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Cost-effectiveness of a Community-based Hypertension Improvement Project (ComHIP) in Ghana: results from a modelling study

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ABSTRACT

Objective To undertake a cost-effectiveness analysis of a Community-based Hypertension Improvement Project (ComHIP) compared with standard hypertension care in Ghana.

Design Cost-effectiveness analysis using a Markov model.

Setting Lower Manya Krobo, Eastern Region, Ghana.

Intervention We evaluated ComHIP, an intervention with multiple components, including: community-based education on cardiovascular disease (CVD) risk factors and healthy lifestyles; community-based screening and monitoring of blood pressure by licensed chemical sellers and CVD nurses; community-based diagnosis, treatment, counselling, follow-up and referral of hypertension patients by CVD nurses; telemedicine consultation by CVD nurses and referral of patients with severe hypertension and/or organ damage to a physician; information and communication technologies messages for healthy lifestyles, treatment adherence support and treatment refill reminders for hypertension patients; Commcare, a cloud-based health records system linked to short-message service (SMS)/voice messaging for treatment adherence, reminders and health messaging. ComHIP was evaluated under two scale-up scenarios: (1) ComHIP as currently implemented with support from international partners and (2) ComHIP under full local implementation.

Main outcome measures Incremental cost per disability-adjusted life-year (DALY) averted from a societal perspective over a time horizon of 10 years.

Results ComHIP is unlikely to be a cost-effective intervention, with current ComHIP implementation and ComHIP under full local implementation costing on average US$12 189 and US$6530 per DALY averted, respectively. Results were robust to uncertainty analyses around model parameters.

Conclusions High overhead costs and high patient costs in ComHIP suggest that the societal costs of ensuring appropriate hypertension care are high and may not produce sufficient impact to achieve cost-effective implementation. However, these results are limited by the evidence quality of the effectiveness estimates, which comes from observational data rather than from randomised controlled study design.

Strengths and limitations of this study

► Previous studies have not considered the cost-effectiveness of comprehensive hypertension control strategies incorporating community-based screening and management of hypertension patients as well as information technology tools to support patient education and treatment adherence.

► This economic evaluation used patient-level data from a large before-and-after study of such a community-based model of hypertension care.

► A comprehensive and detailed costing study of the community-based hypertension care model was undertaken from a societal perspective.

► The before-and-after study from which the estimates of effectiveness are derived did not include a control group.

INTRODUCTION

High blood pressure is the leading cause of cardiovascular disease (CVD) and deaths worldwide.[1] The prevalence of hypertension in low-income and middle-income countries (LMICs), where over 80% of CVD mortality occurs worldwide,[2] is estimated to be as high or higher than in many high-income countries.[3] In a systematic review of the burden of hypertension in sub-Saharan Africa (SSA), the overall prevalence of hypertension was estimated at 30%.[4] For individuals with hypertension, treatment with antihypertensive drugs substantially reduces the risk of CVD events, such as stroke, myocardial infarction and heart failure.[5] In Ghana, hypertension is an important public health problem, with its prevalence in adults being estimated to be between 19% and 48%.[6] CVD is also an important public health problem, having been identified as the second leading cause of death after diarrhoeal diseases.[7 8] A cross-sectional analysis using data from the 2014 Ghana Demographic and Health Survey

(DHS) showed that 45.6% of hypertensive individuals were aware of their condition, 40.5% were on hypertension treatment, and only 23.8% had their blood pressure controlled.[9]

Previous estimates of the costs and cost-effectiveness of hypertension treatment have suggested that it has the potential to be cost-effective in SSA.[10–13] Based on modelling studies undertaken for the whole of SSA, Murray *et al*[11] Ortegón *et al*[12] and Mendis *et al*[13] found that hypertension treatment and education interventions in high-risk individuals were cost-effective. Rosendaal *et al*[10] estimated, in the context of rural Nigeria, that a hypertension screening, treatment and lifestyle advice intervention could be cost-effective.[10] However, in a context of low hypertension control,[4 9] these previous studies did not include the costs of increasing coverage and adherence by enabling interventions which, in addition to providing hypertension treatment, use both information and communication technologies (ICTs) and community-based screening and management for the control of hypertension. We present here a cost-effectiveness analysis of such a comprehensive intervention to scale up hypertension treatment services at the community level; the Community-based Hypertension Improvement Project (ComHIP) in Ghana.

METHODS
Study setting and intervention
ComHIP was a 2-year hypertension control programme led by the Ghana Health Service (GHS) with support from the international non-profit organisation FHI360. ComHIP is based on a public–private partnership. The private sector is engaged through licensed chemical sellers (LCS), who are community pharmacists. The project uses ICTs and task shifting to enhance the capacity of the GHS to improve management and control of hypertension. The ComHIP implementation has the following components: (1) Community-based education on CVD risk factors and healthy lifestyles; (2) Community-based screening and monitoring of blood pressure by LCS and CVD nurses; (3) Community-based diagnosis, treatment, counselling, follow-up and referral of hypertension patients (when needed) by CVD nurses; (4) Telemedicine consultation by CVD nurses and referral of patients with severe hypertension and/or organ damage to a physician; (5) ICT messages for healthy lifestyles, treatment adherence support and treatment refill reminders for hypertension patients and (6) Commcare, a cloud-based health records system linked to short-message service (SMS)/voice messaging for treatment adherence, reminders and health messaging.[14] ComHIP was implemented in the district of Lower Manya Krobo (from now on, the intervention district). A total of 1339 individuals were enrolled in the programme by December 2016.[15] A full list of ComHIP activities can be found in online supplemental tables S1 and S2 in the supporting information file. For more details about the ComHIP implementation see Adler *et al*.[15] ComHIP was independently evaluated by the

Ghana School of Public Health and the London School of Hygiene and Tropical Medicine—the evaluation included several substudies. The main study was a cohort study of hypertensive individuals enrolled in ComHIP in the intervention district.[15] The primary outcome of this cohort study was hypertension control, and secondary outcomes included changes in blood pressure and knowledge of risk factors for hypertension.[15] The authors found that after 12 months of intervention, 72% of patients had their hypertension controlled and that systolic/diastolic blood pressure were reduced, respectively, by 12.2 and 7.5 mm Hg.[15] In addition to the cohort study, the study team performed two repeat cross-sectional surveys at baseline and endline, one in the intervention district and one in a control district.[14] The primary outcomes of the surveys included hypertension prevalence, hypertension awareness, proportion of individuals under treatment, hypertension control and blood pressure levels.[14] Finally, the evaluation included a cost-effectiveness analysis, the results of which we report here.

Cost-effectiveness analysis design
We performed a cost-effectiveness modelling exercise, estimating the incremental costs per disability-adjusted life-year (DALY) averted, of ComHIP compared with standard hypertension care (ie, current hypertension management practice by the GHS) for a general population of adult individuals aged 18–79 in Ghana. This choice of population was made to be able to represent all individuals in the community.

We modelled two scenarios for ComHIP. The first scenario, *current ComHIP scale-up*, was characterised by the existing implementation of ComHIP in a hypothetical scale-up to a general population of 10 000 adult individuals. In this population, the prevalence of hypertension was estimated based on the total proportion of hypertensive patients found across the intervention and control districts by the cross-sectional survey undertaken by the research team at endline (=33.68%). The scenario involved the annual provision of ComHIP-related services by the GHS and LCS with support from FHI360. The second scenario, *GHS-LCS ComHIP scale-up*, was characterised by the implementation of ComHIP by the GHS and LCS without assuming continuing support from FHI360 in the same population. The difference between the current ComHIP scale-up and the GHS-LCS ComHIP scale-up scenario is that the former scenario uses FHI360 unit costs while the latter uses local unit costs for cost estimation. We took this approach as some of the unit costs incurred by FHI360 are higher than local unit costs. These scenarios were compared with *standard care*, which was characterised by the existing hypertension management by the GHS in a hypothetical scale-up to a general population of 10 000 adult individuals. Online supplemental table S3 in the supporting information file provides further details about the resource consumption characterising the programme costs estimated for the scale-up of the two ComHIP scenarios and of the standard hypertension care

scenario. We note here that although developing a hypothetical scenario with a ComHIP scale-up to the entire population of the country or to the entire population of a region would have been preferable, estimating with some degree of accuracy the resource consumption characterising the programme costs which is required for such a scale-up was not deemed possible.

The cost-effectiveness analysis was conducted over a time frame of 10 years from a societal perspective including healthcare provider and patient costs. Our analysis included extensive primary data collection of the costs of hypertension management from both a provider and patient perspective, combined with effectiveness data from the ComHIP patient cohort and a decision analytical model to estimate costs and health impact over the time frame of the study. The estimation of all input parameters is described below.

The decision analytical model

In order to estimate the cost-effectiveness of ComHIP compared with standard hypertension care, we developed a Markov model that estimated costs and health outcomes associated with the two interventions over a time period of 10 years. The main hypothesis of the model was that better hypertension control under ComHIP reduces the risk of CVD events compared with standard hypertension care. These CVD events can be coronary heart disease (CHD) (including angina and myocardial infarction) and stroke. Lower risk of CVD events leads to a reduction in the number of DALYs lost to patients over the period covered by the model. The Markov model is further described in section 1.1.2 and online supplemental figure S1 of the supporting information file. The model was implemented using Treeage Pro software.[16]

Probabilities of stroke and CHD events

We used the Framingham 10-year risk equations for stroke and CHD (myocardial infarction and angina)[17 18] to estimate the probabilities of stroke and CHD events for the ComHIP and standard care scenarios as a function of individual patient characteristics such as blood pressure levels, age, gender, smoking status and clinical history. Initially, we aimed to obtain this information from individuals on hypertension treatment in the surveys undertaken in the intervention (ComHIP) and control (standard care) districts at the end of the ComHIP evaluation. However, the number of individuals who reported being on treatment for hypertension in these surveys was very low (33 in total across both districts). To obtain the data to populate the Framingham equations, we used individual-level information available from the cohort study, an observational study of patients on ComHIP without a control group of patients on standard hypertension care. Demographic, behavioural and clinical history information in these patients was available at enrolment into the study. At enrolment, patients also reported whether they were on hypertension treatment. Data on blood pressure levels was available at enrolment into the

study and over time as patients went for clinical consultations or blood pressure control visits. To estimate the probabilities of stroke and CVD events in the ComHIP and standard care scenarios, we applied the Framingham 10-year risk equations for stroke and CHD to individual patient characteristics (average systolic and diastolic blood pressure, age, gender, self-reported smoking status, self-reported diabetes status, estimated total-to-high-density-lipoprotein (HDL) cholesterol level) comparing two groups of patients:

► For ComHIP, we used the characteristics from all patients who were on antihypertensive medication in the programme for at least 12 months (n=219). The effect of ComHIP on blood pressure was operationalised in these patients by using the latest blood pressure readings available from these patients as close as possible to the date of their last medication prescription.

► For standard care, we used the characteristics from the subgroup of the 219 patients described above who had reported being on the standard hypertension care at recruitment into the study (n=142). The effect of standard care on blood pressure was operationalised in these patients by using the blood pressure readings available from these patients at enrolment into the study.

For ComHIP, the choice of the 219 patients who were on hypertensive medication for at least 12 months was motivated by the risk of bias associated with including patients lost to follow-up. These patients may have experienced a temporary drop in blood pressure while on ComHIP, but we could not assume that this drop would be maintained after loss to follow-up or impact their longer-term blood pressure levels or CVD risk. For standard care, the inclusion of the subgroup of these 219 patients who had reported being on hypertension treatment at study enrolment was motivated by the evaluation study design. While there were no longitudinal patient-level data available (including data on blood pressure over time or on losses to follow-up) from an equivalent cohort of patients on standard care, there were both data on the standard care treatment status and blood pressure levels when these patients were enrolled in the study.

The two groups of patients were comparable in that they did not differ substantially in terms of blood pressure, key demographic or behavioural characteristics at enrolment into the ComHIP study. Furthermore, they did not differ substantially in terms of blood pressure levels at the time of the last blood pressure measurement (see online supplemental table S4 in the supporting information file).

Using the Framingham risk equations, we estimated the n-year probabilities of CHD and stroke events (n=1–10) in both sets of individual patient data. We then used standard formulas to convert these n-year probabilities to 1year probabilities (ie, the probability of an event between year n and year n+1). We allowed for repeat stroke/CHD events under the assumption, for simplicity,

that the probability of a repeat event was not changed by a previous event. We used beta probability distributions[19] to express uncertainty in the annual probabilities—summary measures of these probabilities can be found in online supplemental tables S5 and S6 in the supporting information file.

The annual probabilities of treatment for first/repeat stroke/CHD and the annual probabilities of death after treatment for first/repeat stroke/CHD were obtained from an expert opinion exercise with two experienced clinicians from the GHS, as there are no data available for these probabilities in the peer-reviewed literature. Each of the two clinicians was asked to provide a low/average/high estimate for these probabilities based on his/her clinical experience. We averaged the results of the expert opinion elicitation exercise across the two clinicians. We used triangular probability distributions to express uncertainty in these annual probabilities. Summary measures of these probabilities are available in online supplemental table S7 in the supporting information file.

The probabilities of hypertension patients dying from causes other than CVD and of no hypertension patients dying from any cause were estimated from the Global Burden of Disease study[20]—see section 1.2.1 in the online supplemental file for more details.

Costs

Our model includes six cost-incurring health states (no hypertension, hypertension, treated first CHD event, treated repeat CHD event, treated first stroke event, treated repeat stroke event). We estimated the annual societal cost per individual (no hypertension) and per patient (hypertension, treated first CHD event, treated repeat CHD event, treated first stroke event, treated repeat stroke event) for each of the two ComHIP scenarios and for the standard care scenario for the 10-year period of the analysis. For all patient costs, annual societal costs were separated into annual costs accruing to the healthcare provider and annual costs accruing to the patient (ie, patient-level costs). Healthcare provider costs were separated into the costs of health service provision to patients (variable costs) and into overhead costs. For all health states, we estimated separately the costs of the first year and the costs of subsequent years.

For the healthcare provider costs of no hypertension, we estimated the hypertension screening costs per individual from the ComHIP database and assigned it to the portion of the population in the intervention/control districts which were not hypertensive. For the healthcare provider costs of hypertension, our starting point for estimating the annual costs per patient of current ComHIP scale-up was the estimation of the annual costs of healthcare provision to patients, including screening (ie, the time of healthcare staff, the medication and diagnostic tests consumed per patient per year) from data in the ComHIP cohort database. For the cost-effectiveness model, these costs were estimated in the sample of 219 patients who were on treatment for at least 12 months in

ComHIP, as this was the sample of patients used for the calculation of intervention effectiveness. For the estimation of the annual costs of implementing the ComHIP programme, we adjusted these costs by the losses to follow-up during the first year on ComHIP. Once we estimated the annual costs of health service provision we estimated the annual overhead costs, that is, the costs of the resources not directly related to health service provision. For this task, we undertook an ingredients-based costing exercise of ComHIP activities. Following standard costing methodology,[21] these activities were divided into those corresponding to the start-up period (the period during which the project was set up, that is, before the implementation of any patient-related activities) and into the postimplementation period (further details can be found in section 1.1.1. and online supplemental table S1 and S2 in the supporting information file). We adjusted all quantities by the changes in programme activities assumed for the scale-up of the project to serve a general population of 10 000 individuals (see online supplemental table S3 in the supporting information file). For GHS-LCS ComHIP scale-up we used the same approach and data but valuing all services currently provided by FHI360 at local prices. Further details of these cost calculations can be found in section 1.1.3 of the supporting information file.

The estimation of the annual healthcare provider costs of hypertension per patient in standard care was based on an expert opinion elicitation exercise with three clinical experts. We used this approach as we could not find information on detailed resource consumption for hypertension patients over a follow-up period of 1 year in the Ghanaian literature. Overhead costs for standard care (technical staff support, administrative staff support, medical and office equipment, vehicles) were estimated based on the overhead costs of ComHIP but excluding the cost of ComHIP-specific activities (training, programme coordination, app development and support) as shown in online supplemental table S3 in the supporting information file.

Annual individual and patient-related costs of hypertension screening and management in ComHIP were estimated using a survey of ComHIP patients (n=257) and in standard care using a survey of patients with hypertension in the district not in ComHIP (n=130). Patients were asked questions about the direct medical expenditures, direct non-medical expenditures and productivity losses due to time seeking treatment and time lost to work (both valued at the reported monthly income)—see online supplemental table S8 in supporting information file.

A breakdown of the annual societal costs per patient for standard care, including both healthcare costs and patient-related costs can be found in online supplemental tables S9–S11 in the supporting information file.

Annual CHD and stroke healthcare provider costs were estimated using clinical expert opinion elicitation exercises and annual CHD and stroke patient costs using a mix of clinical expert opinion and data from the same patient surveys as above—for more details see online

supplemental tables S12–S14. Annual societal costs for CVD treatment in the ComHIP and standard care scenarios are shown in online supplemental table S15.

We used gamma probability distributions[19] to express uncertainty in the costs per patient of the hypertension health state for ComHIP and triangular probability distributions over a wide range (±30%) to express uncertainty in the annual costs of no hypertension, of hypertension for standard care and in the annual costs of CVD-related health states.

Disability weights

Disability weights for the different health states included in the Markov model (hypertension, CHD/treated, CHD/untreated, stroke/treated, stroke/untreated) were drawn from the Global Burden of Disease 2016 study.[20] The uncertainty range for these parameters was based on varying degrees of severity for each condition also from the same study (see online supplemental table S16 in the supporting information file). The death state was assigned a disability weight of 1. We used triangular probability distributions to express uncertainty in the disability weights.

Analysis

We estimated the mean incremental cost per DALY averted of the ComHIP scenarios compared with standard care. All results are expressed in constant 2017 US$ using the average 12-month exchange rate between the US$ and the Ghanaian cedi for 2017 (US$1=GH₵4.38).[22] Costs and health outcomes were discounted at an annual rate of 3%. We used the most recent estimate of the willingness to pay (WTP) threshold reflecting opportunity costs from Ghana[23] adjusted for inflation (=US$645) and, in sensitivity analysis, the Ghanaian gross domestic product (GDP) per capita for 2017 (=2025 US$).[24] The GDP per capita has been used as a cost-effectiveness threshold in published evaluations of similar interventions—see, for example, Roseendal et al[10] and Gaziano et al.[25] Uncertainty in the input parameters was assessed using a probabilistic sensitivity analysis (PSA; Monte Carlo simulation) in which input parameters were randomly sampled from their respective distributions in 10 000 iterations. We performed a sensitivity analysis on the estimation of CVD probabilities using the WHO CVD Risk Chart Working Group CVD risk charts for Western SSA.[26] For details, see section 2.1.2 and online supplemental tables S17 and S18 in the supporting information file. In addition, we performed a threshold analysis on key parameters (shown in section 2.1.3 and online supplemental table S19 in the supporting information file).

In addition to the above, as our comparison focuses only on those retained on care, we performed a scenario analysis modelling the cost-effectiveness of ComHIP and standard care including in both interventions lost to follow-up in hypertension treatment during the first year:

▶ For ComHIP, out of 905 individuals aged 18–79 in the ComHIP cohort who started treatment, 686 (76%) were lost to follow-up before the end of the first year. To incorporate first-year losses to ComHIP follow-up into the Markov model, we estimated the annual risk of CHD/ stroke of these 686 individuals using their last available blood pressure readings. We estimated the first-year hypertension treatment costs of these individuals for their duration of follow-up.

▶ For standard care, we had no data on lost to follow-up, so we used the proportions of those receiving standard care at enrolment to those who were not receiving standard care at enrolment (56%:44%) as an indirect estimate of first-year lost to follow-up. We then estimated separately the annual risk of CHD/ stroke for individuals in the two groups using their blood pressure readings at the time of enrolment into the ComHIP cohort. We also adjusted the first-year costs for those estimated to be lost to follow-up assuming that they spent on average the same amount of time on treatment as those lost to follow-up in the ComHIP cohort. Finally, we also explored a second scenario where standard care had as high a lost to follow-up as ComHIP (76%).

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS
Costs of hypertension across scenarios

Table 1 shows the annual societal costs of hypertension management in the base case for the two ComHIP scenarios and for the standard care scenario. These are the total annual costs (including hypertension screening, diagnosis and treatment) to the healthcare provider and to patients of implementing ComHIP and standard care for a population of 10 000 adults in the intervention district. A detailed breakdown of these costs is provided in section 2.2 and online supplemental tables S20–S22 of the supporting information file.

From table 1, current ComHIP scale-up is estimated to have an annual societal cost of US$903 285—it is 20% more costly than GHS-LCS ComHIP scale-up at US$751 322 per year—this difference is due to the lowering of unit costs (for the most part salaries) in the transfer of services between FHI360 and the GHS. At US$462 636 per year, standard care annual societal costs are 51% and 62% of the costs of current ComHIP scale-up and GHS-LCS ComHIP scale-up, respectively. With respect to the costing structure, note that postimplementation costs make up the bulk of all annual costs (96% and 98% for each respective ComHIP scenario and 100% for the standard care scenario). Of these postimplementation costs, the largest cost driver is health service provision (the time of healthcare staff, the medication and diagnostic test costs, the patient-level costs including time seeking healthcare, out-of-pocket expenditures and time lost to work,

Table 1 Annual societal costs of hypertension screening, diagnosis and treatment (2017 US$)

Scenario	Healthcare provider costs	Patient-level costs	Societal costs	%
SCENARIO (no of patients on hypertension treatment)	CURRENT ComHIP SCALE-UP (n=3368)			
Annual start-up costs (incremental costs*)	33 097 (33 097)	-	33 097 (33 097)	4
1. ComHIP app development	5229	-	5229	16
2. Training	11 338	-	11 338	34
3. Management	16 529	-	16 529	50
Annual post-implementation costs (incremental costs*)	475 645 (222 289)	394 543 (185 263)	870 188 (407 552)	96
1. ComHIP app support	15 672	-	15 672	2
2. Acquisition of clinical and IT equipment	20 849	-	20 849	2
3. Health service provision to hypertensive patients	179 845	385 633	565 478	65
4. Health service provision to non-hypertensive individuals	42 820	8910	51 730	6
5. Management	216 459	–	216 459	25
Total annual costs (incremental costs*)	508 742 (255 386)	394 543 (185 263)	903 285 (440 649)	100
Overhead costs=total annual costs – health service provision	286 076			
Overhead costs per patient	84.94			
SCENARIO (no of patients on treatment)	GHS-LCS ComHIP SCALE-UP (n=3368)			
Annual start-up costs (incremental costs*)	15 499 (15 499)	-	15 499 (15 499)	2
1. ComHIP app development	207	-	207	1
2. Training	8955	-	8955	58
3. Management	6338	-	6338	41
Annual post-implementation costs (incremental costs*)	341 280 (87 924)	394 543 (185 263)	735 823 (273 187)	98
1. ComHIP app support	7660	-	7660	1
2. Acquisition of clinical and IT equipment	20 849	-	20 849	3
3. Health service provision to hypertensive patients	179 845	385 633	565 478	77
4. Health service provision to non-hypertensives	42 820	8910	51 730	7
5. Management	90 106	-	90 106	12
Total annual costs (incremental costs*)	356 779 (103 423)	394 543 (185 263)	751 322 (288 686)	100
Overhead costs=total annual costs - Health service provision	134 115			
Overhead costs per patient	39.82			
SCENARIO (no of patients on treament)	STANDARD CARE (n=3368)			
Annual start-up costs	-	-	-	0
1. ComHIP app development	-	-	-	-
2. Training	-	-	-	-
3. Management	-	-	-	-
Annual post-implementation costs	253 356	209 280	462 636	100
1. ComHIP app support	-	-	-	0
2. Acquisition of clinical and IT equipment	9929	-	9929	2
3. Health service provision to hypertensive patients	192 527	209 280	401 807	87
4. Management	50 900	-	50 900	11
Total annual costs	253 356	209 280	462 636	100
Overhead costs=total annual costs – health service provision	60 829			
Overhead costs per patient	18.06			

Sources: own calculation based on cost analysis.
*Incremental costs with respect to the annual costs of the standard care scenario.
ComHIP, Community-based Hypertension Improvement Project; GHS-LCS, Ghana Health Service-licensed chemical seller.

Table 2 10-year costs of different scenarios by cost component (2017 US$)

	Current ComHIP scale-up	%	GHS-LCS ComHIP scale-up	%	Standard care	%
Total costs (Incremental costs*)						
Health service costs	1 386 292 (−199 408)	18	1 386 292 (−199 408)	22	1 585 700	32
Overhead costs	2 215 779 (1 752 299)	30	1 038 827 (575 347)	16	463 480	9
Patient-level costs	2 863 469 (1 268 919)	39	2 863 469 (1 268 919)	46	1 594 550	33
Costs of CVD	974 190 (−286 570)	13	974 190 (−286 570)	16	1 260 760	26
TOTAL 10 year costs (Incremental costs*)	7 439 730 (2 535, 240)	100	6 262 778 (1 358 288)	100	4 904 490	100

Sources: own calculation based on cost-effectiveness modelling.
*Incremental costs with respect to the costs of the standard care scenario.
ComHIP, Community-based Hypertension Improvement Project; CVD, cardiovascular disease; GHS-LCS, Ghana Health Service-licensed chemical seller.

and the costs of screening non-hypertensives) with 71%, 84% and 87% of the postimplementation costs respectively, followed by the programme management costs (coordination meetings and field activities, technical staff support, administration costs) with 25%, 12% and 11%, respectively. Importantly, note the cost structure from table 1 results in an annual overhead cost per patient that differs substantially across scenarios—US$84.94 for the current ComHIP scale-up scenario, about twice as large as for the GHS-LCS ComHIP scale-up scenario and four times as large as for standard care. For the estimation of the annual programme costs, with lost to follow-up, the average annual societal costs per patient were US$197.20 in current ComHIP scale-up, US$152.10 in GHS-LCS ComHIP scale-up and US$119.63 in standard care.

For the cost-effectiveness analysis, with no losses to follow-up, the average societal costs per patient in year 1 with initial diagnosis (without initial diagnosis) were US$264.17 (US$244.56) in current ComHIP scale-up, US$219.05 (US$199.44) in GHS-LCS ComHIP scale-up, and US$157 (US$141) in standard care. Of note, current ComHIP care was on average 68% (73%) more expensive per patient than standard hypertension care. GHS-LCS

ComHIP scale-up was on average between 39% (41%) more expensive per patient than standard care. The main cost drivers for these cost differences were, first, the differences in overhead costs and, second, the difference in patient-level costs which is mainly due to a higher number of visits to the healthcare provider in ComHIP.

Cost-effectiveness analysis

Table 2 presents the total costs in the base case of the different scenarios over 10 years separated into cost components.
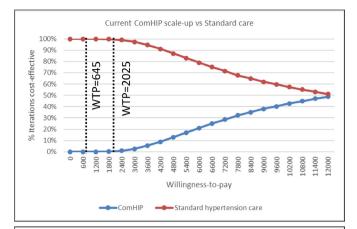
From table 2, note that the overhead costs of hypertension and the patient-level costs are the main cost drivers of the differences in 10-year costs between scenarios. Particularly, note how the overhead costs of current ComHIP scale-up are more than four times the overhead costs of standard care and the patient-level costs of current ComHIP scale-up are 80% greater than the patient-level costs of standard care.

Table 3 shows the results of the base-case cost-effectiveness analysis.

From table 3, in the base case, ComHIP helps prevent on average 75 CHD events and 45 strokes in a

Table 3 Cost-effectiveness analysis (base case)

Intervention	Cost (US$)	Incremental cost (US$)	CVD events (stroke/CHD)	CVD events averted (stroke/CHD)	DALYs	DALYs averted	ICER
Standard care	4 904 490		238/285		7883		
Current ComHIP scale-up	7 439 730	2 535 240	193/210	45/75	7675	208	12 189
Standard care	4 904 490		238/285		7883		
GHS-LCS ComHIP scale-up	6 262 778	1 358 288	193/210	45/75	7675	208	6530

CHD, coronary heart disease; ComHIP, Community-based Hypertension Improvement Project; CVD, cardiovascular disease; DALY, disability-adjusted life-year; GHS, Ghana Health Service; ICER, incremental cost-effectiveness ratio; LCS, licensed chemical seller.
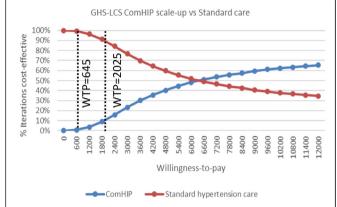
Figure 1 Cost-effectiveness acceptability curves in the base case: Current ComHIP scale-up and GHS-LCS ComHIP scale-up versus standard care. ComHIP, Community-based Hypertension Improvement Project; GHS, Ghana Health Service; LCS, licensed chemical seller; WTP, willingness to pay.

general population of 10 000 individuals over a period of 10 years. Cases averted are driven in the model by the lower average blood pressure levels estimated for

ComHIP (systolic=132.27 mm Hg; diastolic=81.04 mm Hg) compared with standard care (systolic=147.65; diastolic=90.14). 208 DALYs are averted overall. The incremental cost-effectiveness ratio (ICER) of current ComHIP scale-up versus standard care is US$12 189 per DALY averted. For a WTP threshold of US$645 per DALY averted[23] current ComHIP scale-up is not cost-effective, and neither is it for a WTP threshold of 1 GDP per capita (=2025 US$).[24] The ICER of GHS-LCS ComHIP scale-up is US$6530 per DALY averted, also not cost-effective for the same WTP thresholds.

Figure 1 shows, for the base case, the cost-effectiveness acceptability curves resulting for both comparisons from the probabilistic sensitivity analysis (PSA) reflecting uncertainty in the model inputs (the incremental cost-effectiveness scatterplots are shown in online supplemental figures S2 and S3 in the supporting information file).

From figure 1, considering uncertainty in the input parameters, the probability that current ComHIP scale-up is cost-effective is 0% at WTP= US$ 645 and 0.45% at WTP= US$2025. The probability that GHS-LCS ComHIP scale-up is cost-effective is 0.8% at WTP= US$645 and 11.5% at WTP= US$2025.

Table 4 shows the incremental cost-effectiveness of both ComHIP scenarios compared with standard hypertension care after incorporating drop-outs in hypertension treatment.

Assuming a drop-out rate of 44% in standard care, current ComHIP scale-up has an estimated ICER of US$7363 per DALY averted and is not cost-effective at any of the two WTP thresholds. In contrast, GHS-LCS ComHIP scale-up is both more effective and less costly than standard care, which is now the dominated alternative. This is because fewer drop-outs in standard care result in higher overall treatment costs than in GHS-LCS

Table 4 Cost-effectiveness analysis (including drop-outs)

Intervention	Cost (US$)	Incremental cost (US$)	DALYs	DALYs averted	ICER
Current ComHIP scale-up (76% drop-outs year 1) vs standard care (44% drop-outs year 1)					
Standard care	3 583 740		7811		
Current ComHIP scale-up	4 482 100	898 360	7689	122	7363
GHS-LCS ComHIP scale-up (76% drop-outs year 1) vs standard care (44% drop-outs year 1)					
Standard care	3 583 740		7811		Dominated
GHS-LCS ComHIP scale-up	3 371 850	(211 890)	7689	122	
Current ComHIP scale-up (76% drop-outs year 1) vs standard care (76% drop-outs year 1)					
Standard care	2 630 690		7817		
Current ComHIP scale-up	4 482 100	1 851 410	7689	128	14 462
GHS-LCS ComHIP scale-up (76% drop-outs year 1) vs standard care (76% drop-outs year 1)					
Standard care	2 630 690		7817		
GHS-LCS ComHIP scale-up	3 371 850	741 160	7689	128	5789

ComHIP, Community-based Hypertension Improvement Project; DALY, disability-adjusted life-year; GHS, Ghana Health Service; ICER, incremental cost-effectiveness ratio; LCS, licensed chemical seller.

ComHIP scale-up which are not compensated by a higher impact on health outcomes—we did not pick up a higher hypertension control in those reporting being on treatment with standard care vs those reporting not being on treatment. Assuming a drop-out rate of 76% in standard care, neither current ComHIP scale-up nor GHS-LCS ComHIP scale-up are cost-effective at the same thresholds with respective ICERs being US$14 462 per DALY averted and US$5789 per DALY averted.

DISCUSSION

Our study found that ComHIP is unlikely to be a cost-effective health intervention in Ghana for two different cost-effectiveness thresholds: one (lower) opportunity-cost-based threshold[23] and one (higher) based on the Ghanaian GDP per capita. Our base case results were robust considering the uncertainty associated with our underlying assumptions (including substantial uncertainty in the costs of CHD and stroke treatment and uncertainty associated with the annual probability of CHD and stroke events). However, our economic evaluation is fundamentally limited by the evidence quality associated with the effectiveness estimates, which come from observational data rather than from a randomised control study design. Nevertheless, our study provides some important findings. First, this is one of the first studies examining the cost-effectiveness of hypertension screening and treatment using a community scale-up model. This model incorporates community-based education on CVD risk factors and healthy lifestyles, screening and hypertension monitoring by community pharmacists and CVD nurses, community-based hypertension diagnosis, treatment, counselling and follow-up with a cloud-based app for health record system linked to SMS/voice messaging for treatment adherence support and health messaging.[14] We find much higher overhead costs (related to the cost of development of the app, mobile devices, training of community pharmacists and clinical staff, coordination meetings and field activities) and patient-level costs in both ComHIP scenarios. This substantial increase in costs, even when accounting for the higher prices used in international support associated with the current ComHIP scale-up suggests that the costs of ensuring appropriate care are high; and in this case could not produce sufficient impact to achieve cost-effective implementation. Second, our study adopts a societal perspective and thus incorporates not only the costs to the GHS but also the costs to patients of being on hypertension treatment (which are not inconsiderable in the Ghanaian context) and also estimates of the costs of informal care of patients suffering from CVD events.

Our results add to the growing body of evidence on the cost-effectiveness of providing hypertension care in LMICs. In Vietnam, Nguyen et al[27] estimated the cost-effectiveness of alternative hypertension screening options (namely, varying intervals for screening and varying ages to start screening) compared with no hypertension screening using a Markov model over 10 years in the base case. They used the Asia Cardiovascular Risk Prediction Model to estimate the probabilities of CVD events and, like us, modelled repeat CVD events, using a provider perspective. It is unclear whether they included the health system costs of supporting service delivery or just the prices of commodities. They found that for most scenarios the intervention was cost-effective. In Nigeria, Rosendaal et al[10] evaluated the cost-effectiveness of population-level screening and subsequent treatment compared with no screening or treatment. They used a Markov model over 10 years and did not model repeat CVD events. They used different assumptions to model CVD events, including (like us) the Framingham risk equations. For the costs, which were based on an existing costing study[28] and on clinical guidelines, they used the healthcare provider perspective. Using a WTP threshold of 1× GDP per capita (US$2742), they found that hypertension screening, with incremental costs per DALY averted ranging from US$732 to US$7815, could be cost-effective under most assumptions. When using the Framingham risk equation, they found hypertension screening was either not cost-effective or borderline cost-effective depending on the patient eligibility criteria. Finally, there is a third study by Gaziano et al[25] conducted in Guatemala, Mexico and South Africa. They evaluated the potential cost-effectiveness (from a healthcare provider perspective, ie, excluding patient-level costs) of using community health workers to screen for CVD in community settings using a paper-based tool or a mobile app and a Markov model over the lifetime of individuals. The study used CVD risk equations developed by the authors and modelled repeat CVD events. They found that the intervention was either cost-saving or highly cost-effective in all settings. In summary, the results from the literature are not conclusive. Among the possible explanations for the difference between our results and those of the other studies are the following:

1. The use of different risk prediction models.
2. The use of different periods for the estimation of effectiveness—in particular, Nguyen et al[27] and Gaziano et al[25] estimated effectiveness over the lifetime of individuals. Hypertension patients in younger age groups have a lower 10-year risk but a higher lifetime risk of CVD, especially those of African descent.[10 29 30] This may have led to an underestimate of health outcomes in our study which estimated health outcomes over a period of 10 years.
3. The range of costs included—for example, none of the studies except ours used the societal perspective—hence, they did not include any patient-related costs in the analysis. In addition, it is not clear if Nguyen et al[27] included the health system costs of supporting health service delivery; similarly, it is not entirely clear the extent to which Gaziano et al[25] included the overhead costs of administration and other supportive services into their cost estimates.
4. The use of different decision rules for establishing cost-effectiveness. For example, Nguyen et al[27] used

as a much higher threshold for cost-effectiveness (3 × GDP per capita=US$15 000) than we did. It is unclear if their results would hold at the opportunity-cost based threshold of current US$1602.[23]

Our results add to the evidence that current models of hypertension screening are unlikely to be cost-effective; and that much more work is still required to develop methods of implementation to address this growing burden of disease related to hypertension in LMICs.

The Markov model that we have implemented in this cost-effectiveness study has several limitations. While we tried to test sensitivity to loss to follow-up, our evidence base is weak. In a recent study using data from the Ghana DHS about 60% of patients with hypertension are estimated not to follow treatment.[9] Clearly, differences in the patients dropping out between ComHIP and standard care would affect cost-effectiveness, should ComHIP retain more people in care. In fact, retention levels were low, including a 3-month period where due to operational levels there was a gap in the provision of Commcare services.[15] We did not explore the effects on blood pressure and costs of the interventions in the short term (ie, under 1 year). This was due to the lack of follow-up data from patients on standard care. In addition, the estimation of CVD patient-level costs included data from few individuals (n=7). Although these data were supplemented with expert opinion from clinicians and the resulting costs estimates were subjected to sensitivity analysis, we acknowledge its limitations. Further, the model relies on the Framingham risk equations to estimate the risk of CVD events. These equations were estimated based on a cohort of hypertensive patients from the USA, and hence are not validated for patients from Ghana. We chose to model cost-effectiveness over a period of 10 years (the time span for which the Framingham equations provide predicted CVD probabilities) and did not project cost-effectiveness over the lifetime of the cohort. As mentioned before, hypertension patients in younger age groups have a lower 10-year risk but a higher lifetime risk of CVD, which means that we may have underestimated the health outcomes and hence the cost-effectiveness of ComHIP by not extending the modelling to the lifetime of the cohort. In addition, the Framingham equations were used to estimate the effect of short-term changes in blood pressure on the risk of stroke and CHD for patients under treatment for these conditions. This may have led to an overestimation of the annual probabilities of stroke and CHD in the cost-effectiveness model. Furthermore, as in other cost-effectiveness studies of hypertension interventions, we only modelled CHD and stroke as possible adverse events of hypertension. This is due to lack of data about the relationship between hypertension and the risk of other illnesses, but it likely led to an underestimate of the benefits of ComHIP. In addition, for pragmatic reasons, we used triangular distributions to characterise uncertainty in the following parameters—the probability of treatment for first time/repeat stroke or CHD, the probability of death after first time/repeat

stroke or CHD, the cost of hypertension treatment in the standard care scenario and the cost of screening non-hypertensives. An improved characterisation of uncertainty would have involved modelling this uncertainty in these parameters with gamma or beta distributions.

CONCLUSION

Hypertension is a growing global public health issue, for which effective treatment is available. While our study does not demonstrate positive economic evidence on the ComHIP model of care, it is critical to note that our result was driven by the way the intervention was delivered. Unfortunately, ComHIP failed to develop a model of delivery that achieved sufficient levels of retention and use at an acceptable cost. Our study along with others, suggests that there is an urgent remaining need for a substantial programme of global research, using sound study designs, to establish cost-effective ways of delivering this effective treatment to the populations who need it in LMICs.

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of the translations (including but not limited to local regulations, clinical guidelines, terminology, drug names and drug dosages), and is not responsible for any error and/or omissions arising from translation and adaptation or otherwise.

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