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a retrospective analysis

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Cost-effectiveness and budget impact of the community-based management of hypertension in Nepal study (COBIN): a retrospective analysis

Anirudh Krishnan, Eric Andrew Finkelstein, Per Kallestrup, Arjun Karki, Michael Hecht Olsen, Dinesh Neupane

Summary
Background The greatest risk factor for cardiovascular disease is hypertension, which can be alleviated via diet, exercise, and adherence to medication. Yet, blood pressure control in Nepal is inadequate, which is partly hindered by a lack of evidence-based, low-cost, scalable, and cost-effective cardiovascular disease prevention programmes. The community-based management of hypertension in Nepal (COBIN) study was a 12-month community-based hypertension management programme of blood pressure monitoring and lifestyle counselling intervention undertaken by female community health volunteers (FCHVs) in Nepal, against usual care, which showed success in reducing blood pressure. Here we aimed to retrospectively quantify the budget impact and cost-effectiveness of the scale-up of the programme.

Methods In this retrospective analysis, we collected participant-level data from the COBIN study; programme delivery cost data from programme administrators from the COBIN study group; and population and other data from WHO, the World Bank, and the Nepalese Government. We estimated costs per participant and total costs of a national scale-up of the COBIN programme focusing on two scenarios: scenario A, delivery of the intervention to only people aged 25–65 years with hypertension; and scenario B, delivery of the intervention to all adults aged 25–65 years regardless of hypertension status. Effectiveness was based on in-trial blood pressure reductions converted to cardiovascular disease disability-adjusted life-years (DALYs) averted. The primary cost-effectiveness measure was incremental cost per averted cardiovascular disease DALY (calculated using the incremental cost-effectiveness ratio [ICER]) from a health system perspective, including programme delivery and incremental medication costs. We did univariate sensitivity analyses of scenario B to assess the effect of uncertainty in key parameter values in our calculations.

Findings From a health system perspective, the first-year budget impact was US$7·1 million in scenario A and $10·8 million in scenario B. With each subsequent year, the costs decreased by approximately 50%. In the base-case cost-effectiveness analysis, from the health system perspective, scenario A resulted in an ICER of $582 per DALY averted and scenario B resulted in an ICER of $411 per DALY averted. The ICER was most sensitive to uncertainty in the number of total avertable cardiovascular disease DALYs in the eligible population.

Interpretation The programme is projected to be highly cost-effective in both scenarios compared with the WHO thresholds for cost-effectiveness for Nepal. For policy makers intending to meet the UN Sustainable Development Goal of reducing premature mortality from non-communicable diseases, this intervention should be considered.

Funding Duke-NUS Medical School, Singapore.

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Introduction Cardiovascular disease has become the leading cause of death worldwide, accounting for 32% of deaths in 2016. High blood pressure is the greatest risk factor for cardiovascular disease. Despite treatment advances and the availability of low-cost efficacious medicines, hypertension prevalence continues to rise in low-income and middle-income countries.

Cardiovascular disease accounts for 12.5% of total healthy life-years lost in Nepal, for which uncontrolled hypertension is the leading risk factor. In Nepal, despite a prevalence of 28%, hypertension control remains low at 15%. Without increasing investment in blood pressure control, Nepal is unlikely to meet the 2015 UN Sustainable Development Goal of reducing premature mortality from noncommunicable diseases by a third by 2030. However, advocating for increased investment in hypertension prevention and control requires evidence-based solutions generated in a local context.

We recently reported the results of the community-based management of hypertension in Nepal (COBIN) cluster randomised controlled trial, a 12-month community-based blood pressure monitoring and lifestyle counselling intervention undertaken by female community health volunteers (FCHVs), against usual care. FCHVs typically focus on promoting safe maternal and child health, and...
family planning. COBIN adapted the existing FCHV model to deliver a community health worker-led hypertension prevention and management programme. FCHVs were trained to screen blood pressure, counsel on healthy lifestyle, refer hypertensive patients, and follow-up on adherence to antihypertensive medication via home visits. At the end of 1 year, systolic blood pressure was significantly lower in the intervention group compared with the control group, showing that a simple FCHV-led lifestyle intervention can effectively reduce blood pressure among individuals with hypertension. However, nothing is known about the cost-effectiveness, affordability, and scalability of the programme.

Here we present a retrospective analysis of the budget impact and cost-effectiveness of scaling-up COBIN nationally. Our cost-effectiveness analysis aims to facilitate comparison of COBIN to other community-based interventions in similar settings and common thresholds for cost-effectiveness. Our budget impact analysis aims to allow policy makers to identify and budget for the immediate and future costs if the programme is expanded beyond the trial settings. Additionally, we test whether scaling-up the intervention by building on the existing FCHV programme is less expensive than a stand-alone programme with dedicated community health workers, and budget impact, incremental costs, and effectiveness are calculated relative to usual care. We also analysed a secondary model based on building on the existing maternal and child health programme, using existing FCHVs to deliver the intervention in addition to their existing responsibilities. All analyses assume that the programme would reach all households across the country within the first year and be delivered to newly identified cases subsequently. Details on all parameters and assumptions in the analysis are in the appendix (p 1).

### Data collection and analysis

We undertook a retrospective costing exercise to quantify the incremental cost of delivering the intervention on the basis of labour tracking and billed expenses captured by the research term throughout the intervention period. For all expenses, including labour, materials, supplies, services, and rent, we quantified costs at the market rate. We inflated costs to 2018 Nepalese rupees (NRs) and present them as 2018 US dollars (US$1=NRs118·26) and international (purchasing power-adjusted) US dollars (I$1=US$3·21). To calculate the number of people aged 25–65 years in Nepal with hypertension, prehypertension, and normal blood pressure, we obtained estimates of the national...
population in this age range from the World Development Indicators 2017 dataset, and multiplied these by our in-trial estimates of prevalence of hypertension (defined as $\geq 140$ mm Hg systolic blood pressure and $\geq 90$ mm Hg diastolic blood pressure) and prehypertension (defined as $120–139$ mm Hg systolic blood pressure and $80–89$ mm Hg diastolic blood pressure). We used these estimates as inputs in the analyses to obtain costs of scale-up in each of the programme delivery scenarios.

**Budget impact analysis**

We did the base-case budget impact analysis from a health system perspective that includes the nationwide programme delivery cost, including FCHV labour remunerated at the national minimum wage of NRs6500 or US$66 per month calculated for a standard work week of 40 h, and annual incremental costs of antihypertensive medication. However, in the existing primary health-care programme, FCHV labour is voluntary and unremunerated. Although our primary analysis assumes that remuneration would be essential to a sustainable scale-up, we present a secondary budget impact analysis from the current government perspective, including all the aforementioned costs except FCHV labour. For scenario A, we scaled up inputs from in-trial costs on the basis of the above method to provide an estimate of the cost of providing COBIN nationwide to all people aged 25–65 years, following trial eligibility criteria (ie, involved in a previous population-based survey, with no plans to migrate out of the study area, and not severely ill or pregnant). We present budget impact estimates for the first 3 years after nationwide implementation.

In the base-case analysis from the health system perspective, we assume the following factors in our scale-up model of the first year: FCHV training would be done in each of 753 local-level bodies comprising urban municipalities with up to 1 million inhabitants and rural municipalities with populations of 20,000–30,000 people; 5079 full-time FCHVs in 77 districts in the country would be trained in and provided with instruments for blood pressure monitoring and lifestyle counselling. Additionally, training would be done three times in each local-level body to account for larger numbers of FCHVs in the scale-up than in the trial.

**Cost-effectiveness analysis**

We did the cost-effectiveness analysis from the same health-system perspective as the budget impact analysis and adopted a lifetime perspective for both costs and effectiveness. The in-trial measure of effectiveness for the cost-effectiveness analysis is the mean reduction in mm Hg in systolic blood pressure from baseline to the end of follow-up at 1 year after randomisation in the COBIN trial. The primary measure of effectiveness is the number of projected cardiovascular disease-associated disability-adjusted life-years (DALYs) averted. DALYs are a generic measure of disease burden that combines healthy years of life lost due to premature death with those lost due to periods of disability. Both effectiveness measures were quantified separately for each scenario.

For the in-trial measure of effectiveness in the study population, To calculate the cost per mm Hg reduction in systolic blood pressure, we used the incremental cost-effectiveness ratio (ICER). The numerator of the ICER is the incremental cost of providing COBIN to the eligible population nationwide, including the current value of incremental medication costs for a lifetime (calculated as 30 years—ie, the remaining life expectancy at age 45 years, the mean age of the sample; discounted at 3% per annum in accordance with WHO guidelines) assuming a 50% mean lifetime medication adherence rate. In our calculation, we applied medication costs for those in the study population diagnosed with hypertension at baseline screening and requiring medication; and in the intervention group (ie, those who received home visits, lifestyle counselling, and blood pressure monitoring) who were newly receiving antihypertensive medication during the intervention period incremental to usual care. The denominator is the mean reduction in systolic blood pressure in the intervention group compared with usual care (ie, the control group), measured in mm Hg for scenarios A and B based on intention-to-treat analyses.
We distributed total national cardiovascular disease DALYs by hypertension status (people who are hypertensive, prehypertensive, and normotensive) by calculating the population attributable fraction of hypertension and prehypertension (trichotomous exposure)\(^1\) with those with normal blood pressure as the reference category using the following equations:

\[
AF_1 = \frac{p_1(RR_1 - 1)}{1 + p_1(RR_1 - 1) + p_2(RR_2 - 1)} \tag{1}
\]

\[
AF_2 = \frac{p_2(RR_2 - 1)}{1 + p_1(RR_1 - 1) + p_2(RR_2 - 1)} \tag{2}
\]

where \(AF_1\) is the fraction of cardiovascular disease DALYs attributable to people who are prehypertensive and \(AF_2\) is the fraction attributable to those who are hypertensive; \(p_1\) is the proportion of the sample who are prehypertensive at baseline and \(p_2\) is the proportion of the sample who are hypertensive at baseline; and \(RR_1\) is the fraction of relative risk of cardiovascular disease for people who are prehypertensive and \(RR_2\) is the fraction of relative risk for those who are hypertensive.

We obtained the relative risks of cardiovascular disease for a range of blood pressure measurements from Gu et al\(^2\) and matched them to the COBIN population to calculate the sample-specific relative risks of cardiovascular disease, with those with normal blood pressure (ie, systolic blood pressure <120 mm Hg and diastolic blood pressure <80 mm Hg) as the reference category. We calculated the attributable fractions using equations (1) and (2). We then multiplied these fractions by the total cardiovascular disease DALYs in Nepal among those aged 25–65 years, which we extracted from the Global Burden of Diseases, Injuries, and Risk Factors study 2017,\(^1\) to estimate the cardiovascular disease DALYs attributable to hypertension and prehypertension. We subtracted these attributable DALYs from the total DALY burden, allocated the remaining (background DALYs) to people who are hypertensive, prehypertensive, and normotensive by their prevalence weights, and added back in the attributable DALYs to calculate the total DALYs borne by each subgroup (for calculations see appendix p 2).

Previous studies\(^8,25\) have shown a linear association between reduction in blood pressure and percentage reduction in risk of coronary heart disease, stroke, and cardiovascular disease mortality for systolic blood pressure before treatment in the range 110–180 mm Hg, and that a sustained reduction of 10 mm Hg systolic blood pressure results in an approximately 22% reduction in risk of coronary heart disease and 41% reduction in risk of stroke events and mortality. Other literature has shown that blood pressure improvements reduce the incidence of cardiovascular disease events and does not appear to differentially affect fatal and non-fatal events.\(^9\) Therefore, we assume that every percentage reduction in coronary heart disease events translates into the same percentage reduction in cardiovascular disease DALYs, if people who are hypertensive maintain the blood pressure reductions throughout their lifetime. On the basis of this assumption and the literature, we assume that every 1 mm Hg reduction in systolic blood pressure translates into a 2·2% reduction in cardiovascular disease DALYs, which is the more conservative estimate from the literature.\(^25\)

For each programme delivery scenario, the total cardiovascular disease DALYs borne by individuals of each hypertension status is multiplied by the percentage reduction in cardiovascular disease DALYs to estimate the number of DALYs averted if COBIN is scaled up nationwide (ie, the primary measure of effectiveness).

To calculate the cost per cardiovascular disease DALY averted, the numerator of the ICER is the same as that for the proximal cost-effectiveness measure, and the denominator is the projected number of cardiovascular disease DALYs averted nationwide. We qualified the eligible population and projected cardiovascular disease DALYs averted in each scenario. We considered an ICER below US$2505 per DALY averted (three times Nepal’s nominal gross domestic product [GDP] per capita) to be cost-effective for Nepal, on the basis of WHO-CHOICE guidelines for low-income and middle-income countries.\(^11,16\)

Sensitivity analysis

We did univariate sensitivity analyses to assess the effect of uncertainty in key parameter values on the primary cost-effectiveness measure in scenario B, the more expensive scenario, including: varying the systolic blood pressure reduction among people who are hypertensive, prehypertensive, and normotensive by the 95% CI from trial outcomes data;\(^27\) varying the discount rate to 0% and 6% (the approximate long-term real interest rate in Nepal);\(^28\) and increasing and decreasing by 50% estimates of prevalence of hypertension and prehypertension separately, costs separately for each programme delivery cost category (eg, training, labour, travel), incremental cost of lifetime medication, lifetime medication adherence, the number of additional DALYs attributable to having hypertension or prehypertension separately, and percentage change in DALYs for each 1 mm Hg reduction in systolic blood pressure.

Role of the funding source

The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report. The corresponding author had full access to all the data in the study and had final responsibility for the decision to submit for publication.

Results

The sampling frame and study design have been described previously.\(^12,28\) In brief, between April 1, 2015,
and Dec 31, 2015, 1638 participants in 14 clusters in Lekhnath municipality, Nepal, were randomly assigned to the intervention group (n=939) or control group (n=699). 730 (49%) were normotensive, 303 (22%) were prehypertensive, and 435 (30%) were hypertensive.10

COBIN was delivered to 939 participants at a cost of US$13 525 (I$43 433). The in-trial annual cost was US$14 per participant (I$46); costs by category are shown in table 1.

The national population of Nepal in 2017 was approximately 29·3 million, of whom 12 355 334 were aged 25–65 years.11 Based on the hypertension prevalence of 24-9% as calculated for this adult population in the COBIN trial,12 and a resulting eligible population of 3 077 519 people in scenario A, we estimated the programme to cost US$2·31 (I$7·40) per participant. For the stand-alone scenario B, we estimated a first-year budget impact of US$0·88 (I$2·82) per participant from the health system perspective (table 1). The budget impact was estimated at US$7·1 million for scenario A and US$0·8 million for scenario B. In scenario B, the projected expenditure decreased by 51·9% (ie, a total of US$0·83 per participant) in the second and third years. In the secondary model analysis in scenario A, the first-year budget impact was estimated to be US$10·3 million overall or US$0·83 per participant (2·6% lower than the stand-alone model). Given the total national population of 29·3 million people, the budget impact was estimated to be US$0·37 per capita. Nepal’s 2015 total health expenditure was US$44·42 per capita,29 suggesting an estimated 0·8% increase resulting from this intervention.

In the stand-alone model of scenario B, from the health system perspective, FCHV labour and travel costs accounted for the largest share of the budget impact: 62% for labour and 20% for travel costs in the first year. From the government perspective, first-year budget impact was US$0·34 per participant; a total of US$4·2 million in the first year. 62% for labour and 20% for travel costs in the first year. In the COBIN trial Nationwide scale-up year 1 Year 2 Year 3

<table>
<thead>
<tr>
<th>Cost Breakdown</th>
<th>COBIN trial</th>
<th>Nationwide scale-up</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Year 1</td>
<td>Year 2</td>
</tr>
<tr>
<td><strong>Female community health volunteers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training†</td>
<td>$2·17 (15%)</td>
<td>$0·04 (5%)</td>
</tr>
<tr>
<td>Travel†</td>
<td>$6·04 (42%)</td>
<td>$0·17 (20%)</td>
</tr>
<tr>
<td>Labour‡</td>
<td>–</td>
<td>$0·04 (5%)</td>
</tr>
<tr>
<td>Materials, equipment, instruments§</td>
<td>$2·20 (15%)</td>
<td>$0·03 (4%)</td>
</tr>
<tr>
<td><strong>Program administration</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Admin and oversight†</td>
<td>$3·21 (22%)</td>
<td>$0·04 (4%)</td>
</tr>
<tr>
<td>Communication and other overheads</td>
<td>$0·78 (5%)</td>
<td>$0·01 (1%)</td>
</tr>
<tr>
<td><strong>Patient costs</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medication‖</td>
<td>–</td>
<td>$0·04 (4%)</td>
</tr>
<tr>
<td>Total per participant</td>
<td>$14·40 (100%)</td>
<td>$0·88 (100%)</td>
</tr>
</tbody>
</table>

Data are currency in US$, with proportion of total price per participant in parentheses where appropriate. In scenario B, the intervention is delivered to all people aged 25–65 years nationwide. Cost is scaled to 2018 US$. COBIN=community-based management of hypertension in Nepal. †One training session per local-level body at US$6·75 per training session. US$1 per day for 8446 volunteers. US$566 per month per volunteer, 5 min per person for each blood pressure measurement, 30 min per household for lifestyle counselling, and 10 min per household for travel. US$68 per volunteer blood pressure monitor, height measure, and scale. §One national administrator at US$3208 per month, seven provincial administrators at US$1014 per month each, 77 district level supervisors at US$383 per month each. ¶One training session 51% 95% CI resulted in an ICER range of US$307–624 per DALY averted. Among cost parameters, the ICER was most sensitive to the incremental annual medication cost and lifetime medication adherence, resulting in an ICER range of US$312–511 per DALY averted. The sensitivity of the base-case ICER to changes in key parameters is shown in table 3.

The mean difference in reduction of systolic blood pressure at 1 year between intervention and control arms in the COBIN trial was −2·28 mm Hg (95% CI −3·77 to −0·79) for participants who were normotensive, −3·08 mm Hg (−5·58 to −0·59) for those who were prehypertensive, and −3·77 to −0·79) for participants who were normotensive,22 and in-trial prevalences of prehypertension of 27·4% (449 of 1638) and hypertension of 24-9% (408 of 1638), we estimated that 5·8% of all cardiovascular disease DALYs were attributable to prehypertension and 24-7% to hypertension (appendix p 2). Furthermore, in 2017 Nepal had a cardiovascular disease burden of 619194 DALYs among people aged 25–65 years with a third estimated to be borne by people who are normotensive (appendix p 2). Scenario A was projected to eliminate 28056 cardiovascular disease DALYs and scenario B was projected to eliminate 48764 cardiovascular disease DALYs.

In the base-case cost-effectiveness analysis, scenario A resulted in an ICER of US$582 (I$1869) per cardiovascular disease DALY averted and scenario B resulted in an ICER of US$411 (I$1321) per cardiovascular disease DALY averted (table 2). In terms of the in-trial effectiveness measure, the ICERs were US$1·68 per mm Hg reduction in systolic blood pressure for scenario A and US$0·52 per mm Hg reduction for scenario B.

Univariate sensitivity analyses in scenario B show that increasing or decreasing the total avertable cardiovascular disease DALYs had the greatest effect on the primary outcome, with the ICER ranging US$274–823 per DALY averted (table 3). Varying the reduction in systolic blood pressure among people who were hypertensive to the bounds of its 95% CI resulted in an ICER range of US$307–624 per DALY averted. Among cost parameters, the ICER was most sensitive to the incremental annual medication cost and lifetime medication adherence, resulting in an ICER range of US$312–511 per DALY averted. The sensitivity of the base-case ICER to changes in key parameters is shown in table 3.

Table 1: Cost breakdown of the COBIN trial and budget impact per participant if COBIN was delivered nationwide (scenario B), from the health system perspective.
Discussion

We found that a community-based intervention in Nepal could be a cost-effective solution to control blood pressure. The base-case analysis in the population aged 25–65 years suggested a cost of US$582 per cardiovascular disease DALY averted if the programme was provided nationwide to all people who are hypertensive, and US$411 per cardiovascular disease DALY averted if the programme was delivered to all people regardless of hypertension status. WHO considers interventions that cost less than three times per-capita GDP as cost-effective, and those below GDP per capita as highly cost-effective.\(^{26}\) Compared with these thresholds, the COBIN programme is estimated to be highly cost-effective given Nepal’s annual GDP per capita of US$835 for 2017.\(^{27}\)

Predictably, the trial showed people who are hypertensive to have the greatest systolic blood pressure reduction.\(^{28}\) However, we estimated the cost per cardiovascular disease DALY averted to be almost 30% lower if the programme was delivered to everyone nationwide than if just delivered to people who are hypertensive. Moreover, a third of avertable cardiovascular disease DALYs under scenario B were estimated to be borne by people who are normotensive, indicating the added value of interventions that can cost-effectively reduce cardiovascular disease risk in the general population.

Given Nepal’s population of 29·3 million people,\(^{29}\) the first-year budget impact of US$10·8 million (scenario B) from the health system perspective translates to US$0·37 per capita, an approximate 0·8% increase on Nepal’s per-capita total health expenditure.\(^{29}\) From the government perspective, the cost of 50–14 per capita suggests an increase of 1·7% on the government health budget.\(^{29}\) Furthermore, our analyses showed a reduction of more than 50% in the budget impact in subsequent years. Our cost-effectiveness analyses showed that delivering the programme nationwide would result in a reduction of the total DALY burden (9·228 540 DALYs in 2017) of 0·5%, and reduction in cardiovascular disease DALYs (116 2732) of 4·2% nationwide from all causes.\(^{1}\) Our analyses assume the programme could be scaled-up in 1 year, suggesting that these results are an upper bound of both the costs and benefits of COBIN. Although the projected programme is estimated to be highly cost-effective, whether such an investment is deemed worthwhile depends on public health priorities of the government and funders in Nepal. Nonetheless, our results show that COBIN is a low-cost, scalable model for primary prevention and management of hypertension.

The primary cost-effectiveness and budget impact models assume that the programme operates separately from, although similar to, the existing maternal and child health programme and is staffed by community health workers whose sole task is prevention of cardiovascular disease. Interestingly, the secondary model of building on the existing maternal and child health programme would not generate substantial savings, because reductions in

---

**Table 2: Budget impact and cost-effectiveness of the COBIN programme, by delivery scenario**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Hypertensive only</th>
<th>Total population</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-year budget impact</td>
<td>US$7,096,038</td>
<td>US$10,824,493</td>
</tr>
<tr>
<td>Incremental cost for cost-effectiveness analysis</td>
<td>US$16,328,189</td>
<td>US$20,064,555</td>
</tr>
<tr>
<td>Mean reduction in systolic blood pressure, mm Hg</td>
<td>4.90</td>
<td>3.15</td>
</tr>
<tr>
<td>Cost per mm Hg reduction in systolic blood pressure</td>
<td>$1.68 (I$ 4.41)</td>
<td>$0.52 (I$ 1.65)</td>
</tr>
<tr>
<td>Cardiovascular disease DALYs borne, DALYs</td>
<td>260,256</td>
<td>619,194</td>
</tr>
<tr>
<td>Avertable cardiovascular disease DALYs</td>
<td>280,506</td>
<td>48,764</td>
</tr>
<tr>
<td>Eligible population, n</td>
<td>3,077,519</td>
<td>12,355,334</td>
</tr>
<tr>
<td>Cost per cardiovascular disease DALY averted</td>
<td>US$5,812 (I$1869)</td>
<td>US$4,411 (I$1,321)</td>
</tr>
</tbody>
</table>

Currency data are in 2018 US dollars and international US dollars. COBIN=community-based management of hypertension in Nepal. DALY=disability-adjusted life-year. *Average of in-trial reduction in systolic blood pressure in each group weighted for proportion within sample. †Calculated using the population attributable fraction method. I-Based on an estimated 2·2% reduction in cardiovascular disease DALYs per 1 mm Hg reduction in systolic blood pressure.

**Table 3: Results of univariate sensitivity analyses, if COBIN was delivered nationwide (scenario B), from the health system perspective**

<table>
<thead>
<tr>
<th>Assumed parameter values</th>
<th>Low</th>
<th>Base-case</th>
<th>High</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Additional cardiovascular disease DALYs</td>
<td>24,382</td>
<td>48,764</td>
<td>73,146</td>
<td>$823</td>
<td>$1,274</td>
</tr>
<tr>
<td>Systolic blood pressure reduction, mm Hg</td>
<td>2.00</td>
<td>4.90</td>
<td>7.78</td>
<td>$624</td>
<td>$307</td>
</tr>
<tr>
<td>Hypertensive patients</td>
<td>0.59</td>
<td>3.08</td>
<td>5.58</td>
<td>$497</td>
<td>$351</td>
</tr>
<tr>
<td>Prehypertensive patients</td>
<td>0.79</td>
<td>2.28</td>
<td>3.77</td>
<td>$477</td>
<td>$362</td>
</tr>
<tr>
<td>Normotensive patients</td>
<td>2.00</td>
<td>4.90</td>
<td>7.78</td>
<td>$624</td>
<td>$307</td>
</tr>
<tr>
<td>Total avertable cardiovascular disease DALYs</td>
<td>24,382</td>
<td>48,764</td>
<td>73,146</td>
<td>$823</td>
<td>$1,274</td>
</tr>
</tbody>
</table>

| Costs | | | | | |
| FCHV training | $255,380 | $510,799 | $764,339 | $406 | $407 |
| FCHV travel | $107,494 | $2,140,988 | $231,482 | $290 | $433 |
| FCHV labour | $3,339,924 | $6,679,849 | $10,019,773 | $343 | $480 |
| Materials, equipment, instruments | $203,323 | $406,646 | $609,970 | $407 | $416 |
| Admin and oversight | $234,052 | $469,104 | $763,656 | $407 | $416 |
| Communication and other overheads | $171,963 | $343,926 | $525,089 | $410 | $413 |
| Incremental annual medication cost | $240,565 | $481,131 | $721,696 | $312 | $511 |

| Prevalence | | | | | |
| Hypertension | 12% | 25% | 32% | $360 | $463 |
| Prehypertension | 14% | 27% | 43% | $355 | $468 |
| Mean lifetime medication adherence | 25% | 50% | 75% | $312 | $511 |
| Discount rate | 0% | 3% | 6% | $508 | $356 |

All currency data are in 2018 US$. COBIN=community-based management of hypertension in Nepal. DALY=disability-adjusted life-year. FCHV=female community health volunteer. *Low values are 50% of the base-case value and high values are 150% of the base-case value. †Low and high values are the bounds of the 95% CIs from the primary outcome analysis in the COBIN trial. | -effectiveness analysis US$16 | DALY=disability-adjusted life-year. *Average of in-trial reduction in systolic blood pressure in each group weighted for proportion within sample. †Calculated using the population attributable fraction method. I-Based on an estimated 2·2% reduction in cardiovascular disease DALYs per 1 mm Hg reduction in systolic blood pressure.
travel time and elimination of travel costs are more than offset by greater resource requirements for training and providing each of the approximately 50000 FCHVs with blood pressure monitors and other house-visit equipment. Nonetheless, factors beyond the short-term cost implications of implementing either model might be relevant to payers focused on long-term sustainability. First, FCHVs have, over many years of working in their communities, gained experience and built trust that is essential for effective service delivery. Second, as the primary care programme expands to cover other non-communicable diseases, substantial scope exists for cost sharing and extending benefits beyond cardiovascular disease DALYs.

Similar interventions have been tested successfully in other low-income and middle-income countries. In Argentina, a programme involving 60–90 min monthly to bimonthly lifestyle counselling sessions over 18 months reduced systolic blood pressure by a mean of 6·6 mm Hg (95% CI 4·6–8·6) more among those with uncontrolled hypertension in the intervention group compared with those in the control group, at a cost of US$103 per participant. A less intensive intervention in Pakistan providing quarterly home visits to people with hypertension had a cost of US$3·34 per participant, and produced a mean systolic blood pressure reduction of 5·6 mm Hg (95% CI 3·7–7·4). Our programme also targeted people who are normotensive and prehypertensive with a view towards prevention and used existing community health workers (ie, FCHVs). Although methods differ and costs and effectiveness are not directly comparable between COBIN and these previous programmes, the substantially lower per-participant costs for a similar systolic blood pressure reduction of 4·9 mm Hg among hypertensives via our programme suggests our model is more cost-effective than these other interventions.

Our study has several limitations. First, our estimates are based on a model that converts reduction in blood pressure to the number of DALYs averted. Although we used conservative assumptions in our base-case analysis and the programme remains highly cost-effective overall, it is less so when total avertable cardiovascular disease DALYs are 50% lower, longer term studies than the COBIN trial should be done to determine the accuracy of this association. Second, our analyses assume that the benefits of blood pressure reduction would continue throughout an individual’s lifetime, thereby reducing total cardiovascular disease DALYs by the same proportion as cardiovascular disease events. Third, medication adherence data were not collected from COBIN trial participants. We applied available estimates from the literature and did sensitivity analyses around the estimates of avertable DALYs and lifetime medication costs and adherence, which showed that the ICER was most sensitive to the estimate of avertable DALYs, although still highly cost-effective based on the WHO-CHOICE threshold. Fourth, questionnaire responses administered to participants as part of the COBIN trial did not measure health-care utilisation and related costs. Thus, we were unable to incorporate estimates of potential cost offsets from improved blood pressure control. Fifth, because of a lack of separate data on cardiovascular disease DALY burden for people who are normotensive, prehypertensive, and hypertensive, we allocated DALYs to each group on the basis of relative risks of cardiovascular disease. Although we present our results for two scenarios, we focused our analyses on the scenario in which everyone aged 25–65 years was eligible. Moreover, we assessed the sensitivity of our estimates to uncertainties in the proportion of DALYs borne by each hypertensive status group, and we found that uncertainty in this parameter does not substantially affect the ICER. Finally, we did sensitivity analyses of the range of values represented by parameters’ 95% CIs for which true uncertainty could be quantified from participant-level data and by an increase or decrease of 50% of the base-case value for parameters for which 95% CIs were unavailable. As a result, interpretation as to which parameter has the greatest influence on our estimate should be made with caution because the influence is partly an artifact of how we modelled uncertainty.

This study is the first to analyse a cost-effective community intervention in Nepal for the management of hypertension. The programme’s low cost and scalable model that builds on the existing primary health infrastructure is a viable strategy to effectively and efficiently respond to the growing cardiovascular disease epidemic in Nepal and other similar settings.

Contributors

DN, PK, and AKa implemented the trial in Nepal, and MHO was responsible for data analysis and manuscript writing for the original trial. AKr, EAF, and DN conceptualised the present study. AKr and EAF designed the analysis plan and did the analysis. AKr wrote the first draft of the manuscript with input from EAF and DN. All authors revised and approved the manuscript.

Declaration of interests

We declare no competing interests.

Data sharing

Data are available upon reasonable request made in writing to the corresponding author.

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