Daviaud, E. et al. (2017). South-Africa (Goodstart III) trial: community-based maternal and newborn care economic analysis. Health Policy and Planning, 32: i53-i63
http://dx.doi.org/10.1093/heapol/czw112

UNIVERSITY of the WESTERN CAPE

South-Africa (Goodstart III) trial: community-based maternal and newborn care economic analysis

Emmanuelle Daviaud, Lungiswa Nkonki, Petrida Ijumba, Tanya Doherty, Joy E. Lawn, Helen Owen, Debra Jackson and Mark Tomlinson

Abstract

In light of South Africa's generalized HIV/AIDS epidemic coupled with high infant mortality, we undertook a cluster Randomized Control Trial (2008–10) assessing the effect of Community Health Worker (CHW) antenatal and postnatal home visits on, amongst other indicators, levels of HIV-free survival, and exclusive and appropriate infant feeding at 12 weeks. Cost and time implications were calculated, by assessing the 15 participating CHWs, using financial records, mHealth and interviews. Sustainability and scalability were assessed, enabling identifier of health system issues. The majority (96%) of women in the community received an average of 4.1 visits (target seven). The paid, single purpose CHWs spent 13 h/week on the programme. The financial cost per mother amounted to $94 ($23 per home visit). Modelling target coverage (95% mothers, seven visits) and increased efficiency showed that if CHWs spent 25 h/week on the programme, the number of CHWs required would decrease from 15 to 12. The intervention almost doubled exclusive breastfeeding (EBF) at 12 weeks and showed a 6% relative increase in EBF with each additional CHW visit. Home visit programmes improve access and prevention but are not an inexpensive alternative: the observed cost per home visit is twice that of a clinic visit and in target/efficiency scenario decreases to 70% of the cost of a clinic visit. Ensuring sustainability requires optimizing the design of programmes and deployment of human resources, whilst maintaining impact. However, low remuneration of CHWs leads to shorter working hours, low motivation and sub-optimal coverage even in a situation with well-resourced supervision. The community-based care programme in South-Africa is based on multi-purpose CHWs, its cost and impact should be compared with results from this study. Quality of support for multi-purpose CHWs may be the biggest challenge to address to achieving higher efficiency of community-based services.
Trial registration number: ISRCTN41046462

Introduction

South Africa is fighting a generalized HIV/AIDS epidemic with ante-natal prevalence rate at 29.5% in 2011 (SANDOH 2012). In recent years, the scale-up of programmes to prevent mother-to-child transmission (MTCT) of HIV has led to a rapid decrease in the number of newly infected children (0–14) (Goga *et al.*

2012, UNAIDS 2012). Although under 5 mortality has decreased between 6 and 10% per year since 2006 (Kerber *et al.* 2013), neonatal mortality has not been shown to decrease since 2001 (Bradshaw *et al.* 2011) (Box 1). Both high rates of antenatal care [91.9% of pregnant women, in the province of Kwazulu-Natal in 2012 (DHIS 2012)] and facility-based deliveries [91% average for South Africa (DHIS 2012)] suggest good access to care, yet many women still fail to attend the recommended clinic postnatal visit within 6 days of giving birth let alone the WHO recommendation of within 2 days (WHO 2013). Scheduled maternal and newborn postnatal visits occur at 6-weeks. Furthermore, health workers tend to focus on treatment rather than prevention or behavior change, leading to sub-optimal rates of exclusive breastfeeding (EBF) and other practices critical to newborn care (Tomlinson *et al.* 2014).

Community-based programmes involving pregnancy and postnatal home visits have shown to lead to important reductions in neo-natal mortality in Asia (Bang *et al.* 1999; Baqui *et al.* 2008, 2009; Kumar *et al.* 2008). The World Health Organization (WHO) and United Nations Children's Fund (UNICEF) published in 2009 a joint statement on home visits for the newborn child as a strategy to improve survival (UNICEF and WHO 2009).

Box 1. South Africa at a glance

	South Africa
Total population 2014	54,001,953
Millennium Development Goal Progress	
Improve Child Survival (MDG4) neonatal mortality	Not met
Improve Maternal Health (MDG5)	Not met
Child and newborn mortality data	
Number live births (2015)	1,111,000
Neonatal mortality rate per 1000 live births (2015)	11
Annual number of newborn deaths	11,000
Mortality rate per 1000 live births for children under-5 (2015)	41
Annual number of child deaths under-5	42,000
Health system (2007-2014)	
Number of nurses & midwives (2013)	260,700
Nurses & midwives per 10,000 (2007-2013)	51.1
Skilled* attendant at birth	94%
Antenatal care coverage**, >1	97%
Antenatal care coverage**, at least x4	87%
PNC for mothers, within 2 days	No data
Under-fives with suspected pneumonia receiving antibiotics	No data
Overseas Development Assistance (ODA) 2010	
ODA (US$) to 0-5 year olds from all donors	5,041,132

Context Community Care: In 2010, The South African National Department of Health (SANDAH), shifted the focus of the PHC system from a more passive curative to an active population based approach involving CHWs.

***Data sources**: Population data (The World Bank); Skilled attendant at birth, <5s receiving antibiotics; ANC coverage & number of nurses and midwives per 10,000 (World Health Statistics 2015, WHO); neonatal and under-five mortality (UN Interagency Group for Child Mortality Estimation 2015); number of nurses and midwives (WHO- Data by country); annual live births and PNC coverage (Countdown to 2015-2015 Profile); ODA (Pitt 2012 & Hsu 2012 using OECD data)*
***Note**: number of nurses and midwives and PNC are for the most recent year*
** Doctor, nurse or midwife*
***Percentage of women (aged 15–49) attended by any provider*

In 2010, a Cochrane review concluded that community-based models for neonatal care are promising (Lassi *et al.* 2010). Lefevre *et al.* (2013) study is Bangladesh showed that an intervention with pregnancy and postnatal home visits was cost-effective to reduce neonatal mortality, whilst a community intervention with health education and no home visits was not (Lefevre *et al.* 2013). More recently, a cost effectiveness study of newborn home visits in Ghana (Pitt *et al.* 2016), showed that the intervention is cost-effective (cost/DALY at <3 GDP per capita) even with a very small reduction in the neonatal mortality rate (1% reduction over the 32.7 rate at baseline).

Background on the cluster randomized controlled trial

In 2008, the South African Medical Research Council (SAMRC) initiated a cluster Randomized Controlled Trial (cRCT), the Goodstart III CHWs home visiting programme, consisting of 30 randomized clusters (15 intervention and 15 control), in Umlazi, a densely populated peri-urban settlement in Kwazulu-Natal province and the second largest township in the country. The primary outcome(s) of interest were to assess the effect of Community Health Worker (CHW) home visits during pregnancy and after birth on levels of HIV-free survival, exclusive breast feeding at 12 weeks after birth, coverage of care, behavioural indicators (antenatal HIV testing, a postnatal clinic visit within 7 days of life, uptake of cotrimoxazole amongst HIV-exposed infants, and uptake of family planning) and levels of post-partum depression. This intervention was designed as a stand-alone programme as this type of intervention was not, at that stage, part of a standard community-based care package. For further details on the trial design see Tomlinson *et al.* (2011).

The 15 CHWs from the intervention clusters were trained for 10 days on home entry, brief motivational interviewing techniques, disclosure, antenatal care, infant feeding with emphasis on EBF, breast problems and diseases, interaction with newborns, baby blues and postnatal depression, and neonatal care, including danger signs in newborns and their mothers that might warrant a referral. The training was based on a manual compiled by the principal investigators drawing on several resources, including consultation with designated training authorities in South Africa and the WHO/UNICEF Breastfeeding Counselling Course. Training was delivered through role plays, demonstrations, real-life experiences and discussions. Visits in the intervention arm included two home visits during pregnancy, one in the first 48 h after delivery, then at 3–4 days, 10–14 days, 3–4 weeks and a final visit at 8–9 weeks. Each home visit was designated to cover specific topics with a focus on key messages related to the outcomes of the study. For details on the specific content of each home visit see Tomlinson *et al.* (2011).

In the 15 control clusters CHWs provided essential information and support to pregnant women on how to obtain state social welfare grants. Visits in the control arm included one home visit during the antenatal period and two postnatal visits at 4–6 and 10–12 weeks. Low birth weight neonates (<2500 g) were to receive two extra visits during the first week.

The intervention had a significant impact on one of the primary outcomes, EBF (Relative risk 1.92 (95% CI: 1.59–2.33). There was a differential effect according to the mothers HIV status with the intervention having a greater effect amongst HIV negative women [RR 2.16 (95% CI 1.71–2.73)], but no differential effect according to mothers' education or socio-economic status (Tomlinson *et al.* 2014). It is important to note that this intervention was undertaken at a time when national policy did not support EBF for HIV positive women.

Looking forward with the new infant and young child feeding policy supporting EBF for all women irrespective of HIV status, this CHW programme could plausibly be expected to have a more homogeneous impact amongst HIV positive and negative women. A dose-response relationship between CHW visits and EBF was also found, with each additional CHW visit corresponding to a 6% relative increase in EBF. However, there was no overall impact on HIV-free survival (5.4 vs 4.5%), which could plausibly be due to the intervention coinciding with the rapid scale up of prevention of MTCT of HIV services together with the roll out of antiretrovirals which drastically reduced MTCT rates and mortality in both arms. Improvements were observed in many of the secondary outcomes, such as knowledge of newborn danger signs, clinic visits within the first week of life, testing for HIV-exposed infants at 6 weeks and availability of cotrimoxazole in the house at 12 weeks postnatally (Tomlinson *et al.* 2014).

CHW programmes do involve the use of limited social resources and thus there are compelling reasons for some form of economic evaluation to establish whether such resources are deployed efficiently (Walker and Jan 2005). During the 1980s, health planners took little account of the recurrent costs of Community-Based Health Programmes and many CHW programmes have failed because of lack of financial sustainability. International experience has shown that when planning CHW programmes it is essential to calculate the real cost of supervision, together with the costs of salaries, drugs and so on for each new CHW (Makan and Bachman 1997).

To assess the intervention's sustainability and the feasibility of replication in other districts, we aimed to first estimate the financial costs of the intervention and assess CHWs' and supervisors' time. We then built scenarios with increased coverage and increased efficiency and concluded on health systems issues of relevance for the planning of home-visit based interventions.

Methods

Pregnant women, 17 and older, residing in the 15 intervention clusters during the recruitment period and capable of providing informed consent, were included in the study sample. Twenty-one CHWs were recruited and trained to ensure continuity of service, although only 15 were working at any point in time. CHWs received a monthly stipend of USD 256 to complete an average of 7 home visits per pregnant mother in their cluster and identify new pregnancies. Each CHW was given a cell-phone with a monthly recharge voucher. Two part-time supervisors were employed to support and supervise CHWs as well as linking daily with the local hospital to get information on new deliveries, their remaining time being spent on research activities.

The intervention took place in three overlapping phases: the design phase (design of intervention, of material and of training curriculum), the set-up phase (recruitment of staff, initial training, duplication of material, and acquisition of equipment for the implementation) and the implementation phase (recruitment of mothers, home visits). The time period for each phase is illustrated in Figure 1. The main intervention was implemented between June 2008 and December 2010. The implementation year costed covered the period of April 2009 to March 2010.

Setting

The district of Umlazi in the KwaZulu-Natal province of South Africa was selected for the cRCT because of the high prevalence of HIV, since one of the intervention's aims was to integrate newborn and HIV oriented services in a high HIV prevalence setting. The 2010 antenatal HIV prevalence in the Umlazi district was estimated at 41% (SANDOH 2010) and the infant mortality at 42 per 1000 live births (Day *et al.* 2011).

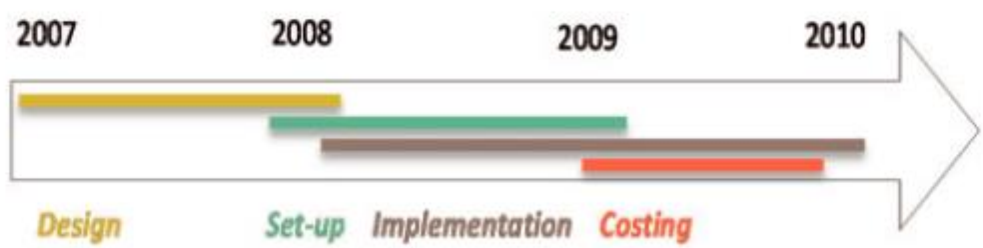


Figure 1. Goodstart III study time period

Data collection

Data were collected on financial costs as well as CHWs' and CHW supervisors' use of time using the Excel-based COIN (Cost of Integrating Newborn) Care Tool, designed for a multi-country study by the SAMRC in collaboration with the Saving Newborn Lives programme (Save the Children USA).

Using a bottom-up approach, a SAMRC health economist recorded data on costs prospectively from the standalone intervention's financial records. Data were independently checked by a senior health economist. Information on the use of CHWs' and their supervisors' time was also collected. For each home visit, the amount of time spent in the home was captured by the CHW's cell phone via the mobile health (mHealth) management system. The research and programme utilization of mHealth as used by CHWs in Umlazi is outlined in Box 2. This form of recording was used by opposition to asking CHWs to fill diaries for 2 weeks with time recording, as it could cover all visits for a year hence more reliable given the limited number of CHWs. However, this mHealth recording did not cover CHWs' travel time and other activities (administration, meetings, travel and identification of new pregnancies in the catchment area). This information was then obtained from a review of study records (meeting agenda's, weekly plans etc.) and from interviews with supervisors and with members of the research team. Average travel time for home visits was estimated for each CHW through interviews at the end of the year with the relevant supervisors who had a good knowledge of each CHW patch. The use of the supervisors' time was determined through records reviews and structured interviews with supervisors and confirmed by the project manager and members of the research team.

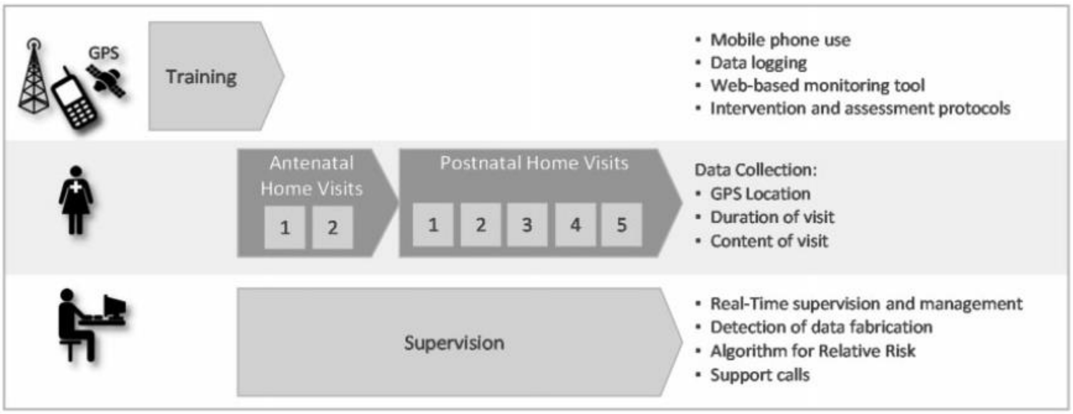
Exclusion of research costs was made through a bottom-up approach: for every expenditure, relevant staff was asked what percentage of time or expenditure was for research and for intervention. This breakdown was further verified with the project manager and Principal Investigator.

Analysis

Analysis was undertaken from the perspective of the provider excluding research-related expenses. The total cost of the intervention represents annualized design and set-up costs plus a full year of implementation. Annualized capital costs taking into account each item's expected useful life years were calculated. Recurrent set-up costs were allocated three useful life years, the length of the intervention, including the training costs due to the existence of refresher training, without refresher training they would have been annualized on the basis of 1.5 life years. Financial and economic costs are presented. For the latter a discount rate of 3% was applied to capital and set-up costs. All costs were adjusted for inflation based on the Consumer Price Index produced by Statistics South Africa and converted to 2015 US dollars (ZAR 12.5 ¼ US $1) (Oanda 2015). Financial costs were broken down between design costs (one-off costs which will not be incurred if the programme is rolled out to another district, design of training, of material, of mHealth software), set-up costs (costs which will occur if the programme is rolled out in a new district, typically printing of material, recruitment, initial training, kits), and those associated with one year of implementation (salaries, cell-phone top ups, transport, stationary).

In order to reflect budgetary implications, and those of replication in a new district, we excluded design costs and assessed the cost per mother/child pair and the cost per home visit for the intervention. To present a fuller picture of expenditure for home-visit programmes, costs were also presented annualized per capita, based on the total population of the intervention's catchment area. In order to better identify the impact of the number of CHWs and supervisors on costs, excluding design, CHWs' and supervisors' costs were broken into fixed costs (e.g. training, clothing/material, the CHW kit, mHealth and remuneration) and variable costs (e.g. dependent on the number of mothers visited or number of CHWs supervised). Costs of materials and clothing in the CHW kit were itemized and presented independently. We analysed CHWs' and supervisors' use of time per categories of activity.

Box 2. Learning from mHealth in Goodstart III programmatic and research cost implications



As CHWs received a monthly stipend, their remuneration was included in fixed costs. Supervisors' time being largely defined by the number of CHWs supervised, the supervisor remuneration was included in variable costs.

Analysis of time was done in several steps: to compensate for the small number of CHWs, we did a bootstrap analysis of the mean length of duration of home visits with 1000 repeats, thereby decreasing the error around the estimate. The mean obtained from boot strapping was similar to that of the recorded visits, but the 95% CIs were drastically reduced. To ensure that CHWs travel time for home visits, as obtained from interviews, was not underestimated, we compared this time with reports of travel time in other similar studies presented in the Supplement, which range from 20 to 45 minutes.

In South-Africa, whilst the official policy is that CHWs should be employed full-time, informal feedback from the national health department district cluster officials indicates support for CHWs only working 75% of a full time position—which is the existing situation in several provinces. A 30 h a week translates into 25 h a week excluding the daily 1 h break, an amount of time very similar to the 4 h 58 min observed in the Ethiopia study for the Health Extension Workers, also low paid but multi-purpose CHWs (Mangham-Jefferies *et al.* 2014). CHWs time on the intervention, with confidence intervals, is presented as a percentage of these 25 h a week.

We then modelled the resource implications and financial cost per mother/child pair and the cost per home visit of different scenarios.

Scenario 1: Target coverage and target number of home visits per mother: we set at 95% the proportion of pregnant women in the community being visited and at seven the number of home visits per mother/child pair.

Scenario 2: Increased coverage, CHW workload and therefore efficiency. We modelled the number of CHW and supervisors Full Time Equivalents (FTEs) required setting at 35 h/week the time spent by CHWs on the combined activities of the intervention, and modelled the implications for CHW catchment area, travel time, number of home visits and supervision requirements. We defined as four the target number of home visits per mother, in line with the Joint Statement of WHO and UNICEF (WHO *et al.* 2009).

Scenario 3: Standardization to a population of 100 000 with South Africa's average fertility rate, with two home visit targets (4 and 7) and at 50, 70 and 95% coverage of all mother-child pairs We set at 50% the minimum coverage, and applied a 20% increase in percentage in line with the PLOS mothers newborn and children in sub-Sahara Africa series (Friberg *et al.* 2010).

We then set at 95% the optimum target, reflecting coverage obtained in several countries presented in this supplement. To get a better understanding of affordability we calculated the cost per capita total population and expressed it as a percentage of public sector health expenditure per capita ($244) (World Bank 2015).

Results

Coverage of the intervention

During the three years of the implementation a total of 1894 mothers were recruited to participate in the trial. This represents 96% of the pregnant women in the intervention area. Each mother was visited 4.1 times on average. Forty percent of mothers had the target seven home visits or more, 31% of mothers had fewer than four visits and 69% had four or more visits.

From April 2009 to March 2010, the period of implementation analysed for the costing analysis, 923 mothers were visited, 258 of them starting before April 2009. A total of 3804 home visits were conducted which amounted to an average 5.4 visits per week for each of the 15 CHWs. This number excludes home visits to the same mothers which took place after March 2010.

Costs of the intervention

Annualized cost of the intervention was $94 937 for financial costs ($96 041 economic costs) of which 9% was allocated to designing the intervention ($8432 and $8943, respectively), 10% to set-up ($9790 and $10 383), and 81% to recurrent implementation costs ($76 715). Figure 2 reflects the distribution of costs in each phase of the intervention. The cost drivers varied with each of the phases: during the design phase, consultancies for material development, essentially the design of the mHealth system were the main cost driver, representing 77% of costs. During the set-up phase, training was the main cost driver (45%) followed by equipment (16%) and staff (12%), whilst in the implementation phase staff costs, accounted for 72% of costs.

Since design costs will not be incurred again if the intervention is rolled out to new districts, these costs are excluded from the analysis below which focuses on repeatable costs: Set-up costs annualized and one year recurrent implementation costs. After excluding the one-off design costs, the average cost per mother visited was $94 (with an average cost per home visit of $23) for both financial and economic costs.

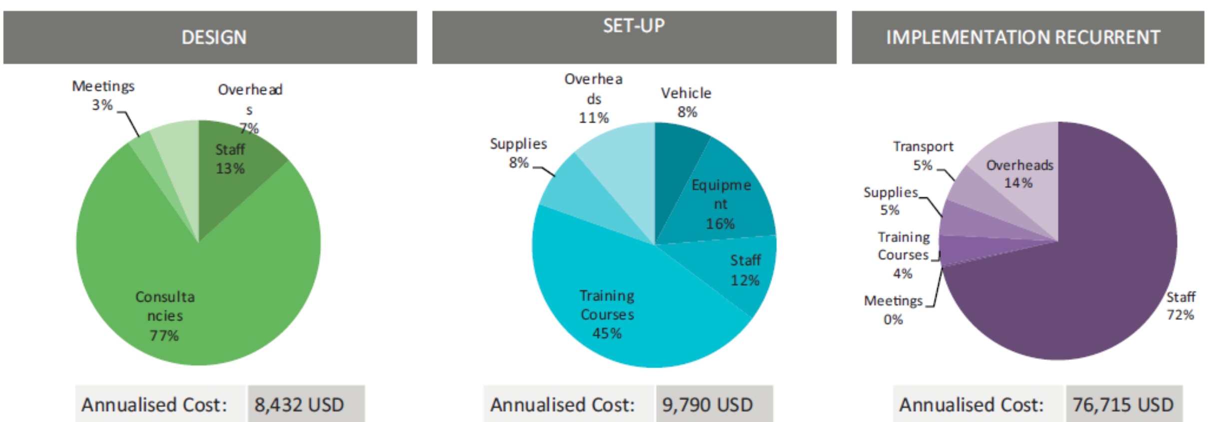


Figure 2. Financial costs in the Goodstart III programme and distribution of costs by phase: design, set-up and implementation (USD 2015)

Overall, repeatable costs amounted to $2.4 per capita total population in the intervention area, or 0.8% of public health expenditure per capita. Of the repeatable costs, 63% were CHWs fixed costs ($3624 per CHW), independent from the level of activity: training, kit, cell phone plus monthly voucher and remuneration (Table 1). Supervision costs amounted to 20% of repeatable costs ($8535 per supervisor) (Table 1), supplies to mothers 4% ($3.7 per mother) and overheads 14%.

Time utilization

CHW time

CHWs' time was shared between home visits (and travel), administration, supervision meetings and identification of new pregnancies. Of the 3804 home visits performed between April 2009 and March 2010, 39 visits were excluded from analysis due to extreme values for length of home visits. The average time in home for home visits was 28.1 min (95% CI 27.3–28.9), and the median time 27 min, with no significant difference between pregnancy and postnatal visits: time per pregnancy visit ranged from one minute (mothers not at home) to 330 min, with a median value of 25 min. Time for postnatal visits ranged from 1 to 340 min, with a median of 28 min. The average travel time in this high density area was estimated at 30 min per home visit. In the other similar studies in this supplement, median travel time ranged from 20 min in Malawi, to 32 min in Uganda and 45 min in Tanzania, in mainly rural areas. For the purpose of modelling the best and worst scenario, we assumed the travel time to be between 20 and 40 min. Besides home visits, CHWs spent an average of 4 h a week identifying new pregnancies in their cluster (3–5 h), another 3 h attending a weekly meeting for supervision and distribution of tasks, and 1 h a week on administration and scheduling of visits. CHWs spent a total of 13 h a week on the intervention, all activities combined, or 52% of the 25 h weekly working time, ranging from 11 h (44%) to 15 h (60%) for worst and best scenarios (Table 2).

Supervisor time

Each supervisor spent an average of 19 h a week in the field assessing the quality of CHWs visits or conducting spot-checks with beneficiaries (mothers), an average of 2.5 h per week per CHW. An average of 4 h a week per supervisor was spent on group supervision meetings, and 3.5 h a week on administration. The supervisors' administrative activities entailed assessing the completion of planned CHW visits (recorded by the mHealth system), checking the recruitment forms used for mothers and linking with hospital for deliveries to ensure timely first postnatal visits by CHW. The two supervisors spent each an average of 70% of FTE on the intervention, the remaining 30% being used for research activities, which were excluded from this analysis.

Scale-up scenarios modelled

Scenario 1: target coverage (95%) and seven visits per mother

As 96% of pregnant women in the community took part in the programme the coverage of pregnant women has already reached the target. This scenario examines the resources implications of the existing 15 CHWs increasing the number of home visits per mother-baby pair from the observed 4.1 to the target seven. If 95% of mothers received the seven visits, the total number of home visits would increase by 68% and each CHW would make an average of nine home visits a week and spend an additional 4 h a week on the intervention activities moving from 13 to 17 h a week or 66% of their available work-time of

25 h. No additional supervisor time would be required. The cost per mother would remain the same the cost per home visit would decrease from $22.7 to $13.5 (Table 3). As supplies were given once to each mother, they were not dependent on the number of home visits per mother. Transport costs were not modified by increased home visits since CHWs were walking to homes.

Table 1. Annualized fixed costs in the Goodstart III programme ($US 2015)

per CHW		
Fixed costs per CHW	In $2015	
Training	285	
Kit/Clothing/Material/Cell phone	49	
Transport, including share of driver salary	199	
Remuneration	3068	
Air time	23	
Total	3624	
per supervisor, by Full Time Equivalent (FTE)		
Annualized costs	Per supervisor	
	70% FTE	1 FTE
Fixed costs		
Training	58	58
Capital Vehicle	376	376
Capital Equipment	403	403
Meetings and Supplies	170	170
Total	1008	1008
Variable costs		
Transport	2046	2835
Remuneration	5207	7438
mHealth	274	392
Total	7527	10 664

Table 2. Length of time CHWs spend on the intervention programme and home visits, by type of activity and number of visits per week and proportion of maximum time

CHWs time on home visits	Median time per home visit (min)			Average home visits/ week per CHW	Home visit hours per week per CHW	
	Travel	in Home	Total Time			
	30	27	57	5.3	5.02	
Time on the programme per CHW	Average actual hours per week			Average total hours/ week on programme	Maximum hours/ week on programme	Actual time as % of maximum
	Home visits	Admin and meetings	Identification of new pregnancies			
	5	4	4	13	25	57%

Table 3. Goodstart III programme actual costs and standardized modelled costs for three scenarios (USD 2015)

		Actual	Scenario 1: package as per study design	Scenario 2: increased CHW workload and efficiency		Scenario 3: Standardization to 100 000 total population		
		Average number of achieved visits	Target visits	Four visits	Target visits (seven)	Single purpose CHW—average four visits per mother		
	Coverage	Achieved	Target	Target		Variable		
	% of potential mothers visited	96%	95%	95%	95%	50%	70%	95%
Activity	Number mothers visited	923	913	913	913	1059	1482	2011
	Number visits/mother	4	7	4	7	4	4	4
	Total home visits	3804	6394	3654	6394	4235	5928	8046
	Number CHWs	15	15	7	12	15	15	15
	Number mothers per CHW/year	62	61	132	75	69	97	132
	Visits per CHW/week	5	9	11	11	6	8	11
Time	% CHW time on programme	52%	66%	100%	100%	77%	86%	100%
	Supervisors FTEs	1.4	1.4	0.7	1.2	1.5	1.5	1.5
Cost	Cost per mother ($)	$93.7	$94.7	$46.8	$78.7	$65.4	$48.0	$36.5
	Cost per home visit	$22.7	$13.5	$11.7	$11.2	$16.4	$12.0	$9.1
	Programme cost	$86 505	$86 464	$42 755	$71 867	$89 320	$91 135	$93 404
	Programme cost per capita total population	$2.06	$2.06	$1.02	$1.71	$0.89	$0.91	$0.93
	Public health expenditure per capita	$244						
	Programme cost as % public health expenditure per capita	0.8%	0.8%	0.4%	0.7%	0.4%	0.4%	0.4%

Scenario 2: increasing the coverage, workload and efficiency of CHWs in the study area

This scenario analyses the number of CHWS and supervisors FTEs required focusing on optimizing time use by CHWs and assesses the resources implications for various levels of coverage. If CHWs spend 25 h a week on the programme (home visits, meetings, administrative tasks and identification of new pregnancies) instead of the observed 13, each CHW would increase the number of home visits per week and the number of mother-child pairs visited. A higher number of mother–child pairs per CHW would in turn require a larger catchment area per CHW with implications for the travel time which was increased by 50% whilst time for identification of new pregnancies and for administration increased by 25%. Under this scenario, 11 home visits would be conducted per CHW per week as opposed to the observed 5.3 or the 9 modelled in Scenario 1. Supervisor time would increase with the larger geographical area, time per CHW supervised was increased by 15% and by 50% for additional administrative duties. Thus one full-time supervisor would be required per 10 CHWs. For a target coverage of 95% of mothers receiving an average of four visits, the number of CHWs required would decrease from the current 15 to 7, spending 100% of their time on the programme, and 0.7 of a supervisor FTE would be required compared with the current 1.4. The cost per mother would decrease from $94 to $47 and the cost per home visit from $23 to $12. Increasing from the measured four visits to the target seven visits, then 12 CHWs would be required and 1.2 supervisor FTE, the cost per mother would stand at $78 and the cost per home visit at $12.

Scenario 3: standardization to a 100 000 population

Scenario 3 also models the implications of Scenario 2 for a total population of 100 000 with the South Africa average total fertility rate: 2117 pregnancies would be expected per year. The cost for a 95% coverage with four visits (coverage similar to that observed in the study at 96% coverage with 4.1 visits) would amount to $37 per mother and $9 per home visit. The programme cost with single purpose CHWs would represent 0.4% of public health expenditure per capita.

Discussion

This article describes the financial and human resources implications of the 'Goodstart III CHWs home visiting programme' during pregnancy and postnatal period. Beyond quantifying the resources involved in the programme, this article attempts to identify the health systems implications of a programme based on single purpose CHWs and the challenges encountered to optimize the deployment of human resources to ensure sustainability.

The intervention was able to increase EBF prevalence at 12 weeks from 15% in the control clusters to 29% in the intervention clusters, a significant change in the South African context where EBF has been very low and difficult to improve through facility-based interventions. The length of EBF increased with each additional home visit. This improvement would also have important health benefits for mothers and infants and potential cost savings to the health system from morbidity associated with not breastfeeding, which are not quantified in this analysis. In the 2008 Lancet Nutrition Series, Black estimated that suboptimum breastfeeding was estimated to be responsible for 1-4 million child deaths and 44 million DALYs (10% of DALYs in children younger than 5 years) (Black *et al.* 2008). Rollins *et al.* (2016) argue that breastfeeding has additional short term and long term health and economic positive impact on the child (including higher intelligence), the mother and society.

If the intervention has had a positive health impact, its format of implementation may need to be reviewed. With an economic cost per mother of $94, compared with the other two countries presented in the Supplement, who have paid CHWs: in Ethiopia it stood at $30 and at $16 in Malawi. The programme is also expensive in the South-African context with a cost of $23 per home visit, when the average recurrent cost of a clinic visit with a professional nurse was $9.5 (District Health Expenditure Review 2011 adjusted to 2015 $). The high costs in the study are due primarily to the status of CHWs and to their deployment in the programme. The CHWs in the study were paid at the level set by the government, but poorly paid (37% lower than the lowest salary package in the public sector e.g. cleaner). This remuneration level is justified by the government on the basis that work as a CHW is temporary and that the training offered provides a stepping stone to better career. This differs widely with the view of many CHWs.

The average time in home was at 28 min shorter than the other studies in the supplement where it stood at 30 min in Tanzania, 32 min in Ethiopia, 40 min in Uganda and 49 min in Malawi. As such it is unlikely that time could be reduced to increase efficiency, it is also unlikely that the average would be significantly longer given the high number of visits monitored.

In the study CHWs spent only 13 (11–15) h/week on programme activities (52% of possible productive time), there are several plausible reasons. First given the shorter hours, but also justified by CHWs by the low stipend, CHW work is often considered as part-time employment: two CHWs were working for another NGO, and another two studying; secondly, many of the CHWs were themselves mothers with young children, an attribute which has been linked to higher quality of care (Kawakatsu *et al*. 2015), but were leaving to be available for their own children in the afternoons. Thirdly, although not documented in published literature, it is possible that in urban areas CHWs receive less community recognition than in rural areas where much fewer services are available, thereby decreasing their motivation. The fact that employment was only temporary, for the length of the study, may have also affected the level of motivation. In addition, CHWs were at times prevented to carry out home visits due to the high incidence of criminal activities. Several CHWs were mugged or hijacked and needed counselling. The high HIV/ AIDS prevalence contributed also negatively to CHWs performance. Support/supervision may also have played a role, this is discussed below. Finally, due to the requirements of the cluster RCT, the intervention area was divided in 15 clusters with one CHW per cluster. If the target of seven home visits would have been achieved, CHWs would have spent 66% of their time on the programme, pointing to the fact that the population covered by each single purpose CHW may have been too low to enable maximum use of their time. The estimation of catchment population per CHW was based on expected pregnancies which may have been overestimated.

Supervision was well-resourced with two dedicated supervisors (70% of a full-time each) with between 7 and 8 CHWs each, compared with Bhutta *et al.*'s (2010) suggestion of one supervisor for 20–25 CHWs. Well-resourced supervision is more likely in research set-up compared with a routine set-up (Gilson *et al*. 1989; Lehmann and Sanders 2007). In addition, a complex mHealth system was set-up for the intervention for the purpose of research and supervision. This enabled the Goodstart III home visit programme to collect data, enable real-time supervision and monitoring and schedule further antenatal and postnatal visits. Supervisors had received training and support to use mHealth as a management tool. Still, despite the significant time spent on planning and supervision including use of mHealth, and despite the low workload per CHW, the average number of visits per mother was well below target. This highlights the difficulty of running an efficient community-based care service, and the central role of quality support/supervision to enhance CHWs motivation level, but also to communicate the level of expectations and performance back to CHWs. However, if accountability is expected from CHWs, a system of accountability should also be in place for supervisors. Such systems seldom exist.

For this intervention, it is unclear whether recurrent management costs would have increased in the absence of a mHealth system. There is limited and unclear evidence for the benefits of mHealth, especially for long-term results (Strachan *et al.* 2012; Braun *et al.* 2013; Aranda-Jan *et al.* 2014). In an evaluation of the capacity of the South-African health system to use mHealth for community-based services, Leon *et al.* (2012) notes that organizational culture and capacity for using health information for management, and the poor availability and use of Information Communication Technology in primary health care (PHC) are key barriers to effective use of an MHealth system (Leon *et al.* 2012). For the current implementation in South Africa in the context of the new PHC Re-engineering approach, only in few areas are CHWs equipped with cell phones.

A generic issue about community-based care is that the concept of 'optimal use of CHW time' is often neglected in the design of programmes, whether by research or by actual implementing agencies, public sector or NGOs. This may be due to the low remuneration of CHW and of supervisor (whose FTE package was 85% of the entry point package of a staff nurse in the public sector) so that programme managers may assume that these lower salaries translate to low costs. This, however, ignores the impact of the CHWs fixed costs (training, kits and remuneration as well as management and administration overheads), which are incurred independently from the number of mothers visited. In the study, CHWs fixed costs represent 63% of programme costs, with large impact on the cost per mother and home visit when the number of mother or home visits is low. In addition supervision costs are largely dependent on the number of CHWs to be supervised and vary only slightly with the number of mothers per CHW. With an increasing level of activity by CHWs, fewer CHWs would be required and the number of FTE supervisors would decrease. The size of fixed costs per CHW advocates for the recruitment of fewer but full-time CHWs. However such an approach would require CHWs to be paid an entry level state salary with benefits. The reliance on CHWs with low stipends, hence effectively short working hours, is an expensive approach, further emphasized in the case of single purpose CHWs. Lehmann and Sanders (2007) noted in their review of community-based services 'CHW programmes are therefore neither the panacea for weak health systems nor a cheap option to provide access to health care for underserved populations'.

However, to combine optimizing the effectiveness of a community-based intervention and the need for efficiency to ensure sustainability is complex. Higher workload per single focus CHW requires a larger catchment area. For this intervention, the appropriate timing of the first postnatal home visit (within 48 h after birth) has been shown to be central to the impact (Tomlinson *et al.* 2014). In South Africa where in 2012 over 90% of deliveries took place in facilities (Health Systems Trust) the systematic link between supervisor and delivery facilities and between supervisor and CHW is crucial. The remaining 10% of deliveries are likely to represent those more at risk. Ensuring such a timely visit requires a small catchment area in a peri-urban settlement so that the CHW has a good knowledge of the population (Swartz 2013) and much reduced travel time. However, a small catchment area may mean limited hours of work would be required by CHW for a standalone programme. This paper has shown that this option is costly. If a CHW was covering several programmes for the same population, the cost of training, of kits and of supervision would not increase proportionally, and a household would be interfacing with one CHW rather than several, and avoid overlaps. Integrating this maternal/neonatal intervention into a community-based IMCI programme, or wider integrated package, is likely to enable a better use of resources, and have a greater likelihood of achieving improved health outcomes at a community level. Much debate is taking place (van Ginneken *et al.* 2010) on the impact of multi-purpose CHWs covering several programmes, with the risk of CHWs being overwhelmed by too many tasks (Teklehaimanot *et al.* 2007). In the Malawi study presented in this Supplement, Health Surveillance Assistants could only manage coverage of 36% for the neonatal programme. In other countries, multi-purpose CHWs with strong supportive teams in countries like Brazil (Celletti *et al.* 2010) or Bangladesh (Jaskiewicz and Tulenko 2012) have shown positive impacts. A study in Bangladesh of the impact of increasing workload on quality of care among CHWs (Puett *et al.* 2012), the authors found that adding curative (malnutrition management) to preventative tasks did not affect the quality of care when CHWS had strong support/supervision.

In South Africa, this intervention took place during the re-engineering of the PHC platform. In the PHC package the ward-based outreach team is composed of multi-purpose CHWs supervised by a community-based professional nurse, now replaced by a staff nurse due to the shortage of professional nurses. In the PHC re-engineering vision, each CHW delivers an integrated package, initially with major emphasis on mother and child and infectious diseases (HIV/TB) with incremental introduction of additional programmes. A CHW is intended to cover 300 households in urban areas, down to 150 in deep rural areas, representing respectively an average of 24 and 12 pregnant women per year per CHW. The number of households covered by CHW was calculated from needs, coverage and time per type of visit (Daviaud and Subedar 2012; Nsibande *et al.* 2013). The ward-based PHC outreach model has a target of seven visits built in for the perinatal period (pregnancy and postnatal). Similar interventions are thus planned but within the context of an integrated package for households. In the context of a much reduced catchment population per CHW, the CHWs knowledge of their community should be better, and time for the identification of new pregnancies reduced, as would the relative share of administration and supervision time with the integrated package.

The maternal/neonatal share of the CHW activity would, at <5 hours a week, represent about 19% of the CHW 25 h productive time for seven visits per mother and 95% coverage (Table 4). The time implications of this suggest that such an important package can potentially be delivered with high coverage in the new PHC model. However, the study has shown that even with low CHW workload and well-resourced supportive supervision the target number of visits was not reached. Moving to scale as part of the routine delivery of services as currently happening in South-Africa may encounter the many difficulties experienced by community-based packages from motivation to supportive supervision to appropriate and sustained funding as documented in Lehmann and Saunders (2007). To our knowledge, no study has yet assessed the implementation or the impact of community-based services in the context of the PHC Re-engineering programme in South-Africa. A study assessing pregnancy and postnatal home visits in this context of generic CHWs in a routine set-up may show lower coverage than observed in this study. Would the impact on the health of mothers and infants become insignificant raising the issue of possible narrowing the scope of CHWs to IMNCI only?

However, efficiency may not be the only criteria which influences the design of a community-based programme, especially for high impact care and hard to reach populations. Evaluation of the current implementation in the context of multi-purpose CHWs as part of the PHC Re-engineering would provide very valuable information, enabling a comparison with the results of the study with single purpose CHW to understand costs and impact in a routine setting.

Strengths and limitations

This study provides detailed information on the costs and human resources implications of implementing a home visit programme, as well as information on time per type of activity, a type of data not often available. It thus highlights health system issues around deployment of CHWs, a point largely unexplored whilst crucial for planners to make such programmes sustainable.

The two main limitations of the study are: the small number of CHWs involved and the reliability of time monitoring. The small number of CHWs might affect the generalizability of the findings in particular regarding time utilization. We attempted to overcome an aspect of this limitation through the use of the bootstrapping technique with a 1000 repetitions for time in homes. The other components of CHW time utilization were estimated from interviews with supervisors and project manager. We provided a range, from worst to best scenario regarding time, and feel confident that it did not affect the validity of the findings, given the large underutilization of CHWs. Interviews with supervisors followed a very detailed grid for time utilization.

Conclusion

This study located in a difficult to serve South African township due to high levels of violence and very high HIV prevalence shows that it is possible to provide home visits and change behaviours such as EBF, which facility-based services do not manage. The high cost of the intervention emphasizes the need to reevaluate the design of such a programme to reach optimal deployment of CHWs, pointing to a move from single purpose to multi-purpose CHWs. It also highlights the importance of high quality support, supervision and feedback to CHWs to limit the impact of low motivation, hence low performance, associated in part with low remuneration. Quality of support for CHWs may be the biggest challenge that the PHC re-engineering in South-Africa needs to address to achieve greater efficiency of community-based services.

Table 4. Time implications of Goodstart III programme if implemented by multi-purpose CHWs in the context of PHC re-engineering

	Target coverage: 95% of potential mothers		
	Per multi-purpose CHW		
Population per CHW	Urban 1200	Rural 900	Deep-rural 600
Number mothers visited/year	24	18	12
Number visits/mother	7		
Total number of home visits	168	126	84
Visits per CHW/week	3.5	2.6	1.8
Travel time per home visit[a]	20	35	60
Time in homes	27	27	27
Meetings, supervision and new pregnancies	120	120	120
Total time/week	4.7	4.7	4.5
% CHW 25 h productive time a week	19.0%	18.9%	18.2%

[a]Travel time per home visit has been reduced due to the fact that this is a multi-purpose worker with the possibility of organizing other home visits in the same area.

Acknowledgements

We would like to acknowledge all the women and their babies who participated in the study, as well as the Community Health Workers, supervisors and data collectors. We thank Helen Owen for support in preparing figures for the paper.

Funding
This supplement publication cost was supported by the Health Systems Research Unit, South African Medical Research Council. The "Cost of Integrated Newborn (COIN) Care Tool" was developed by the South African Medical Research Council and funded by Save the Children's Saving Newborn Lives programme. MT, TD & DJ were also supported by the South-African National Research Foundation.

Conflict of interest statement.
None declared.

References

Aranda-Jan CB, Mohutsiwa-Dibe N, loukanova S. 2014. Systematic review on what works, what does not work and why of implementation of mobile health (mHealth) projects in Africa. *BMC Public Health* 14: 188.

Bang AT, Bang RA, Baitule SB, Reddy MH, Deshmukh MD. 1999. Effect of home-based neonatal care and management of sepsis on neonatal mortality: field trial in rural India. *Lancet* 354: 1955–61.

Baqui AH, Ahmed S, El Arifeen S *et al*. 2009. Effect of timing of first postnatal care home visit on neonatal mortality in Bangladesh: a observational cohort study. *Bmj* 339: b2826.

Baqui AH, El-Arifeen S, Darmstadt GL, *et al*. 2008. Effect of community-based newborn-care intervention package implemented through two service-delivery strategies in Sylhet district, Bangladesh: a cluster-randomised controlled trial. *Lancet* 371: 1936–44.

Bhutta ZA, Lassi ZS, Pariyo G, Huicho L. 2010. *Global experiences of community health workers for delivering health related millennium development goals: a systematic review, country case studies, and recommendations for integration into national health systems*. Geneva: WHO Global Health Workforce Alliance.

Black RE, Allen LH, Bhutta ZA *et al*. 2008. Maternal and child undernutrition: global and regional exposures and health consequences. *Lancet* 371: 243–60.

Bradshaw D, Dorrington RE, Laubscher R. 2012. *Rapid mortality surveillance report 2011*. Cape Town: South African Medical Research Council. ISBN: 978-1-920618-00-1.

Braun R, Catalani C, Wimbush J, Israelski D. 2013. Community health workers and mobile technology: a systematic review of the literature. *PLoS One* 8: e65772.

Celletti F, Wright A, Palen J *et al*. 2010. Can the deployment of community health workers for the delivery of HIV services represent an effective and sustainable response to health workforce shortages? Results of a multicountry study. *Aids* 24: S45–57.

Daviaud E, Subedar H. 2012. Staffing norms for Primary Health Care (PHC) in context of PHC re-engineering report. National Department of Health. Medical Research Council, South Africa. http://www.mrc.ac.za/healthsystems/StaffingNorms.pdf.

Daviaud E, Owen H, Pitt C *et al*. 2017a. Overview, methods and results of multi-country community-based maternal and newborn care economic analysis. *Health Policy and Planning* 32: i6–i20.

Day C, Gray A, Budgell E. 2011. *South African Health Review*. Cape Town: Health Systems Trust.

DHIS. 2012. *District Health Information System Database*. South Africa: National Department of Health.

Friberg IK, Kinney MV, Lawn JE *et al*. 2010. Sub-Saharan Africa's mothers, newborns, and children: how many lives could be saved with targeted health interventions? *PLoS Med* 7: e1000295.

Gilson L, Walt G, Heggenhougen K *et al*. 1989. National community health worker programs: how can they be strengthened? *Journal of Public Health Policy* 10: 518–32.

Goga AE, Dinh TH, Jackson DJ, Group FTSS. 2012. *Evaluation of the Effectiveness of the National Prevention of Mother-to-Child Transmission (PMTCT) Programme Measured at Six Weeks Postpartum in South Africa, 2010*. Cape Town: South African Medical Research Council, National Department of Health of South Africa, and PEPFAR/US Centers for Disease Control and Prevention.

Jaskiewicz W, Tulenko K. 2012. Increasing community health worker productivity and effectiveness: a review of the influence of the work environment. *Human Resources of Health* 10: 38.

Kawakatsu Y, Sugishita T, Tsutsui J *et al*. 2015. Individual and contextual factors associated with community health workers' performance in Nyanza Province, Kenya: a multilevel analysis. *BMC Health Services Research* 15: 442.

Kerber K, Lawn J.E et al. 2013. South African child deaths 1990–2011: Have HIV services reversed the trend enough to meet Millennium Development Goal 4? *AIDS*: 23 October 2013. 16(21). pp. 2637–48. doi: 10.1097/01.aids.0000432987.53271.40.

Kumar V, Mohanty S, Kumar A *et al*. 2008. Effect of community-based behaviour change management on neonatal mortality in Shivgarh, Uttar Pradesh, India: a cluster-randomised controlled trial. *Lancet* 372: 1151–62.

Lassi ZS, Haider BA, Bhutta ZA. 2010. Community-based intervention packages for reducing maternal and neonatal morbidity and mortality and improving neonatal outcomes. *Cochrane Database of Systematic Reviews* 11:CD007754. doi: 10.1002/14651858.CD007754.pub2.

Lefevre AE, Shillcutt SD, Waters HR *et al*. 2013. Economic evaluation of neonatal care packages in a cluster-randomized controlled trial in Sylhet, Bangladesh. *Bulletin of World Health Organization* 91: 736–45.

Lehmann U., Sanders D, 2007, Community health workers: What do we know about them? WHO, Evidence and Information for Policy, Department of Human Resources for Health Geneva, January 2007

Leon N, Schneider H, Daviaud E. 2012. Applying a framework for assessing the health system challenges to scaling up mHealth in South Africa. *BMC Medical Informatics and Decision Making* 12: 123.

Makan B, Bachman M. 1997. An economic analysis of community health workers. Programmes in the Western Cape Province. Health Systems Trust. ISBN: 1-919743-07-3.

Mangham-Jefferies L, Mathewos B, Russell J, Bekele A. 2014. How do health extension workers in Ethiopia allocate their time? *Human Resources for Health* 12: 61.

Nsibande D, Doherty T, Ijumba P, *et al*. 2013. Assessment of the uptake of neonatal and young infant referrals by community health workers to public health facilities in an urban informal settlement, KwaZulu-Natal, South Africa. *BMC Health Services Research* 13: 47.

Oanda, Historical exchange rates,2015, http://www.oanda.com/lang/fr/currency/historical-rates/

Pitt C, Tawiah T, Soremekun S, *et al*. 2016. Cost and cost-effectiveness of newborn home visits: findings from the Newhints cluster-randomised controlled trial in rural Ghana. *Lancet Global Health* 4: e45–56.

Puett C, Coates J, Alderman H, Sadruddin S, Sadler K. 2012. Does greater workload lead to reduced quality of preventive and curative care among community health workers in Bangladesh? *Food and Nutrition Bulletin* 33: 273–87.

Rollins NC, Bhandari N, Hajeebhoy N *et al*. 2016. Why invest, and what it will take to improve breastfeeding practices? *Lancet* 387: 491–504.

SANDOH. 2010. The National Antenatal Sentinel and HIV and Syphilis Prevalence Survey. South Africa. National Department of Health, 2011, www.health.gov.za/.. ./101-2011rp?.. .national-antenatal-sentinel-hiv-and-syphilis-prev.

SANDOH. 2012. The 2012 National Antenatal Sentinel HIV and Herpes Simplex type-2 prevalence Survey, South Africa, National Department of Health. South Africa. https://www.health-e.org.za/wp-content/uploads/2014/05/ASHIVHerp_Report2014_22May2014.pdf.

Strachan DL, Kallander K, Ten Asbroek AH *et al*. 2012. Interventions to improve motivation and retention of community health workers delivering integrated community case management (iCCM): stakeholder perceptions and priorities. *American Journal of Tropical Medicine and Hygiene* 87: 111–9.

Swartz A. 2013. Legacy, legitimacy, and possibility: an exploration of community health worker experience across the generations in Khayelitsha, South Africa. *Medical Anthropology Quarterly* 27: 139–54.

Teklehaimanot A, Kitaw Y, Yohannes AG *et al*. 2007. Study of the working conditions for health extension workers in Ethiopia. *Ethiopian Journal of Health Development* 21: 246–59.

Tomlinson M, Doherty T, Ijumba P *et al*. 2014. Goodstart: a cluster randomised effectiveness trial of an integrated, community-based package for maternal and newborn care, with prevention of mother-to-child transmission of HIV in a South African township. *Tropical Medicine and International Health* 19: 256–66.

Tomlinson M, Doherty T, Jackson D *et al*. 2011. An effectiveness study of an integrated, community-based package for maternal, newborn, child and HIV care in South Africa: study protocol for a randomized controlled trial. *Trials* 12: 236.

UNAIDS. 2012. Global AIDS Response Progress Report. South Africa.

Van Ginneken N, Lewin S, Berridge V. 2010. The emergence of community health worker programmes in the late apartheid era in South Africa: an historical analysis. *Social Science and Medicine* 71: 1110–8.

Walker DG, Jan S. 2005. How do we determine whether community health workers are cost-effective? Some core methodological issues. *Journal of Community Health*, 30: 221–9.

WHO. 2013. *WHO Recommendations on Postnatal Care of the Mother and Newborn*. Geneva: WHO Library Cataloguing-in-Publication Data.

WHO, UNICEF, USAID & CHILDREN, S. T. 2009. *WHO-UNICEF Joint Statement on Home Visits for the Newborn Child: A Strategy to Improve Survival*. Geneva: World Health Organization.

World Development Indicators - Data | The World Bank data.worldbank.org/data-catalog/world-development-indicators- 2015.