Merom et al., 2005; Petrunoff et al., 2016). Future research should aim to use more robust study designs (described below). However, it is recognised that it is not always feasible to do so when evaluating complex public health interventions (Craig et al., 2008).

There remain gaps in knowledge as to the effectiveness of changing the environment to influence walking for transport. Given the small number of studies in these areas, and limitations in study designs used which may have led to bias (Benton et al., 2016), more research using rigorous methodology is needed to develop the evidence in this area. However, evaluating interventions which aim to change the physical environment presents challenges for research due to researchers having no control over the interventions delivered and uncertainty as to whether and when environmental changes will be implemented (Ogilvie et al., 2010). These types of interventions are typically not suitable for evaluation using randomised control designs. This is because the intervention is usually being delivered at a specific location, therefore randomisation to receive the intervention is usually not possible. Identifying suitable control or comparison groups/sites is also difficult. This is due to challenges finding groups/sites matched on key characteristics because of differences in local contexts. Natural experiments are often used for research in this field taking advantage of opportunities where environments are being changed as part of real-world projects or policies (Craig et al., 2012). These are feasible but are challenging to implement (Ogilvie et al., 2010).

Recommendations for future evaluation of physical environment interventions which aim to promote walking for transport in real-world settings are provided as part of this thesis (Paper 5). Suggestions with regard to research design include using the approach taken in the iConnect study

whereby participants who lived varying distances from the improved route were surveyed in order to assess exposure to varying 'doses' of the intervention (Ogilvie et al., 2012). In addition, comparison routes matched on key characteristics could be used (Krizek et al., 2009). Alternatively, if there are multiple intervention sites, and these have been identified at the start of the intervention, a step-wedge cluster randomised study design could be used. This would enable sites to act as control sites and then be randomly assigned to commence the intervention at different time points (Hemming et al., 2015). This study design may be challenging to use in environmental interventions which have uncertainties around the timing of environmental improvements. In community-based projects where local residents are involved in designing and implementing interventions, such as making small-scale changes to local environment to promote walking, future studies might consider the use of citizen science (Hinckson et al., 2017). Researchers could then work more closely with community members using a community-participatory based approach, to improve both intervention delivery and the research designs used in the implementation and evaluation of real-world interventions. Overall, working with stakeholders to engage in the process as early as possible and facilitate the use of the most rigorous research designs is important (Humphreys et al., 2017).

There are also gaps in knowledge as to the effectiveness of interventions to promote walking to work and this is an area for substantial future research. Improving the quality of research designs used to evaluate walking to work interventions is also a priority for research in this field. The use of cluster randomised controlled studies to study workplace walking to work interventions is feasible (Audrey et al., 2015) and should be prioritised. Alternatively, the use of step wedge designs might offer a suitable pragmatic approach for evaluating interventions being delivered in workplaces (Hemming et al., 2015).

Understanding implementation in real-world settings is important for optimising delivery of interventions (Peters et al., 2013). Research in this thesis found that implementation of the two interventions reported in this thesis was challenging and resource intensive, resulting in changes to strategies (loss of fidelity) during the interventions and different levels of implementation at different sites. The adaptation of interventions during implementation has implications for assessing the effectiveness of interventions but may be important in embedding and scaling-up interventions in practice. The trade-off between fidelity and adaptation requires further research (Chambers & Norton, 2016). Using implementation science methodology to understand and optimise the delivery of walking for transport interventions in real-world settings is important. Existing frameworks and

models are available (Tabak et al., 2012) and should be used to guide implementation research for future walking for transport interventions.

Many interventions to promote walking for transport are being implemented in practice. These are typically poorly evaluated thereby missing an opportunity to develop the evidence base (Hanson & Jones, 2017). There is an opportunity for researchers to work with practice to improve the design, implementation and evaluation of real-world interventions. This presents several challenges and opportunities outlined above. Establishing research-practice partnerships may help to improve this (Giles-Corti et al., 2015) and support the development of a robust evidence base for promoting walking for transport.

## 5.2 Implications for practice and policy

Promoting walking for transport is of interest to a variety of stakeholders from multi-disciplinary fields of work. It is likely to require investment and action from all partners in a collaborative, comprehensive and co-ordinated manner to effectively implement interventions which increase walking for transport and overall physical activity levels. Developing individual level programmes requires input from a range of sectors to design and implement intervention components. Making changes to the physical environment requires transport and urban design/planning teams, often (but not always) based in local authorities, to plan and undertake small- and large-scale infrastructure changes and implement local transport policy and plans. Employers have a role to play in increasing walking for transport by promoting sustainable travel to work through delivering programmes, developing a supportive organisational culture, advocating for the provision of a suitable pedestrian-friendly walking environment in and around the workplace with public transport options, and implementing organisational travel policy. Communities have a role to play in identifying local barriers to walking for transport and lobbying local authorities for improvements, as well as undertaking some environmental improvements themselves and taking responsibility for maintenance of the improvements.

The findings in this thesis should be considered in the future design, planning and implementation of interventions. Detailed recommendations for the development and implementation of community-based and workplace-based walking for transport interventions are provided as part of this thesis (Papers 6, 7 and 8). In summary, the following key recommendations for practitioners and policy-makers are outlined below:

- Practitioners should engage with researchers at an early stage of intervention development to co-produce interventions and ensure they are based on evidence and theory. This will maximise potential effectiveness, make effective use of funding available and allow time to develop robust evaluation study designs to improve the quality of the evidence base (Craig et al., 2008; Glanz & Bishop, 2010; Hawkins et al., 2017).
- Practitioners and policy makers should ensure sufficient funding is made available for researchers to undertake robust evaluation of interventions being delivered in real-world settings. Time should be incorporated into intervention planning to enable robust evaluation methods and measures to be put in place before the intervention starts.
- In changing the physical environment to promote walking for transport, the following should be considered:
  - Different attributes of the physical environment are associated with different behaviours being undertake for different purposes. This requires improved walking and cycling infrastructure, access to destinations (and therefore mixed land use) and general environmental quality to create overall 'activity friendly' environments within and outside neighbourhoods. This should be considered in future transport and planning policy.
  - Convenient access to public transport at destinations such as workplaces may be more important than a supportive physical environment in encouraging walking for transport. This may be particularly important for individuals who live too far from work (or other destinations) to walk for the entire journey. Action should be taken to ensure public transport is available, but also that it is reliable. This confirms existing policy guidance (National Institute for Health and Care Excellence, 2018).
  - Working with local authorities may help to support the implementation of local environmental improvements. However, local authorities may have limited funding and capacity to undertake substantive changes in a timely manner therefore this should be managed carefully. Further investment is needed at national and local level to support these types of initiative.
  - Using community engagement approaches, including community consultation and action, can be used to make small-scale changes to key routes in the local neighbourhood. This may be an effective method to improve the physical and social environments to help promote walking for transport. These types of initiative do however require considerable resource and capacity for effective implementation which should be taken into consideration in intervention planning.
- Interventions to promote walking to work are likely to need to address multiple levels of influence on the behaviour based on the socio-ecological model (Sallis et al., 1998). In addition to

improving the physical environment in the neighbourhood around workplaces and increasing provision of public transport, strategies should be tested which include some, or all, of the following approaches:

- changing individual perceptions of the availability of public transport and the local environment regarding walking and cycling by increasing awareness of public transport stop locations and providing information about walking routes;
- increasing confidence and intention to walk to and from work through using recognised behaviour change techniques such as 'prompt-self monitoring of behaviour' (which has been shown to increase efficacy beliefs and reduce perceived barriers) and 'prompt intention formation' (by encouraging the person to decide to act or set a general goal) (Bird et al., 2013);
- increasing social support from colleagues, for example by using a 'buddy' scheme or 'walking champions' to encourage other employees to walk;
- changing employee perceptions of the distance they live from work by increasing awareness of routes and journey times using walking and public transport;
- implementing organisational travel plans which might include increasing car park charges at destinations and making car use for work less convenient (such as moving car parking off site) (Brockman & Fox, 2011; Cairns et al., 2010; Petrunoff et al., 2016).

## 5.3 Overall conclusion

Despite the evidence demonstrating the benefits of physical activity for health, population levels of physical activity in adults remain low. Strategies are urgently needed to increase physical activity. Promoting walking for transport offers a potential strategy for intervention as walking is free, acceptable to most of the population and can be incorporated into daily travel behaviour. To date, walking for transport has often been studied in combination with walking for other purposes, such as leisure or exercise, or has been combined with cycling for transport under the umbrella of active travel. However, this does not allow for specificity in understanding the factors influencing the behaviour or developing targeted and tailored interventions to promote the behaviour. The present thesis identifies factors operating at different levels which influence walking for transport behaviour in adults, confirming the need for specificity in studying both the behaviour and the contexts in which the behaviour is undertaken. It also provides evidence of the barriers and facilitators for implementing, and the potential impact of, community- and workplace-based interventions which aim to promote the behaviour. Researchers, practitioners and policy-makers should take these research findings into consideration in the future design, planning and implementation of co-

produced, multi-level interventions which aim to promote walking for transport. Future research should identify causal factors influencing walking for transport, improve intervention content and optimise intervention implementation. Researchers should address methodological limitations of work in this area, including the application of more rigorous study designs and the use of more reliable and valid measures of walking for transport and overall physical activity. This work supports future research in understanding and promoting walking for transport in adults with the primary aim of increasing population physical activity levels to prevent chronic disease and improve health and well-being.

## Chapter 6. References


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