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Original Article

Community-Based Interventions for Newborns in Ethiopia (COMBINE): Cost-effectiveness analysis

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Abstract

About 87 000 neonates die annually in Ethiopia, with slower progress than for child deaths and 85% of births are at home. As part of a multi-country, standardized economic evaluation, we examine the incremental benefit and costs of providing management of possible serious bacterial infection (PSBI) for newborns at health posts in Ethiopia by Health Extension Workers (HEWs), linked to improved implementation of existing policy for community-based newborn care (Health Extension Programme). The government, with Save the Children/Saving Newborn Lives and John Snow, Inc., undertook a cluster randomized trial. Both trial arms involved improved implementation of the Health Extension Programme. The intervention arm received additional equipment, support and supervision for HEWs to identify and treat PSBI. In 2012, ~95% of mothers in the study area received at least one pregnancy or postnatal visit in each arm, an average of 5.2 contacts per mother in the intervention arm (4.9 in control). Of all visits, 79% were conducted by volunteer community health workers. HEWs spent around 9% of their time on the programme. The financial cost per mother and newborn was $34 (in 2015 USD) in the intervention arm ($27 in control), economic costs of $37 and $30, respectively. Adding PSBI management at community level was estimated to reduce neonatal mortality after day 1 by 17%, translating to a cost per DALY averted of $223 or 47% of the GDP per capita, a highly cost-effective intervention by WHO thresholds. In a routine situation, the intervention programme cost would represent 0.3% of public health expenditure per capita and 0.5% with additional monthly supervision meetings. A platform wide approach to improved supervision including a dedicated transport budget may be more sustainable than a programme-specific approach. In this context, strengthening the existing HEW package is cost-effective and also avoids costly transfers to health centres/hospitals.

Keywords: Newborn, maternal, community health worker, supervision, economic, cost-effectiveness, Ethiopia, multi-purpose community health worker, sepsis management, transport

Key Messages

- *Package and evaluation design:* COMBINE was a cluster randomized trial in a population with one HEW per 2500 population and one volunteer Community Health Worker (vCHW) per 30–50 households. Both arms received an enhanced version of the government's Health Extension Program (additional training, home visits by volunteers and HEWs and supervision support). In the intervention arm, management at health post by HEWs of neonatal PSBI was added.
- *Coverage:* 95% of pregnant women covered with an average of 5.2 contacts per mother–newborn pair during the pregnancy and postnatal period, 79% of all visits were done by vCHWs. Volunteers were crucial to assist HEWs, who covered multiple programmes.
- *Cost-effectiveness*: The addition of PSBI management at community level was estimated to reduce post-Day 1 neonatal mortality by 17%. Such a reduction translates to a cost per DALY averted of 47% of the GDP per capita, and would make the intervention highly cost-effective by WHO thresholds and cost-effective by the new approaches to cost-effectiveness which emphasize opportunity costs to the health system and have lower thresholds.
- *Standardized cost per 100 000 population in routine set-up with 95% of women receiving at least four visits:* cost per mother/baby is $1.78, cost per home visit is $0.45 ($US 2015).
- *Implications for sustainability:* the cost-effectiveness is dependent on the PSBI being added to an existing package of community-based maternal newborn care, in this case through Ethiopia's HEW. This evaluation was part of a trial with more resources for training, equipment, supervision and transport and for routine scale-up, supervision will be especially critical.

Introduction

Ethiopia is the second most populous country in Africa, with a population of over 96 million (United Nations 2015). Despite meeting MDG4 to reduce child mortality by two-thirds, less progress has been made for neonates where an estimated 87 000 neonates (0–27 days) die in Ethiopia each year, almost half of under five deaths (Mekonnen *et al.* 2013; Countdown 2015) . Poor access to health care facilities (Okwaraji *et al.* 2012) and low care-seeking behaviour (Central Statistical Authority 2012; Mebratie *et al.* 2014) have contributed to over 85% of women giving birth at home without a skilled birth attendant (Teferra *et al.* 2012; Bayou and Gacho 2013; Shiferaw *et al.* 2013; UNICEF 2013; Agency 2014) (Box 1). Primary health care is delivered through health centres and at community-level health posts staffed with health extension workers (HEWs). The HEWs, on average two per health post, divide their time between health post and community outreach activities. Nurses from the health centre supervise HEWs.

To address the high number of newborn deaths, the government, Save the Children/Saving Newborn Lives (SNL) and John Snow, Inc. (JSI) programme in Ethiopia undertook a cluster randomized trial, 'Community-Based Interventions for Newborns in Ethiopia' (COMBINE), in 22 clusters in 2 regions: Oromia and Southern Nations Nationalities and Peoples' Region (SNNPR) (Figure 1). In both arms of the COMBINE trial, HEWs referred sick newborns to health centres, where newborns with possible serious bacterial infection (PSBI) were managed according to national Integrated Management of Newborn and Childhood Illness (IMNCI) protocols. In intervention areas, management of neonatal PSBI was also made available at health posts. There, HEWs treated newborns for seven days with daily gentamycin injections and oral amoxicillin was administered by caretakers twice daily. Volunteer Community Health Workers (vCHWs) were recruited for the study to conduct home visits and community education in both arms—some were later absorbed into the Health Development Army (HDA) established and trained by the government (Supplementary Data).

The overall aim of the COMBINE trial was to provide evidence of the additional benefit, in terms of newborn lives saved and cost, of delivering PSBI management at health posts against a background of high-quality implementation of the existing government policy [Health Extension Programme (HEP) with Integrated Community-Case Management (iCCM) of common childhood illnesses]. The primary outcome of interest of the effectiveness study was all-cause neonatal mortality after first day of life.

To assess whether the programme was cost-effective and affordable, a costing study in both arms accompanied the effectiveness study. Prior to this, no such effectiveness or costing information was available for PSBI management at community level.

This article is part of a series of eight papers in the Health Policy and Planning supplement which reports the results of a multi-country analysis of additional costs and resources for community-based maternal/newborn care. Standardized definitions, a comparable approach and scale up analyses are described in the first paper of the supplement (Daviaud *et al.* 2017a).

Objectives of the costing study specifically for COMBINE (Figure 2)

1. To assess the incremental cost of the Health Extension Programme for neonatal care according to existing policy in the programmes with and without PSBI management as implemented in the research set-up.
2. To assess the cost-effectiveness of PSBI management at health posts in the intervention arm compared to the control arm.
3. To assess the affordability of integrating community-based identification and management of infections in neonates by HEWs supported by vCHWs in a routine setting.
4. To quantify the financial implications of scale-up in a routine set-up.

Methods

Within each region clusters were allocated to either control or intervention arm, using restricted randomization. In both arms, implementation of the maternal and newborn component of the HEP was done as described in the existing policy, requiring additional inputs to fully implement the policy: providing some equipment to health posts and improving monitoring and supervision. A programme of home visits was introduced in both arms. The intervention arm also added the provision of PSBI management at health posts by HEWs.

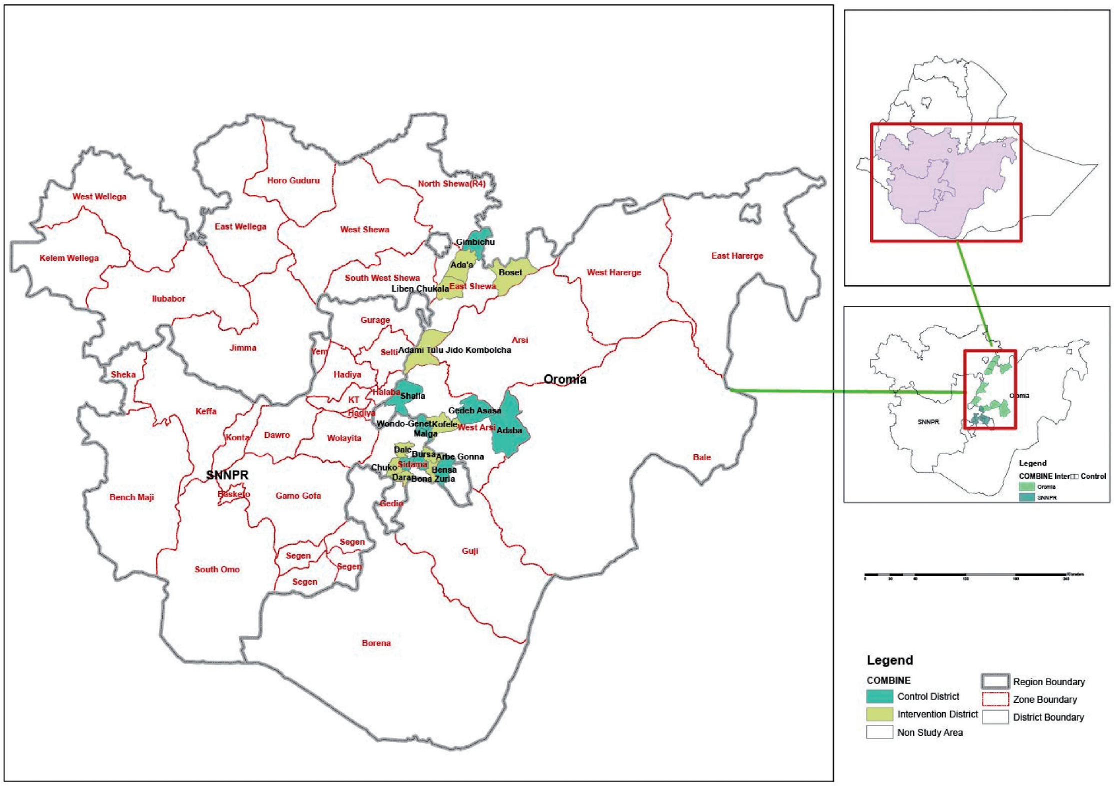

Figure 1. Location of COMBINE intervention and control districts

Economic Analyses			Arms	Results of analyses
Time analysis	HEW time per category activities		Intervention	• Time on the programme • % of HEW total time on the programme • Feasibility of integration programme in HEW routine activities
Incremental cost analysis	Research set -up	Financial costs	Control	Programme costs - 2 arms
		Economic costs	Intervention	ICER: Incremental cost per death averted intervention arm
	Routine set -up	Financial costs	Control	Programme costs - 2 arms
			Intervention	• Cost per mother and per visit • Sustainability: % public health expenditure
			Intervention	Scale -up analysis

Figure 2. Overview of the economic evaluations undertaken for the COMBINE Crct

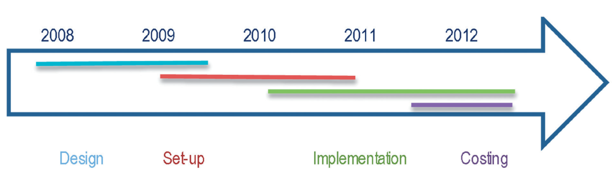

Figure 3. Study time period

In all clusters, antenatal and postnatal home visits by HEWs and vCHWs were implemented. During these, HEWs and volunteers used an illustrated, maternal and newborn health card for counselling and review of key messages. A smaller version of the card was given to pregnant women. The card covered the benefits of focused antenatal care, birth planning and emergency preparedness, essential newborn care and care seeking for maternal and newborn danger signs and family planning. Another card was also developed for counselling on maternal and newborn danger signs during postnatal home visits. If during a home visit danger signs were identified, the baby was referred to the nearest health centre. In the intervention arm, oral and injectable antibiotics were provided at health posts when referral was not possible or acceptable for some reason. No treatment was available at health posts in the control clusters. The programme established a simple notification system between vCHWs and HEWs for identification of pregnant women and births, as well as the identification and referral of sick neonates, with active participation of families. HEWs also encouraged mothers to use local health centres or health posts.

Timeline

The study was divided into three phases: the design phase (defining the programme, designing training materials, job aids and

Table 1 Profile of activity per cadre of worker

	Control	Intervention
Number of health posts	61	70
Number HEWs	117	142
Number volunteers	1695	1830
Number health centre supervisors	20	23
Number P.Os supervisors (40% on supervision)	18	19
Population per HEW	2889	2449
Population by vCHW	199	190
Number mother/neonate pair visited at least once	8588	9760
% of potential pairs covered	94.8%	94.7%
Average number of mother/neonate per HEW/year	73	69
Average number of mother/neonate per volunteer/year	5	5
Actual number contacts for the year by HEWs	7759	12 112
Actual number home visits for the year by volunteers	30 998	35 338
Average number contacts per HEW per week	1.4	1.8
Average number home visits per volunteer per week	0.4	0.4
Average number contacts per mother/neonate by HEW	0.9	1.2
Average number home visits per mother/neonate by volunteer	4.0	4.0

communication materials), the set-up phase (purchase of equipment, motorbikes and consumables, recruitment of staff, training of trainers, initial staff training and initial meetings with community) and the implementation phase (Figure 3). Study data reflect costs of the 2008–11 set-up periods and 1 year of implementation January–December 2012. Data on costs for the design activities were not available. Data collection thus focused on set-up and implementation costs.

Data collection

The 2012 activity data for home visits by HEWs and vCHWs were routinely collected by the research project and extracted from the programme monitoring and evaluation system. The number of deliveries in 2012 in the study areas was estimated from the end-line survey of women of reproductive age, conducted in 2013 and included a 3-year pregnancy history. Time allocation data were extracted from an embedded research study carried out in 2013 by the London School of Hygiene and Tropical Medicine (Mangham-Jefferies *et al.* 2014), to understand the range of HEW activities. In 69 kebeles in the intervention area, 131 HEWs completed a diary for 4 consecutive weeks, a total of 20 123 entries, 127 HEWs participated during that period in the neonatal programme.

We used a provider perspective to calculate costs for the health system and funder; household costs and research costs were excluded. We collected financial costs (additional expenditure for the programme) and economic costs, which includes opportunity costs for the provider (Table 1). As part of the HEP, HEWs receive salaries from the government and have 1 year of basic training. The COMBINE programme provided refresher and additional in-service training. HEWs received 6 days (refresher) iCCM (Integrated Community Case Management) training, of which 1.5 days specifically focused on neonatal care. HEWs in both arms also received 4 days training on conducting home visits and three additional days on how to work with vCHWs. In the intervention arm, HEWs had an additional day of training on infection management. In total, HEWs received 13 days training in the control and 14 days in the intervention arm prior to study implementation. Supervisors and HEWs received the same training and allowance. vCHWs received 4 days training, and 2 days refresher training, on conducting home visits (counselling on maternal and neonatal care and identification and referral of sick newborns).

Supervision took place at several levels. HEWs are expected to receive monthly supervision from supervisors at the health centre as part of the routine HEP, but its implementation was weak at the time of the study. To compensate, 38 Project Officers (POs) with nursing backgrounds were employed by the study. POs worked in both arms supporting two to four health posts and made at least two visits per month to each health post, with HEWs' health centre supervisors when possible. At each health post, POs, HEWs and volunteers held monthly meetings to review home visit coverage trends, documentation and counselling and assessment skills. In the intervention arm, additional monthly meetings were held to review data on PSBI management and provide clinical mentoring. A quarterly review meeting involving both supervisors and HEWs provided additional onsite refresher training and support in both arms. The additional support/supervision provided by PO amounted to 40% of a full-time equivalent per PO. COMBINE provided health posts in both arms with job aids and basic medicines and supplies, where there was shortage. No transport costs for home visits by HEWs and vCHWs are included as travel was done on foot.

Capital equipment was defined as any equipment usable for more than 1 year and included motorbikes for POs and HEW kits, both with 3 years expected life. Training costs were annualized over 3 years. Data on POs' salaries as well as costs of additional community and supervision meetings were provided by the Ethiopia SNL finance department. POs kept a log of distance travelled and reason for travel, from which distance covered for supervision of health posts were extracted. Quantities and unit costs for drugs, and HEW kits, were collated from the SNL finance department and the UNICEF health department which contributed to some of the purchases. Management costs included an additional 20% of PO's salaries for their management and M&E activities. Overheads, share of SNL office and administration costs, were calculated on the base of COMBINE related offices as a percentage of total offices costs. To calculate opportunity costs, vCHWs time was valued using the daily agricultural wage in 2012 (Josephsona *et al.* 2014). Actual salary packages were used to estimate the cost of HEWs' and health centre supervisors' time. For the purpose of annualization, a discount rate of 3% was used (Walker and Kumaranayake 2002) for capital and set-up costs.

Cost data were collected and analysed using the Excel-based Cost of Integrated Neonatal (COIN) care tool (Daviaud et al

2017a). The base year was 2012. All costs are expressed in USD 2015 after adjusting for inflation (World Databank). The exchange rate of Ethiopian Birr (ETB) to USD in June 2015 was ETB 20.58 to US$1.

Analysis

The number of mother and baby pairs visited is defined as the number of mothers who received at least one home visit during pregnancy or after birth. Average numbers of visits per mother are presented, disaggregated between pregnancy and postnatal visits and between HEWs and vCHWs. Time per type of visit in the home and at health posts were analysed; mean and median times are presented with their confidence intervals. The share of HEW's time spent on the programme, extracted from Mangham-Jefferies *et al.* (2014), was used to assess the feasibility of integrating this programme into the HEW workload on a routine basis average time was used for cost calculations.

Costs are presented for each arm, including set-up costs (total and annualized) and 1 year implementation costs. Annualized set-up and implementation costs are combined to calculate unit costs: cost per mother and cost per visit. Costs are broken down between fixed costs, independent of the number of mothers and babies visited, and variable costs. Fixed costs include capital costs, training, orientation meetings, share of POs salaries and transport, supervision meetings, whilst variable costs covered drugs and supplies. We included the costs of implementing the intervention, but not the costs/savings of potential changes in health service utilization resulting from the intervention. To assess affordability, annualized programme cost is divided by the total population of the study area. This per capita cost is then calculated as a percentage of the 2012 public health expenditure per capita, extracted from the World Data Bank (The World Bank, 2012).

We calculated the newborn Incremental Cost Effectiveness ratios as additional cost per DALY averted in the intervention arm compared with the control arm. The number of additional deaths averted in the intervention arm was extracted from the analysis of impact published separately (Degefie, 2017). The cluster level analysis was adjusted for mortality risk and region. We used the point estimate for the middle case scenario, the upper range of the confidence interval for the best scenario and defined the worst effectiveness scenario as no deaths averted. We calculated the number of DALYs averted using the country 2010 health adjusted life expectancy at birth extracted from the Global Burden of Disease Study 2010 (Evaluation 2010) to which we applied a 3% discount rate. Health adjusted life expectancy at birth stood at 52.5 years (64 years when not health adjusted), discounted DALYs amounted to 26.7 per newborn death averted. For economic costs, the analysis was done at arm level as there was little variation between clusters: coverage was very similar between clusters and the unit costs were the same for similar activities/items within an arm. Quantities of drugs and supplies, hence costs, which could vary between clusters represented under 2% of economic costs. We defined the worst and best cost scenarios by varying the discount rate (0–6%). We use five cost-effectiveness thresholds (CET): the first two are function of the Ethiopia's per capita gross domestic product: 'cost-effective' (cost per DALY averted <3 times GDP per capita) and 'very cost-effective' (<GDP per capita) (World Health Organization 2014). The other CETs are based on opportunity costs of a change in health expenditure. Woods *et al.* (2016) estimate a range of 10–255 (2013 US$) for Ethiopia while Ochalek *et al.* (2015) estimate a range of 6–8 (2000 US$) based on cross-sectional data and 65–93 (2005 US$) using panel data. We updated the suggested thresholds to 2015 USD by translating them back into Birrhs at the time, applying inflation increases up to 2015 and translating back into 2015 USD using the 2015 exchange rate. We combined best case scenarios for effectiveness and cost and worst case scenarios to derive a possible range of cost per DALY averted.

Sensitivity analysis

To assess the affordability of the programme in a routine set-up, we estimated the financial costs of the programme if the programme was run by government in a routine set-up. Since 2012, training of vCHWs is provided by the state, including maternal and newborn health, and has thus been excluded from the additional costs in the sensitivity analysis. Compensation for meetings and training was set at government level ($6), rather than donors' rates ($24), as were the cost of venues and trainers. In the routine set-up, supervision is decreased: no POs and the separate monthly sepsis management review meeting which took place during the intensive support period of the research does not take place, but is integrated in the routine review meetings. These costs were thus excluded. Supervision is provided through the link with the health centres and with a multi-programmes quarterly review meeting involving all health posts. Average costs per visit and per mother/newborn pair visited in the 'routine set-up' are presented. Given the differences between the costs included in the research set-up and those included in the routine set-ups, these costs cannot be compared.

We then estimated the cost of the programme with PSBI management in a routine set-up with lower levels of coverage and fewer visits, as would likely be the case in a routine situation in contrast to a study situation with strong support and monitoring. Three scenarios were modelled:

Scenario 1 reflects the cost per mother/newborn pair visited and per visit if 95% of all mother/newborn pairs were visited with the target number of visits (9). This scenario also covers time implications as well as affordability of the programme expressed as a percentage of public health expenditure per capita.

Scenario 2 varies the coverage of mother/newborn pairs from 50–70 to 95% with an average of four visits per pair.

Scenario 3 standardizes Scenario 2 results for a population of 100 000 with the country's crude birth rate of 33.5 (The World Bank 2012).

We then assessed for each scenario the cost impact of introducing a monthly sepsis management meeting, in recognition of the importance of support/supervision in community-based care activities, and based on the fact that supervision from health centres is often irregular (Miller *et al.* 2013; Doherty *et al.* 2014), partly due to unavailability of transport funds.

Results

Coverage of the interventions

In 2012, 94.8% (8,588) of pregnant and new mothers in the control arm and 94.7% (9,760) in the intervention arm, were visited at home for antenatal and/or postnatal visits. HEWs had contacts with about 73 mothers a year in the control arm and 69 in the intervention arm. VCHWs visited an average of five mothers a year in both arms. The target number of contacts per mother/newborn pair was three HEW contacts and six vCHW contacts. HEW contacts were a combination of home visits and health post visits (Table 1) (Supplementary Data). Analysis of the time allocation survey in the

Table 2. Incremental financial costs for the addition of COMBINE control or intervention package according to phase of implementation—USD 2015

Costs	Pre-implementation: Set-up				Implementation (1 year)	Annualized Set-up & recurrent implementation
	Total costs		Annualized costs ($)			
	Capital	Non-Capital	Capital	Non-Capital		
Financial						
Control (strengthening HEW care) control	26 675	358 069	9488	119 356	109 605	238 449
Intervention (addition of PSBI treatment at health post/community)	28 754	437 704	10 308	145 901	184 878	341 088
Economic						
Control	28 250	379 765	10 035	126 588	119 655	256 27
Intervention	30 446	464 225	10 899	154 742	197 916	363 557

intervention arm shows that 23% of antenatal visits took place in homes and 77% in health posts, whilst 59% of postnatal visits were in homes (including the early PNC visits) and 41% at health posts. In the control arm, each mother had an average of 0.9 contacts with a HEW and 4 vCHW home visits. In the intervention arm there were an average of 1.2 HEW contacts per mother, 29% higher than the control arm, and 4 vCHW home visits.

HEWs had an average of 1.4 programme-related contacts a week in the control arm and 1.8 in the intervention arm. For vCHWs, numbers of home visits were similar in both arms at 0.4 visits a week. There were an average of 14 vCHWs per HEW in the control arm and 13 in the intervention arm. Each vCHW covered a total population of about 190. Supervisors from health centres spent an average of 7% of their time on supervision in the control arm and 11% in the intervention arm, with a ratio of six HEWs per supervisor in both arms. In addition, POs spent ~40% of their time on supervision with a ratio of 6.5 HEWs per PO in the control arm and 7.9 in the intervention arm.

The mean time for a HEW home visit, excluding travel time, was 28 min for pregnancy visits and 36 min for postnatal visits (median 23 min with no significant difference between types of visits) (Supplementary Data). Visits at health posts were shorter (median 15 min), with no significant difference between types of visits. Mangham-Jefferies *et al.* (2014) reported that pregnancy and postnatal visits together with time for travel, meetings and administration, represented 14.6% of the recorded HEW time. During the Mangham-Jefferies study, HEWs recorded in their 4-week diary an average of 3.5 visits per week, whilst 1.8 visits a week were recorded by the programme's routine monitoring system during 2012, such a difference is frequently observed during the period where survey participants are monitored. On average, in 2012 HEWs spent around 9.2% of their time on the neonatal programme.

Effectiveness of the intervention

Of the neonates identified with PSBI in the intervention arm, 10% were referred and 90% were treated at health posts, with a treatment completion rate of 79% (Degefie *et al.* 2017). The number of deaths in the first 36 h declined in both arms, with no evidence that PSBI treatment in the intervention arm was associated with a reduction in first day deaths (RR 1.04; 95% CI 0.70–1.55; $P = 0.83$). Post-day-one neonatal mortality declined more in the intervention arm (17.9–9.4) than the control arm (14.4–11.2). After adjusting for baseline mortality risk and region, the post-day-one mortality risk ratio estimated from a cluster level analysis was 0.83, with substantial uncertainty (95% CI 0.55–1.24; $P = 0.33$). Results from the individual level analysis suggest a greater reduction (27%) in post-day-one all-cause mortality in intervention areas (RR 0.72; 95% CI 0.49–1.06; $P = 0{\cdot}09$).

Costs

The annualized financial cost of the programme in the research set-up was $238 449 ($256 279 for economic costs) in the control arm and $341 088 ($363 557) in the intervention arm (Table 2), difference between arms were mainly due to costs of additional supervision meetings. Set-up represented 54% of financial cost in the control arm and 46% in the intervention arm (Table 3). Training accounted for ~92% of set-up costs in both arms: $120 (non-annualized) per vCHW in both arms and $1230 per HEW in the control arm, $1446 in the intervention arm. Capital equipment costs covered the purchase of motorcycles for POs, and the HEW's kit: bag, watch, pregnancy and iCCM under 2 months' registers, a non-annualized cost of $32 per HEW excluding drugs and clinical supplies. No additional capital expenditures were required for the programme. The main cost driver during the implementation year was supervision/support (supervision meetings, POs salaries and transport): 76% of implementation costs in control arm and 80% in the intervention arm. Management and overheads represented 13 and 11%, respectively. Combining annualized set-up costs and implementation costs, fixed costs represented 99% of financial costs in the control arm and 98% in the intervention arm. Supervision costs (training supervisors, POs' salaries and transport and supervision meetings) represented 39% of the annualized financial programme costs in the control arm and 46% in the intervention arm (Table 3).

Financial costs per mother seen were $28 in the control arm ($30 economic cost) and $35 in the intervention arm ($37), and the costs per visit were $5.7 ($6.1 economic) and $6.6 ($7.1), respectively (Figure 4). Financial cost of the programme amounted to $0.7 per capita in the control arm and $1 in the intervention arm, representing, respectively, 4 and 5.5% of the estimated $18 public health expenditure (Government own+donors) per capita in 2015 USD. Economic costs of the programme amounted to $0.8 per capita total population in the control arm and $1.1 in the intervention arm, or 4.5 and 6.1% of the public health expenditure per capita.

Cost-effectiveness analysis

An estimated additional 18 deaths were averted in the intervention arm, 48 in the best case scenario and none in worst scenario, with 26.7 DALYs averted per death averted (Table 4). The incremental cost per additional death averted was $5960 ($2217–infinite). Incremental cost per DALY averted was $223 ($84–infinite). With a 2012 per capita GDP of $470 in 2015 USD, the COMBINE cost per

Table 3. Annualized set-up and 1 year implementation costs in the COMBINE trial, in USD 2015

	Financial Costs				Economic Costs	
	Total		Share Costs		Total	
	Control	Intervention	Control (%)	Intervention (%)	Control	Intervention
Set-up						
Motorcycles P.Os (Share of)	7632	8056	5.9	5.2	8095	8545
Equipment: Kits	1855	2251	1	1	1940	2355
Meetings Woredas, Community	751	929	1	1	797	985
Training vCHWs	67 874	73 371	53	47	71 987	77 816
Training HEWs	47 969	68 425	37	44	50 875	72 571
Training Supervisors	2762	3177	2	2	2930	3370
Total Set-Up	*128 844*	*156 209*	*100*	*100*	*136 623*	*165 641*
Implementation						
Meetings : Supervision	30 961	79 464	28	43	30 961	79 464
Training Updates	8589	10 134	8	5	8589	10 134
Salaries Supervisors (Share of)	27 477	29 003	25	16	32 123	34 346
Salaries HEWs (Share of)	–	–	0	0	15 639	18 980
Payments vCHWs	–	–	0	0	6262	6760
Transport Supervision	24 965	38 693	23	21	24 965	38 693
Management & Overheads	14 374	20 908	13	11	14 374	20 908
Drugs	3202	5785	2.9	3.1	3202	5785
Clinical Supplies	37	892	0	0.5	37	892
Total Implementation	*109 605*	*184 879*	*100*	*100*	*119 655*	*197 916*
Total	***238 449***	***341 088***			***256 279***	***363 557***

DALY averted represents 47% (18%–infinite) of GDP per capita. The WHO CET thresholds were $1410 (three times GDP per capita) per DALY averted for PSBI treatment at community level to be considered cost-effective and $470 (GDP per capita) to be considered very cost-effective. The maximum threshold according to Woods *et al*. (2016) would be $288 (61% of GDP per capita) and according to Ochalek *et al*. (2015) $215 based on panel data (46% of GDP per capita) and $19 (4%) based on cross-sectional data.

Sensitivity analysis

Financial costs in routine set-up

If the neonatal programme was integrated into the routine system, with the modifications described in the methodology section, and assuming that the number of mothers seen and the number of contacts remained unchanged, annualized financial costs of the programme would be $12 079 in the control arm and $18 796 in the intervention arm, representing $0.04 per capita total population in the control arm and $0.05 in the intervention arm, or 0.2% of the country per capita public health expenditure in the control arm and 0.3% in the intervention arm.

Focussing on the intervention sites, we varied the level of coverage and number of visits (Table 5). In this study, 94.7% of potential mothers and newborns were seen in the intervention arm, with an average of 5.2 visits per mother/newborn pair. If the target number of visits (nine) per mother was provided (Scenario 1), the cost of the programme would remain unchanged, as would the cost per mother, however cost per visit would decrease to $0.2. With the target three of the nine visits being carried out by HEWs, up from the observed 1.2, HEWs would spend 17% of their time on the programme, up from the observed 9%. However, it is likely that in a routine set-up with more limited support/supervision and monitoring and possibly decreased HEW motivation, the percentage of potential mothers/newborns covered and the number of visits would decrease, as would probably the impact. Scenario 2 models decreased coverage (50, 70 and 95%) with four visits per mother and newborn. With a 47% reduction in coverage, from 95 to 50%, the cost of the programme would decrease by 17% (supplies to fewer mothers/babies). HEWs, covering half of the four visits per mother, would spend 8% of their time on the programme for 50% coverage and 13% for 95% coverage.

Standardizing to a total population of 100 000 with the national birth rate of 33.5 (compared with 27.9 in the study area), the number of HEWs would be 41, keeping the same ratio of HEW per 1000 population (0.41). The financial cost per mother/newborn pair covered would be $2.8 for 50% coverage and four visits per mother and $1.8 for 95% coverage. HEWs would spend, respectively, 9 and 14% of their time on the programme. The programme would represent 0.3% of the public health expenditure per capita.

Adding to the routine set-up the monthly management review to strengthen support/supervision, would translate into an additional $10 304, increasing the programme cost by 58% for 95% coverage. The programme would represent 0.5% of the public health expenditure per capita

Discussion

This study, COMBINE, was the first randomized evaluation to quantify the additional impact of neonatal PSBI management at community level. Other studies have examined this question as part of a package, but not assessed its mortality impact. However, the decision to scale up this potentially challenging intervention will not be based on impact alone, underlining the need for our evaluation here of cost-effectiveness, and crucially of the additional systems inputs and resources required. Enhanced routine implementation (control and intervention arms) involved system strengthening with increased HEW and vCHW training, supervision and procurement of drugs and clinical supplies. The intervention arm added PSBI management at community level.

Adding PSBI management was estimated to reduce post Day 1 neonatal deaths by 17% (45%–0), at a cost of $223 ($84–infinite)

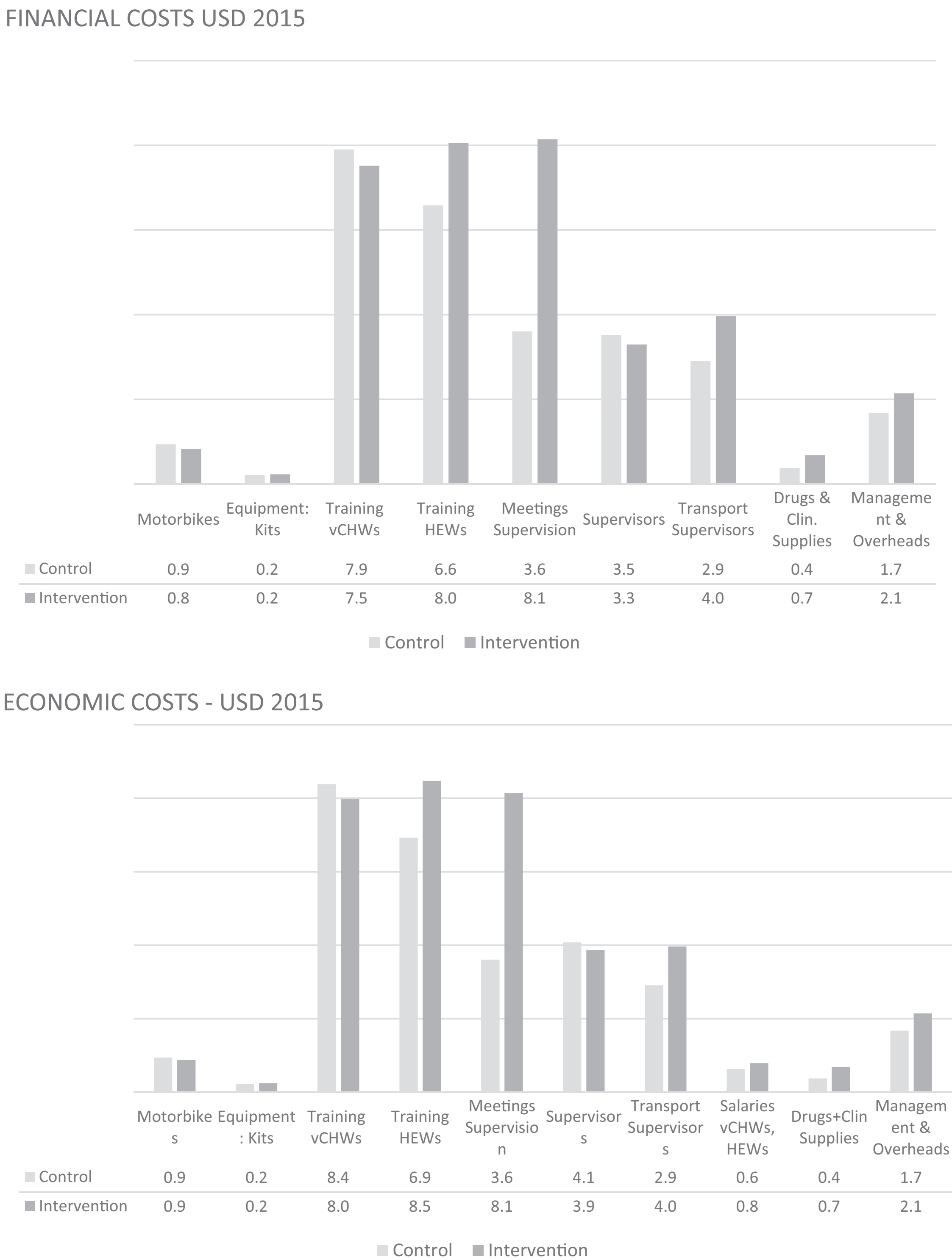

Figure 4. Economic costs chart needs widened slightly to have x axis labels on one line as is hard to red

per DALY averted. Using the WHO cost-effectiveness threshold the intervention is highly cost-effective with a cost per DALY below the GDP per capita. However, this threshold is now questioned by approaches which emphasize that this threshold may be too high since it does not take into account the impact on other health interventions of diverting health expenditure to this program. Woods *et al.* (2016) estimate that for Ethiopia the effectiveness threshold should stand at a maximum of 61% of the per capita GDP, while Ochalek *et al.* (2015) suggest a maximum threshold of 46% of per capita GDP based on panel data and a much lower one of 4% of PCGDP based on cross-sectional data. At 47% of the per capita GDP in the COMBINE study, the cost per DALY averted would make PSBI management at community level cost effective by Wood et al.'s threshold as well as by Ochalek et al.'s higher threshold. Indeed given the fact that this study only assessed neonatal mortality (YL) and not years lived with disability, the effect here is

Table 4. Incremental cost-effectiveness ratio

	Scenarios		
	Middle	Best	Worse
Additional deaths averted 1 year	18	48	–
Health adjusted life expectancy at birth (2010)	52.5	52.5	52.5
DALYs/death averted (discount rate = 3%)	26.7	26.7	26.7
Additional DALYs averted	481	1283	–
Incremental Cost in 2015 USD	107 279	106 435	110 423
Incremental cost per additional death averted	5960	2217	Infinite
Cost/DALY averted	223	84	Infinite
Cost per DALY averted as % of GDP per capita	47%	18%	Infinite

underestimated as the intervention would be anticipated to also reduce impairment and later mortality.

The economic costs in the intervention arm are low at $1.1 per capita. The financial costs at $1 per capita represented 5.5% of public health expenditure per capita ($18), an indicator of the budgetary implications of the programme. These proportions are high partly due to the very low public expenditure per capita in the country, and partly to the intensive support/supervision which amounted to 42% in the intervention arm (46% for the financial costs).

Adapting the programme from a research set-up to a routine set-up will assist policy makers to assess its affordability, acknowledging that decreased level of support in a routine set-up may affect the impact of the intervention. For this programme, this requires assessing the training and supervision/support components in a routine set-up. Some of the training provided by the programme is now integrated as part of the routine set-up and paid by the government: training on home visits, training of HEWs on working with vCHWs and training of vCHWs. We have thus added to the routine set-up 1.5 days of refresher training on the neonatal component of IMCI training. In the research set-up, support/supervision was very intensive, including a quarterly supportive supervision meeting and a monthly health post visit by a supervisor from the health centre (as part of the routine set-up), but it also included an additional monthly review of PSBI management and a project officer who spent an average of 16 h a week on support for about three health posts, each visited three times per month on top of the other supervision meetings. In a Ministry of Health policy change towards the end of the trial, support/supervision by health centre supervisors is now expected to take place weekly, no longer monthly. Supervision will thus involve a quarterly meeting and a weekly health post visit, although the implementation of this policy may be patchy, as even the monthly visits were often not taking place due to lack of funding and of budget line for supervisors' transport, a common thread across countries in evaluations of community-based programmes (Doherty *et al.* 2014a). The per capita financial cost of the programme, as modelled for the routine set-up, would represent 0.3% of the public health expenditure per capita. If the monthly review meeting was added to the routine set-up, the financial costs would increase by 58% and would represent 0.5% of the public health expenditure per capita.

In both arms, a very high proportion of potential mothers and newborn pairs were visited (95%). VCHWs played a very crucial role in sensitising communities, identifying new pregnancies, linking with the HEWs and initiating over 75% of the contacts. The small population per vCHW (190) ensures a good knowledge of the population and good follow-up. In contrast, each HEW covered an average population of 2670. HEWs achieved an average of 1.2 contacts per mother out of their target of three (pregnancy and postnatal combined), spending 9% of their time on the programme. If they had achieved the target number of visits, this proportion of time would have increased to 17%, potentially endangering other functions they are expected to fulfil. This two-tier system based on complementary roles is a central factor to ensure good coverage, follow-up and impact when community-based services include a range of programmes. Leon *et al.* (2015) emphasized the role, often poorly recognized, of voluntary health workers in a number of sub-Saharan countries. The Ethiopian state does however recognize the importance of volunteers by institutionalizing their role in the Health Development Army and funding their training since 2012.

With HEWs covering multiple programmes with limited resources, policy makers and managers face the question of defining the best and most sustainable way to ensure adequate support and supervision for each programme. Is it to have additional programme-specific review meetings if health posts visits by supervisors are too infrequent? Or is it better to strengthen the whole community based platform by ensuring that the existing multi-programme quarterly review by district officials and weekly visits to health posts by supervisors take place as scheduled? What would be the resource implications of securing these weekly visits? Supervisors are already in post and paid by the government to focus specifically on supervision—as such their increased time on supervision would not threaten the delivery of services at health centres as is the case in many countries where the nurse, already overloaded with patients is expected to provide community supervision. The main difficulty to overcome is transport. Supervisors were supplied with motorbikes by government or donors, but there is often shortage/absence of funding or budget lines to secure their maintenance and running costs. We made a crude estimate of a supervisor's motorbike running costs for a year, assuming weekly visits to each health post, with an average return distance of 60 km per health post, and 100 miles per gallon, assuming an additional 20% for maintenance and insurance, and an additional 30% for rough terrain. A supervisor's motorbike running costs would amount to around $543 per supervisor per year. Standardizing these costs for a population of 100 000, with 41 HEWs and around 20 health posts, this would translate into a budget of $2712 to cover the five supervisors' motorbike running costs for the year. To put this amount into perspective, the yearly salary of a HEW is $892. For a total population of 100 000 the yearly running costs of motorbikes, to ensure weekly visits to health posts and supervision-related meetings, would amount to a cost equivalent to the yearly salary package of three HEWs. Such a small additional expenditure could have significant impact on many programmes, if also associated with a well-functioning system for supervisors' accountability to ensure quality supervisory visits.

Table 5. COMBINE trial actual costs and standardized modelled costs for three scenarios—USD 2015

Intervention arm		Actual	Scenario 1: package as per study design	Scenario 2: varying coverage			Scenario 3: standardization to 100 000 total population		
		Average number of achieved visits	Target visits	Average four visits			Average four visits		
	Coverage	Achieved	Target	Variable			Variable		
	% of potential mothers visited	94.7	95	50	70	95	50	70	95
Activity	Total number visits/mother	5.2	9	4			4		
	Number HEW visits/mother	1.2	3	2			2		
	Number vCHW visits/mother	4.0	6	2			2		
	Number mothers visited	9758	9758	5152	7213	9758	1675	2345	3172
	Total Home Visits (HEWs + vCHWs)	50 741	87 821	20 608	28 851	39 032	6700	9380	12 690
	Number HEWs	142	142	142			41		
	Number mothers per HEW/year	69	69	36	51	69	41	57	78
	Visits per HEW/week	1.7	4.3	1.5	2.1	2.9	1.7	2.4	3.3
Time	% CHW time on programme	9	17	8	10	13	9	11	14
	Supervisors FTEs	7.3	7.3		7.3			2.1	
Cost NO monthly supervision meeting	Cost per mother ($)	$1.93	$1.93	$3.04	$2.36	$1.93	$2.76	$2.17	$1.78
	Cost per home visit	$0.37	$0.21	$0.76	$0.59	$0.48	$0.69	$0.54	$0.45
	Programme cost	$18 795	$18 795	$15 644	$17 054	$18 795	$4631	$5089	$5655
	Programme Cost/capita	0.05	0.05	0.04	0.05	0.05	0.05	0.05	0.06
	Programme cost as % Public Health expenditure per capita	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3

Limitations

Whilst we systematically collected data on programme start up and running costs, we did not include design costs (formative research, design of intervention, training materials and job aids) which were not fully detailed. If these would have been included, the cost per DALY averted would have increased. As design costs are one-off costs, these would however not have been included in the calculation of cost per mother or home visit, nor in the affordability assessment in a routine set-up.

The calculation of DALYs averted is based on the number of Life Years Saved and does not include Years Lived with Disability. The number of DALYs may thus be underestimated and as a consequence the cost per DALY averted may be lower than calculated.

Whilst time spent by CHWs on the program was assessed, the time spent by vCHWs was not, and, for the calculation of opportunity costs, vCHWs time was quantified by assuming the same time in homes as reported for HEWs.

Conclusion

Adding PSBI management to a community-based maternal and newborn programme can be cost-effective even when using much lower cost-effectiveness thresholds than those suggested by the WHO. The high cost-effectiveness is dependent on PSBI management being added to an existing package of community-based maternal-newborn care, in this case through Ethiopia's HEW multi-purpose worker (HEW). The high workload of the HEW makes the support from vCHWs essential and dependent on maintaining a high level of quality supervision/support, a challenge for many community-based services. A platform integrated, rather than a programme-specific approach, would be more efficient. Further evaluation of larger-scale routine implementation in Ethiopia would be valuable. Another important question is how this intervention could be implemented in contexts without an existing large-scale community-based maternal-newborn care package, or without this level of support and supervision.

Supplementary Data

Supplementary data are available at *HEAPOL* online.

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Conflict of interest statement. None declared.

Authors' contributions

B.M., D.S., S.C., T.D., S.W., A.B., & J.E.L. were involved in supporting the design and implementation of the COMBINE trial. E.D. and J.E.L. led the design of the COIN Care Tool and have consistently reviewed and extensively provided input into the draft manuscript. B.M. collected the cost data. E.D. and H.O. undertook the analysis. All authors read, provided substantial input and approved the final manuscript.

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