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Cost analysis of the WHO-HEARTS program for hypertension control and CVD prevention in primary health facilities in Ethiopia

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ABSTRACT

Background: In 2020, Ethiopia launched the Ethiopia Hypertension Control Initiative (EHCI) program to improve hypertension care using the approach described in the WHO HEARTS technical package.
Objective: To estimate the costs of implementing the HEARTS program for hypertension control and cardiovascular disease (CVD) prevention in the primary care setting in Ethiopia for adult primary care users in the catchment area of five examined facilities.
Study design: This study entails a program cost analysis using cross-sectional primary and secondary data.
Methods: Micro-costing facility surveys were used to assess activity costs related to training, counselling, screening, lab diagnosis, medications, monitoring, and start-up costs at five selected health facilities. Cost data were obtained from primary and secondary sources, and expert opinion. Annual costs from the health system perspective were estimated using the Excel-based HEARTS costing tool under two intervention scenarios – hypertension-only control and a CVD risk management program, which addresses diabetes and hypercholesterolemia in addition to hypertension.
Results: The estimated cost per adult primary care user was USD 5.3 for hypertension control and USD 19.3 for integrated CVD risk management. The estimated medication cost per person treated for hypertension was USD 9.0, whereas treating diabetes and high cholesterol would cost USD 15.4 and USD 15.3 per person treated, respectively. Medications were the major cost driver, accounting for 37% of the total cost in the hypertension control program. In the CVD risk management scenario, the proportions of medication and lab diagnostics of total costs were 18% and 64%, respectively.
Conclusions: The results from this study can inform planning and budgeting for HEARTS scale-up to prevent CVD across Ethiopia.

1. Background

Ethiopia is a low-income country with a per-capita gross domestic product (GDP) of USD 826 and a per-capita health expenditure of approximately USD 27 in 2019 [1]. In 2019, noncommunicable diseases (NCDs) contributed to 43% of all deaths in Ethiopia [2]. The relative contribution of NCDs and their risk factors to total disease burden is on the rise in Ethiopia [3–5]. Cardiovascular diseases (CVDs) were the second leading cause of premature death and disability in 2019, with 4471 age-standardized disability-adjusted life years (DALYs) per 100, 000 [6]. The number of CVD cases in Ethiopia doubled between 1990 and 2017, from approximately 1.4 million to 2.8 million [7]. In 2015, the national prevalence of hypertension was 16%, with regional variation as high as 25% [8]. Among persons with raised blood pressure, over

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97% did not take hypertension medications, and hypertension was not effectively controlled in nearly half of patients on medication [8]. A previous study showed that the prevalence of uncontrolled hypertension among hypertensive patients on treatment in Ethiopia was very high (48%) [9]. This context suggests the presence of considerable opportunities for improving population health in Ethiopia through scaling up hypertension control and CVD prevention activities.

During the last three decades, Ethiopia implemented a decentralized primary health care system with a community-based Health Extension Program (HEP) that enabled the country to attain better health outcomes in maternal and child health and communicable diseases [10,11]. To tackle the rising NCD burden, Ethiopia adopted a national framework in 2010 following the World Health Organization (WHO) guidelines for essential NCD management in primary care settings, including hypertension, and developed a national strategic action plan in 2014 [12,13]. NCDs also received more attention in the Ethiopian Health Sector Transformation Plan (HSTP– I and II, 2015–2025).[12] However, population-level implementation of CVD prevention and hypertension control may be challenged by resource constraints for primary care in Ethiopia. Increasing population outreach for CVD and hypertension care at the community and primary care level is contingent on an accurate understanding of local costs and cost drivers. Evidence from Ethiopia is limited in that regard. A 2018 study reported that the estimated mean annual direct and indirect costs of hypertension management, based on the patient perspective, were USD 136.6 and 130.7 per patient, respectively [14]. Cost assessments from the health systems perspective in Ethiopia are scarce. A 2015 systematic review using data from 14 LMICs (not including Ethiopia) estimated a range of annual outpatient costs of hypertension management between USD 38 and 566 per patient [15]. In southern Ethiopia, a hospital-based patient-level study estimated the annual direct cost of hypertension management for 406 patients and reported USD 160 per patient annual cost in 2021 [16]. A better understanding of the costs of CVD prevention in primary care is needed for future investments in this area of health system strengthening.

The Ethiopia Hypertension Control Initiative (EHCI) is a program of the Ethiopia Ministry of Health that receives technical support from the World Health Organization and Resolve to Save Lives [17]. The program, launched in 2020, aims to expand hypertension diagnosis, treatment and control using the approach codified in the WHO HEARTS technical package [18]. As of October 2022, the EHCI has enrolled nearly 14,000 patients with hypertension in 58 health centers and ten primary health facilities located in several regions of Ethiopia. The WHO HEARTS technical package outlines a strategy for integrating CVD prevention and hypertension management in primary healthcare settings. The strategy incorporates the use of standardized hypertension treatment protocols, improved access to medications, risk-based management through CVD risk assessment, team-based care through provider task-sharing, and improved patient monitoring. In Ethiopia, EHCI project activities have included the endorsement of a simple hypertension treatment protocol; health worker training in providing protocol-based care; procurement of validated digital blood pressure measurement devices; and establishment of a monitoring system for supply chain management of medications, including the provision of start-up medication to be sold at a subsidized price at the participating health facilities.

This study estimated the expected costs of implementing the components of the HEARTS technical package for CVD prevention using data from the primary care units of five health centers in Ethiopia. Findings from this study can inform policymakers about budget needs for service delivery, population-level scale-up, program cost-effectiveness evaluations, and an informed health insurance strategy.

2. Methods

2.1. Study setting

In Ethiopia, primary care is offered in primary health facilities, health centers, and satellite health posts. The average primary health facility serves about 100,000 people, while a health centre can serve from 25,000 persons in rural areas to 40,000 persons in urban areas. Health posts serve an average of 5000 persons. The first point of contact for NCD care at these facilities is the NCD clinic, which is typically staffed with a full-time medical doctor/health officer and a nurse, sometimes supported by internists [19,20].We obtained the primary care level cost data from the following facilities: Mojo Health Centre (Oromia region), Wolenchity Hospital (Oromia region), Daye Hospital (Sidema region), Dachau Health Centre (Dire Dewa city), Addis Alem Hospital (Amhara region). Considering geographic distribution and population size, the Resolve to Save Lives and Ministry of Health jointly identified these five health facilities from the active HEARTS intervention health facilities. Two health facilities from the Oromia region were selected as this region represented 43% population [20].

2.2. Patient and public involvement

The study did not involve patients or the public in the design, conduct, reporting, or dissemination plans of this research.

2.3. HEARTS hypertension management program in Ethiopia

The HEARTS Technical Package is organized around six modules that can be adapted to the local context: H–Healthy-lifestyle counselling, E—Evidence-based treatment protocols, A—Access to essential medicines and technology, R—Risk-based CVD management, T—Team-based Care, and S—Systems for monitoring. Detailed description of the HEARTS technical package is published elsewhere [18]. The broader set of HEARTS implementation activities include: training staff to deliver standard screening, counselling, and protocol-based treatment; record keeping and reporting; ensuring an adequate supply of necessary drugs, introduction of patient monitoring tools and reporting system; and establishing a mechanism for a patient referral from primary care to secondary care and tertiary care. Guided by the HEARTS hypertension protocol, the clinical management protocol for adults with hypertension (defined as systolic blood pressure (SBP)/diastolic blood pressure (DBP)$\geq$140/90 mm Hg, or SBP/DBP$\geq$130/80 mm Hg with comorbidity or high CVD-risk) entails a first line of treatment with amlodipine 5 mg daily; a second line of treatment using amlodipine 10 mg daily; and a third line of treatment using amlodipine 10 mg plus hydrochlorothiazide 25 mg daily. The prescribed medicines are typically generic, manufactured domestically, and provided free of charge to patients by public health facilities. To provide continuous care more sustainably and to reduce the burden on physicians, a team-based care strategy would be implemented. In this approach, lifestyle counselling tasks to promote healthy behavior would be shared equally between doctors, nurses, and health extension workers (HEWs), while technical tasks such as patient assessment and treatment would be shared between doctors and nurses only. Training sessions were conducted with a pool of selected doctors, nurses and HEWs trained with relevant modules. Although the Ethiopian national hypertension guideline does not include CVD risk assessment or screening for diabetes and raised cholesterol, the ECHI includes these, hence they were costed in the integrated CVD risk management scenario.

2.4. Integrated CVD prevention, including hypertension, diabetes, and hyperlipidemia management

An integrated CVD prevention program scenario includes diabetes and hyperlipidemia management in addition to hypertension

management in primary care patients. The program entails assessing and stratifying the target population by CVD risk. CVD risk stratification is based on the WHO and International Society of Hypertension cardiovascular risk prediction charts and expressed as the probability of developing CVD over 10 years. The CVD risk categories are low (0 to <10%); medium (10–20%); and high (≥ 20%) [21]. The treatment protocol for patients with uncomplicated type 2 diabetes (defined as fasting plasma glucose (FPG) ≥ 7.0 mmol/l or routine plasma glucose (RPG) ≥ 11.1 mmol/l or HbA1C ≥ 6.5%) managed at the primary care level includes metformin (500 mg once daily), metformin (500 mg twice daily), then metformin (500 mg twice daily) and glibenclamide (5 mg) as the first, second, and third lines of treatments, respectively. This protocol was informed by the WHO guidance on the diagnosis and management of diabetes (HEARTS-D) [22]. Although the WHO has not provided any guidance on the management of hyperlipidemia, statins are widely recommended for primary therapy [23]. For this costing exercise, the local consultants and experts proposed a statin-based treatment protocol for hyperlipidemia, including simvastatin (20 mg) as a first line, atorvastatin (20 mg) as a second line, and atorvastatin (40 mg) as a third line of treatment, respectively.

Costs associated with implementing integrated hypertension, diabetes, and hyperlipidemia treatment protocols include provider time spent on estimating CVD risk using risk charts during an annual primary care visit; training in CVD risk estimation, in addition to time spent collecting patient history; medication costs; and diagnostic test costs including provider (technician) time, complete blood count panel, fasting blood glucose, and blood lipid panel tests.

2.5. HEARTS costing tool

Program costs were assessed using the HEARTS costing tool, an Excel-based instrument to collect, track, and evaluate the incremental annual cost of implementing the HEARTS program from the health system perspective. Once program costs and other inputs such as population coverage, risk factor prevalence, and planned provider numbers are entered into the costing tool, the cost calculations are allocated across different HEARTS modules. The tool is organized by HEARTS modules [24]. Appendix Fig. 1 describes the cost components for the respective HEARTS modules [25].

Briefly, the cost elements in the Healthy-lifestyle counselling module 'H' include the costs of training providers in lifestyle counselling, the costs of community awareness programs, and the cost of provider time used to administer brief counselling. The cost elements in Module 'E' include provider time needed to take patient history, conduct physical exams and diagnostic tests, and conduct return visits. Module 'A' encompasses the costs of diagnostic tests (complete blood count panel, blood lipid panel, fasting blood glucose), medications (hypertension, diabetes, and cholesterol), and on-site diagnostic technologies and supplies. Module 'R' includes the costs of training providers to estimate CVD risk with the risk charts and to provide risk-based management to patients. Module "T" reports the cost savings realized from task-sharing by comparing the cost that could have been incurred if the tasks were performed solely by the physicians with costs incurred when the tasks are shared among physicians, nurses, and health extension workers (HEW). Therefore, in the baseline scenario (i.e., in the absence of task-sharing allocation), the costing tool assumes a physician-led program. In our cost projections, we assumed that doctors, nurses, and HEWs would equally share the tasks (i.e., provider time) when applicable. For instance, HEWs would only provide behavioral counselling and screening service, but not CVD risk assessment, or medication prescription. Accordingly, the provider time allocated for behavior counselling and screening will be shared equally among doctors, nurses, and HEWs. Nurses will be trained to do major tasks (i.e., counselling, screening, and assessing CVD risk, and treating according to CVD risk), therefore, providers' time for performing HTN/CVD risk-assessment, prescribing medications, and conducting return-visits are allocated equally between doctors and nurses. While the 'T' module reports the cost savings from team-based care, the accrued cost of provider time (inclusive of doctors, nurses, and HEWs) spent on various tasks is included in the corresponding 'H', 'E', and 'R' modules. Module 'S' reports costs related to human resources, technology (software and hardware), supplies, and training for patient monitoring.

2.6. Data

Appendix Table 1 presents the prevalence of CVD risk factors and cost inputs used to populate the HEARTS costing tool for each health facility. The prevalence of medium and high risk for CVD in the catchment areas ranges between 32% (Oromia Wolenchity Hospital, Diredawa Dechatu Health Center, and Oromia Modjo Health Center) and 41% (Sidama Daye Hospital). Hypertension is the leading risk factor in all catchment areas (24%–14.7%). Physical inactivity (14%–5.2%) and alcohol consumption (8.9%) are the next two major risk factors. Diabetes (11.7%) is a critical risk factor in the catchment area of Amhara Baherdar Addis Alem Hospital [8]. The primary care attendance rate (the proportion of the adult population in the facility's catchment area that is likely to use the facility) was assumed to be 45% for each health facility catchment area. The distributions of patients by CVD risk category and for the pharmacological treatment of hypertension, diabetes, and cholesterol by different treatment lines were adopted from the literature or based on local physician consensus. The local currency was converted to US dollars using the 2021 period average conversion rate of 43.73 BIRR/USD obtained from the International Monetary Fund (IMF) database [26].

The cost assessment involved three steps: the identification of resources necessary to run the program, measurement of resource cost based on unit cost, and estimating costs per patient. The price data for most of the items were taken from the health facilities and pharmacy stores in the facilities. Price information for some medications were also obtained from the Ethiopian Pharmaceuticals Supply Agency (EPSA). Cost data from each facility were collected from July 1 to September 30, 2021. To identify the types of resource inputs, we interviewed facility NCD coordinators, reviewed facility level secondary data sources like the facility registration records, the facility hypertension registration book, and the 2020 District Health information System report of the Ministry of Health.

In this study, we used a micro-costing activity-based approach. To generate the annual costs of providers, we estimated for each provider the time spent on adults visiting the health facility including follow-up visits per year, then multiplied by the salary of each provider to create the annual cost of CVD intervention. Excluding overtime hours and annual leave, we assumed that all staff work an average of 2080 h annually. We assumed the average number of follow-up visits for low, medium, and high CVD risk patients are 1, 2 and 4 times per year, respectively. Capital resources such as medical equipment, blood pressure machines, adult weight scales, chemistry and complete blood count instruments were annuitized based on the number of useful life-years and the initial unit price with a 3% discount rate [27]. We also conducted sensitivity analysis and presented range estimates with respect to four major cost drivers in the study: medicine price, provider time, risk factor prevalence, and number of visits. Baseline cost estimates were compared with the range of cost estimates due to +10% and -10% variations in medicine prices, hypertension prevalence rate, and provider times, as well as varying the numbers follow up visits (+1 and -1), separately.

3. Results

3.1. Population coverage

The total adult population (age 18 and above) in the catchment areas of five health facilities is 247,882, of which 111,547 are adult primary

care user (PC users) (Table 1). The total number of people eligible to receive counselling, screening, diagnosis, and treatment under the two types of HEARTS intervention packages in the five health facilities was determined by the primary care attendance rate, the prevalence of low-, medium-, and high- CVD risk in the population, the prevalence of hypertension, diabetes, and high cholesterol. The estimated number of persons with hypertension, diabetes, and high cholesterol was 20,783, 6,433, and 5,572, respectively (Table 1). Unit costs and other cost inputs were applied to these population parameters to project total program costs.

3.2. Hypertension management program cost

Table 2 reports the estimated annual costs, in 2021 USD and Ethiopian Birr, of implementing the HEARTS hypertension management program in the catchment areas of five health facilities. The total annual cost across all five health facilities was estimated at USD 517,000. This is equivalent to USD 5.3 per adult PC user and USD 9.0 per person treated in the program (Table 3). Cost per adult PC user varies across health facilities, ranging between USD 3.6 to USD 7.1. Appendix Table 4 (panel 1) and Appendix Table 5 show the results of the sensitivity analysis with

Table 1
Population coverage.

	Amhara Baherdar Addis Alem Hospital	Diredawa Dechatu Health Center	Oromia Modjo Health Center	Oromia Wolenchity Hospital	Sidama Daye Hospital	Total
Adult population in need (18+ years) in facility catchment area	65,000	21,182	20,700	76,000	65,000	**247,882**
Adults who present at the health facility	29,250	9532	9315	34,200	29,250	**111,547**
Providing brief counselling						
PC user to receive brief advice	29,250	9532	9315	34,200	29,250	**111,547**
Tobacco use	*1550*	*505*	373	*1368*	*1170*	**4966**
Harmful alcohol use	*2603*	*848*	*829*	*3044*	*2603*	**9928**
Physical inactivity	*4095*	*1334*	*1304*	*1778*	*1521*	**10,033**
Screening and diagnosis of 10-year CVD risk						
Low CVD risk	19,598	6482	6334	23,256	17,258	**72,927**
Medium CVD risk	7313	2288	2236	7729	8483	**28,047**
High CVD risk	2340	763	745	3215	3510	**10,573**
Attending patients with hypertension, diabetes, and high cholesterol						
Hypertension	6932	2288	2236	5027	4300	**20,783**
Diabetes	3422	496	484	1094	936	**6433**
Cholesterol	1463	410	401	1778	1521	**5572**

Note: PC user (primary care user) is an adult who presents at the primary care facility.

Table 2
Total annual cost of HEARTS hypertension control program in five health facilities.

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Total	
	Birr	**USD**	**Birr**	**USD**	**Birr**	**USD**	**Birr**	**USD**	**Birr**	**USD**	**Birr**	**USD**
H: Healthy Lifestyles	**835,657**	**19,109**	**283,608**	**6485**	**266,867**	**6103**	**631,210**	**14,434**	**549,017**	**12,555**	**2,566,359**	**58,686**
H1: Training costs	63,330	1448	36,715	840	36,715	840	63,330	1448	63,330	1448	**263,419**	**6024**
H2: Brief counselling costs	772,328	17,661	246,893	5646	230,152	5263	567,880	12,986	485,687	11,106	**2,302,941**	**52,663**
H2.1: Tobacco	*145,154*	*3319*	*46,402*	*1061*	*34,223*	*783*	*125,498*	*2870*	*107,334*	*2454*	**458,612**	**10,487**
H2.2: Alcohol	*243,749*	*5574*	*77,920*	*1782*	*76,147*	*1741*	*279,234*	*6385*	*238,818*	*5461*	**915,868**	**20,944**
H2.3: Physical inactivity	*383,425*	*8768*	*122,571*	*2803*	*119,782*	*2739*	*163,148*	*3731*	*139,534*	*3191*	**928,460**	**21,232**
E: Evidence-based Treatment Protocols	**1,363,152**	**31,172**	**372,829**	**8526**	**364,345**	**8332**	**1,353,187**	**30,944**	**1,224,532**	**28,002**	**4,678,045**	**106,976**
E1: Ask about patient history - provider time	350,966	8026	96,388	2204	94,195	2154	345,836	7908	295,781	6764	**1,183,165**	**27,056**
E2: Assess via physical exam and diagnostic tests - provider time	175,483	4013	48,194	1102	47,097	1077	172,918	3954	147,890	3382	**591,583**	**13,528**
E3: Return visits - Counsel and treat per protocol - provider time	836,703	19,133	228,247	5219	223,053	5101	834,433	19,081	780,861	17,856	**2,903,297**	**66,391**
A: Access to Essential Medicines and Technologies	**2,816,324**	**64,403**	**930,498**	**21,278**	**909,362**	**20,795**	**2,042,905**	**46,716**	**1,747,460**	**39,960**	**8,446,549**	**193,152**
A1: Hypertension medications	2,814,324	64,357	928,498	21,233	907,362	20,749	2,040,905	46,671	1,745,460	39,914	**8,436,549**	**192,924**
A5: Diagnostic tech., machines & supplies	2000	46	2000	46	2000	46	2000	46	2000	46	**10,000**	**229**
R: Risk-based Management	**59,069**	**1351**	**33,438**	**765**	**33,438**	**765**	**59,069**	**1351**	**59,069**	**1351**	**244,081**	**5582**
R1: Training costs	59,069	1351	33,438	765	33,438	765	59,069	1351	59,069	1351	**244,081**	**5582**
T: Team-based care (Savings from training nurses and CHEs to do Doctors' work)	**241,943**	**5533**	**53,201**	**1217**	**51,150**	**1170**	**167,595**	**3832**	**143,338**	**3278**	**657,225**	**15,029**
T1: Savings from training nurses	190,949	4367	41,165	941	39,930	913	138,945	3177	118,834	2717	**529,822**	**12,116**
T2: Savings from training HEWs	50,994	1166	12,036	275	11,220	257	28,650	655	24,503	560	**127,403**	**2913**
S: Systems for monitoring	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**6,682,718**	**152,818**
S1: Human resources	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	**5,421,797**	**123,983**
S2: Technology	240,000	5488	240,000	5488	240,000	5488	240,000	5488	240,000	5488	**1,200,000**	**27,441**
S3: Supplies	12,184	279	12,184	279	12,184	279	12,184	279	12,184	279	**60,921**	**1393**
Total Program Cost (H+E+A+R+T+S)	**6,410,746**	**146,598**	**2,956,916**	**67,618**	**2,910,556**	**66,557**	**5,422,914**	**124,009**	**4,916,621**	**112,431**	**22,617,752**	**517,214**

Table 3
Hypertension control: cost per adult and per patient.

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Average	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	**Birr**	**USD**
Total Cost per adult (18+ age) who present in health facility	219	5.0	310	7.1	312	7.1	159	3.6	168	3.8	**234**	**5.3**
Medication cost per person treated for hypertension	394	9.0	394	9.0	394	9.0	394	9.0	394	9.0	**394**	**9.0**

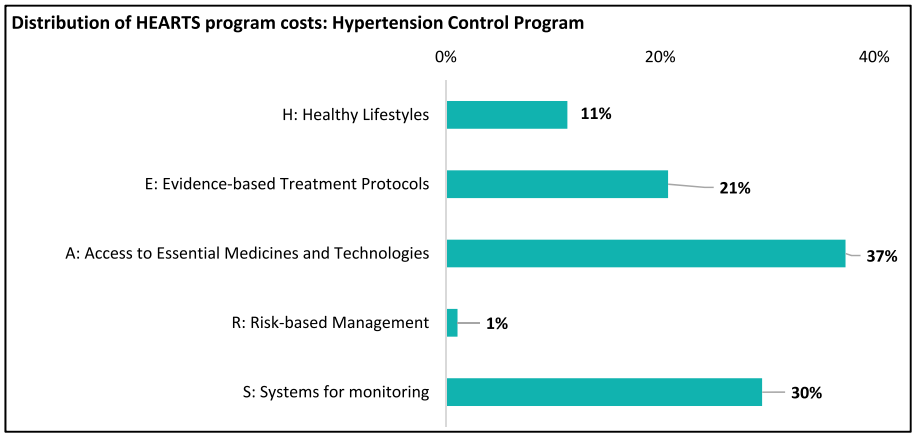

Fig. 1. Hypertension Control: Distribution of annual cost by HEARTS components.

range estimates for total cost *per* adult who present in health facility and medication cost *per* person treated for hypertension, respectively.

The adoption of task-sharing would save USD 15,000, of which USD 12,000 comes from using nurses to complete tasks customarily performed by doctors (i.e., counselling, screening, and assessing CVD risk, and treating according to CVD risk) and USD 3000 comes from using HEWs to provide counselling to change behavior (Table 2).

Fig. 1 presents the distribution of costs by HEARTS components and sub-components. Fig. 1 shows that Module 'A' (Access to medicines and technology) constitutes the most significant cost share (USD 193,000; 37%), followed by Module 'S' (Systems for monitoring; USD 153,000; 30%). Module 'E' (Evidence-based treatment protocols) contributes for 21% of the total cost (USD 107,000).

Appendix Table 2 highlights the time needed from health providers and non-health personnel to implement the hypertension control program. Implementing the program in the catchment areas of five health facilities is estimated to require the full-time equivalent of 19 doctors, 19 nurses, and 1 community health worker, which entails 1.7 FTE doctors, 1.7 FTE nurses, and 0.9 FTE HEWs would be required *per* 10,000 primary care users.

3.3. Risk-based integrated hypertension, diabetes, and high cholesterol management program cost

Table 4 reports the estimated costs of implementing risk-based hypertension, diabetes, and high cholesterol management program in the five health facility catchment areas. The total estimated annual cost across all five health facilities at USD 2.1 million. This is equivalent to USD 19.3 per adult PC user and USD 9.0, 15.4 and 15.3 medication cost per person treated for hypertension, diabetes, and cholesterol, respectively, per annum (Table 5). Appendix Table 4 (panel 2) and Appendix Table 5 show the results of the sensitivity analysis with range estimates for total cost *per* adult who present in health facility and medication cost *per* person treated for hypertension, diabetes, and cholesterol, respectively.

The adoption of a task-sharing approach would save USD 25,000, of which USD 22,000 comes from using nurses to complete tasks customarily performed by doctors (i.e., counselling, screening, and assessing CVD risk, and treating according to CVD risk) and USD 3000 comes from using HEWs to provide counselling to change behavior (Table 4).

Fig. 2 presents the distribution of costs by HEARTS components. Module 'A' (Access to medicines and technology) constitutes the largest cost share (USD 1.7 million; 82%), followed by Module 'E' (Evidence-based treatment protocols, USD 153,000, 7%) and Module 'S' (Systems for monitoring, USD 144,000, 7%).

Implementing the risk-based hypertension, diabetes, and high cholesterol management program at the full population level in all four sub-districts is estimated to require the full time equivalent of 21 doctors, 21 nurses, and 1 HEW (Appendix Table 3). For scaling up, FTE equivalent of 1.9 doctors, 1.9 nurses, and 0.9 HEWs would be required *per* 10,000 primary care user.

Table 4
Total annual cost of HEARTS risk-based hypertension, diabetes, and cholesterol management program in five health facilities.

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Total	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD
H: Healthy Lifestyles	**835,657**	**19,109**	**283,608**	**6485**	**266,867**	**6103**	**631,210**	**14,434**	**549,017**	**12,555**	**2,566,359**	**58,686**
H1: Training costs	63,330	1448	36,715	840	36,715	840	63,330	1448	63,330	1448	263,419	6024
H2: Brief counselling costs	772,328	17,661	246,893	5646	230,152	5263	567,880	12,986	485,687	11,106	2,302,941	52,663
H2.1: Tobacco	*145,154*	*3319*	*46,402*	*1061*	*34,223*	*783*	*125,498*	*2870*	*107,334*	*2454*	*458,612*	*10,487*
H2.2: Alcohol	*243,749*	*5574*	*77,920*	*1782*	*76,147*	*1741*	*279,234*	*6385*	*238,818*	*5461*	*915,868*	*20,944*
H2.3: Physical inactivity	*383,425*	*8768*	*122,571*	*2803*	*119,782*	*2739*	*163,148*	*3731*	*139,534*	*3191*	*928,460*	*21,232*
E: Evidence-based Treatment Protocols	**1,827,820**	**41,798**	**524,254**	**11,988**	**512,324**	**11,716**	**1,896,491**	**43,368**	**1,534,311**	**35,086**	**6,295,199**	**143,956**
E1: Ask about patient history - provider time	350,966	8026	96,388	2204	94,195	2154	345,836	7908	295,781	6764	**1,183,165**	**27,056**
E2: Assess via physical exam and diagnostic tests - provider time	640,151	14,639	199,619	4565	195,076	4461	716,222	16,378	457,669	10,466	**2,208,736**	**50,508**
E3: Return visits - Counsel and treat per protocol - provider time	836,703	19,133	228,247	5219	223,053	5101	834,433	19,081	780,861	17,856	**2,903,297**	**66,391**
A: Access to Essential Medicines and Technologies	**20,653,791**	**472,303**	**6,268,698**	**143,350**	**6,126,090**	**140,089**	**20,935,296**	**478,740**	**21,520,726**	**492,127**	**75,504,600**	**1,726,609**
A1: Hypertension medications	2,814,324	64,357	928,498	21,233	907,362	20,749	2,040,905	46,671	1,745,460	39,914	8,427,124	192,708
A2: Diabetes medication	2,367,335	54,135	342,871	7841	335,069	7662	757,049	17,312	647,476	14,806	4,449,800	101,756
A3: Cholesterol medication	1,008,932	23,072	282,757	6466	276,323	6319	1,226,862	28,055	1,049,290	23,995	*3,844,164*	*87,907*
A4: Diagnostic test	14,461,200	330,693	4,712,571	107,765	4,605,336	105,313	16,908,480	386,656	18,076,500	413,366	*58,764,087*	*1,343,793*
A5: Diagnostic tech., machines & supplies	2000	46	2000	46	2000	46	2000	46	2000	46	*10,000*	*229*
R: Risk-based Management	**234,552**	**5364**	**81,632**	**1867**	**80,535**	**1842**	**231,987**	**5305**	**206,959**	**4733**	**835,664**	**19,110**
R1: Training costs	59,069	1351	33,438	765	33,438	765	59,069	1351	59,069	1351	244,081	5582
R2: Estimate risk using risk charts	175,483	4013	48,194	1102	47,097	1077	172,918	3954	147,890	3382	591,583	13,528
T: Team-based care (Savings from training nurses and CHEs to do Doctors' work)	**402,576**	**9206**	**87,742**	**2006**	**84,905**	**1942**	**291,527**	**6667**	**214,001**	**4894**	**1,080,751**	**24,714**
T1: Savings from training nurses	351,582	8040	75,706	1731	73,685	1685	262,877	6011	189,498	4333	953,348	21,801
T2: Savings from training HEWs	50,994	1166	12,036	275	11,220	257	28,650	655	24,503	560	127,403	2913
S: Systems for monitoring	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**1,336,544**	**30,564**	**6,682,718**	**152,818**
S1: Human resources	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	1,084,359	24,797	5,421,797	123,983
S2: Technology	240,000	5488	240,000	5488	240,000	5488	240,000	5488	240,000	5488	1,200,000	27,441
S3: Supplies	12,184	279	12,184	279	12,184	279	12,184	279	12,184	279	*60,921*	*1393*
Total Program Cost (H+E+A+R+S)	**24,888,363**	**569,137**	**8,494,735**	**194,254**	**8,322,360**	**190,312**	**25,031,526**	**572,411**	**25,147,556**	**575,064**	91,884,540	**2,101,179**

Table 5
Hypertension, diabetes, and cholesterol control: cost per adult and per patient.

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Average	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	**Birr**	**USD**
Total Cost per adult (18+ age) who present in health facility	851	19.5	891	20.4	893	20.4	732	16.7	860	19.7	**845**	**19.3**
Medication cost per person treated for hypertension	394	9.0	394	9.0	394	9.0	394	9.0	394	9.0	**394**	**9.0**
Medication cost per person treated for diabetes	672	15.4	672	15.4	672	15.4	672	15.4	672	15.4	**672**	**15.4**
Medication cost per person treated for cholesterol	670	15.3	670	15.3	670	15.3	670	15.3	670	15.3	**670**	**15.3**

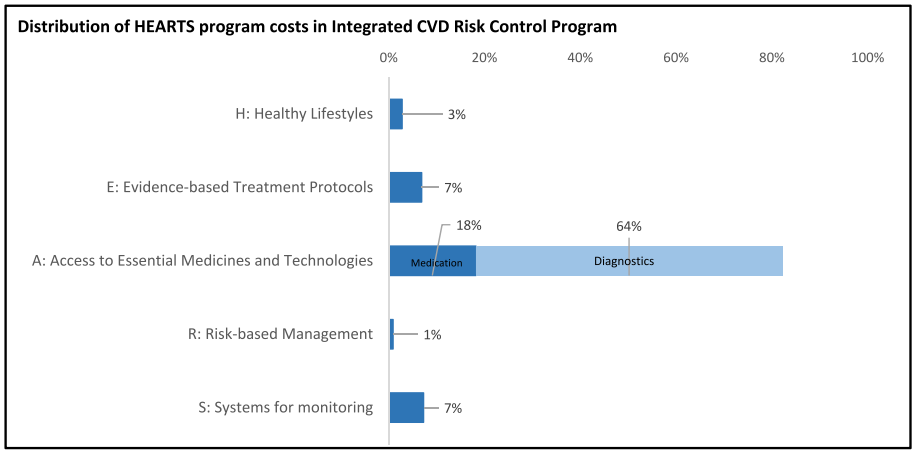

Fig. 2. Integrated CVD risk management: Distribution of annual cost by HEARTS components.

4. Discussion

The EHCI program in Ethiopia aims to utilize the WHO HEARTS technical package to expand hypertension diagnosis, treatment, and control. The study estimates the cost of implementing the HEARTS program in five health facilities in Ethiopia catering to the adult population of the respective catchment areas attending the facilities. Additionally, the study estimated the required human resources for full-service coverage. We assessed two program scenarios: a hypertension management program and an integrated risk-based hypertension, diabetes, and cholesterol management program.

The overall cost per adult attending the health facilities was estimated to be approximately USD 5.3 for the hypertension control program and USD 19.3 for the risk-based comprehensive approach, with variation across health centers. While most of the unit costs are similar across the health centers, there are variations in prevalence estimates for the risk factors (e.g., physical inactivity, hypertension, diabetes, and hyperlipidemia). For instance, the Oromia Wolenchity hospital catchment area reported prevalence estimates of 5.2%, 14.7%, and 3.2% for hypertension, diabetes, and hyperlipidemia compared to 14%, 24%, and 5.2% estimated for the Oromia Modjo Center catchment area, respectively. This resulted in lower *per* adult cost for the Oromia Wolenchity hospital catchment area compared to the Oromia Modjo Center catchment area. The main cost drivers for the hypertension control program are medication expenditures (37%) and the cost of provider time for providing care including multiple visits (21%). In the risk-based integrated approach, the combined costs of hypertension, diabetes, and cholesterol medications and diagnostic tests make up the largest share of the overall program cost (82%). In this study, the annual medication expenditure per patient treated with medications for hypertension, diabetes, and cholesterol are USD 9.0, USD 15.4, and USD 15.3, respectively. The estimates in this study are incremental annual costs in an existing healthcare set-up and the cost elements are largely variable costs.

The analysis also informs us about the additional health care providers capacity required to scale up hypertension and CVD risk management in the catchment area populations. If programmatic task sharing is arranged among different types of providers, the hypertension-only management program would need the full-time equivalent of 19 doctors, 19 nurses, and 1 HEW, whereas the risk-based hypertension, diabetes and high cholesterol management program would need the full-time equivalent of 21 doctors, 21 nurses, and 1 HEW. Across health facilities, the required full-time equivalent of doctors and nurses each vary from 2 to 6.

The bottom-up cost analysis of different health facilities in this study provides estimates at different levels of aggregation and for multiple scenarios (by health facilities and program objectives). This offers flexibility in drawing information required for implementation and expansion at different scales of operation: health facilities, sub-national regions, or national. At a national level, for instance, this study indicates probable gaps in financial and human resources at the systems level. As of 2019, the per capita health expenditure in Ethiopia was USD 27, of which only 23% (USD 6) was borne by the government and almost 38% (USD 10) was out-of-pocket expenditure [1]. Hence, CVD risk prevention and management in the wider population would require innovative plans and concerted efforts of government and stakeholders for sustainable funding. The study also indicates potential for substantial cost saving by utilizing task sharing opportunities among providers. The study assumes equal task sharing which could be customized in order to not only reduce cost but also optimally utilize the limited human resource available in the health sector.

Nonetheless, the government budget impact of implementing HEARTS CVD prevention programs should be weighed against health and economic benefits of the CVD events and deaths that will be averted by preventive measures. For instance, in a retrospective prevalence-based study [16], for the year 2021, total economic burden of hypertension in the southern region of Ethiopia was estimated to be USD 514, 232. Almost 88% of the total burden was due to productivity loss caused by premature mortality and years lost due to morbidity.

There are some limitations of the study. There are not yet published

studies using a HEARTS-based cost analysis in comparable countries, though a future HEARTS costing evaluation is already planned for Nigeria, and others countries may follow. Some of the cost inputs might change within a short period (e.g., drug prices), and few cost items are estimated based on the EPSA. Regional variation in input prices may not be fully represented in cost evaluation of the five health facilities. Uniformity in medicine and test prices are assumed as these are publicly procured or provisioned. However, some variations are incorporated for salaries and wages of providers, and the catchment area population characteristics. This study does not address hypertensive crisis or complication costs of hypertension and diabetes patients. Future cost-effectiveness studies are needed to synthesize anticipated program costs derived here with projected avoided CVD costs and incorporate fatal and non-fatal health outcomes.

This is the first study to assess HEARTS programmatic costs in Africa. The high prevalence rate of CVD in Ethiopia imposes a heavy economic burden on the health system, patients, and households. Thus, investments in the prevention of CVD are needed. The assessment of CVD intervention cost through the HEARTS technical package is vital for policymakers, donors, and planners to plan for equitable access to quality health care and to manage resources for scale-up of CVD interventions in Ethiopia and low- and middle-income countries globally.

Disclaimer

The findings and conclusions in this report are those of authors only and do not necessarily represent the official position of the U.S. Centers for Disease Control and Prevention.

Author contribution

SAB, MJH, SB conceptualized the study, led the formal analysis, implemented the methodology and the excel-based costing tool, and wrote the draft manuscript. DK, and AEM contributed to the study concept, analytical aspects, manuscript write-up and critical review. SAB, GD, MGN, BB, and AW contributed to data collection and critical review of the manuscript. All authors provided critical feedback and helped shape the research, analysis, and manuscript.

Ethics approval

Ethics approval was not required because this research neither involved human or animal participation nor required consent from human participants.

Data statement

The study used publicly available secondary data sources. No proprietary data were used for the analysis.

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Declaration of competing interest

The authors declare no conflict of interest.

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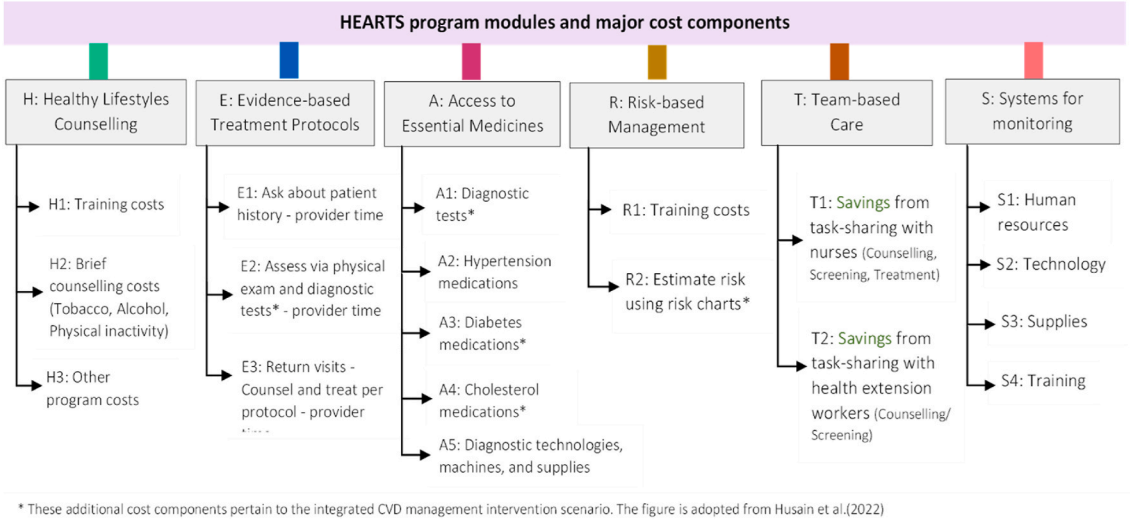
Appendix



Appendix Fig. 1. Major cost components of Ethiopia HEARTS program.

Appendix Table 1
Input costs, cost parameters, and cost assumptions

Input Description	Units	Amhara Baherdar Addis Alem Hospital	Diredawa Dechatu Health Center	Oromia Modjo Health Center	Oromia Wolenchity Hospital	Sidama Daye Hospital
Adult population (18 +)	Persons	65000	21182	20700	76000	65000
Primary healthcare attendance rate (annual)	Percent	45.0%	45.0%	45.0%	45.0%	45.0%
Adult population with risk factors[a]:						
- Use of tobacco products	Percent	5.3%	5.3%	4.0%	4.0%	4.0%
- Hazardous or harmful use of alcohol	Percent	8.9%	8.9%	8.9%	8.9%	8.9%
- Physical inactivity	Percent	14.0%	14.0%	14.0%	5.2%	5.2%
- Hypertension (≥140/90 mmHg)	Percent	23.7%	24.0%	24.0%	14.7%	14.7%
- Diabetes (≥7.0 mmol/L or 126 mg/dl)	Percent	11.7%	5.2%	5.2%	3.2%	3.2%
- Hyperlipidemia (≥6 mmol/L or 190 mg/dl)	Percent	5.0%	4.3%	4.3%	5.2%	5.2%
- Low CVD risk (0 to <10%)	Percent	67.0%	68.0%	68.0%	68.0%	59.0%
- Medium CVD risk (10 to <20%)	Percent	25.0%	24.0%	24.0%	22.6%	29.0%
- High CVD risk (≥20%)	Percent	8.0%	8.0%	8.0%	9.4%	12.0%
Annual wage (in BIRR, including benefits)						
- Doctors	BIRR/year	195,750	156,600	156,600	156,600	156,600
- Nurses	BIRR/year	104,221	96,204	96,204	96,204	96,204
- HEWs	BIRR/year	39,996	39,996	39,996	39,996	39,996
- Lab technicians	BIRR/year	132,384	132,384	132,384	132,384	132,384
- Accountant	BIRR/year	96,204	96,204	96,204	96,204	96,204
- Administrative Assistant	BIRR/year	64,296	64,296	64,296	64,296	64,296
- Clerical Officer	BIRR/year	39,996	39,996	39,996	39,996	39,996
- Custodian	BIRR/year	28,128	28,128	28,128	28,128	28,128
- IT Personnel	BIRR/year	74,316	74,316	74,316	74,316	74,316
- Program Director	BIRR/year	1,211,273	1,211,273	1,211,273	1,211,273	1,211,273
- Program Manager	BIRR/year	564,300	564,300	564,300	564,300	564,300
- Secretary	BIRR/year	39,996	39,996	39,996	39,996	39,996
- Security Officer	BIRR/year	39,996	39,996	39,996	39,996	39,996
- Pharmacist/Chemist	BIRR/year	121,800	121,800	121,800	121,800	121,800
- Statistician	BIRR/year	96,204	96,204	96,204	96,204	96,204
- Supplies manager	BIRR/year	74,316	74,316	74,316	74,316	74,316
Purchasing price (in LCU (BIRR)) of drugs						
Hypertension Medicine						
amlodipine 5 mg	BIRR/ tablet	0.70	0.70	0.70	0.70	0.70
amlodipine 10 mg	BIRR/ tablet	1.40	1.40	1.40	1.40	1.40
hydrochlorothiazide 25 mg	BIRR/ tablet	1.30	1.30	1.30	1.30	1.30
Diabetes Medicine						
metformin 500 mg	BIRR/ tablet	1.20	1.20	1.20	1.20	1.20
Glibenclamide 5 mg	BIRR/ tablet	0.40	0.40	0.40	0.40	0.40
Cholesterol Medicine						
simvastatin 20 mg	BIRR/ tablet	1.20	1.20	1.20	1.20	1.20
atorvastatin 20 mg	BIRR/ tablet	2.35	2.35	2.35	2.35	2.35
atorvastatin 40 mg	BIRR/ tablet	4.70	4.70	4.70	4.70	4.70
Purchasing price (in LCU) of diagnostic tests						
Random blood glucose test (RPG)	BIRR/test	80	80	80	80	80
Blood lipid panel	BIRR/test	320	320	320	320	320
Complete blood count (profile)	BIRR/test	80	80	80	80	80
CVD Risk Screening and Diagnosis						
Approximately how much time (in minutes) does a health provider spend to:						
o Screen patients for total CVD risk (ask about patients' health history)	Minutes/ patient	10	10	10	10	10
o Counsel patients with behavioral risk factors to change behavior (e.g. quit tobacco, cease using alcohol harmfully, increase physical activity)	Minutes/ patient	15	15	15	15	15
o Provide a physical exam (including relevant metabolic screenings) to assess patients' total CVD risk	Minutes/ patient	5	5	5	5	5
o Assess patient risk using a CVD risk chart, counsel patient, and document results	Minutes/ patient	5	5	5	5	5
What other resources are provided to individuals who receive brief interventions for behavioral risk factors?						
o # of 'How to quit' informational materials disseminated per person, annually (print)	#/patient	4	4	4	4	4
o Cost (in LCU) of 'How to quit' informational materials, per unit (print materials)	Birr/leaflet	20	20	20	20	20

(*continued on next page*)

Appendix Table 1 (*continued*)

Input Description	Units	Amhara Baherdar Addis Alem Hospital	Diredawa Dechatu Health Center	Oromia Modjo Health Center	Oromia Wolenchity Hospital	Sidama Daye Hospital
o # of 'How to quit' informational materials disseminated per person, annually (digital)	#/patient	0	0	0	0	0
o Cost (in LCU) of 'How to quit' informational materials, per unit (digital materials)	Birr/leaflet	0	0	0	0	0
Treatment for High CVD Risk						
How many follow-up visits should a person with the following levels of CVD risk undertake annually?	Visits/ patient					
o Low CVD risk (≥0% to <10%)		1	1	1	1	1
o Medium CVD risk (≥10% to <20%)		2	2	2	2	2
o High CVD risk (≥20%)		4	4	4	4	4
Approximately how much time (minutes) will the following health providers spend with a patient during a visit?	Minutes/ patient					
o Generalists/primary care doctors		8	8	8	8	8
o Nurses		8	8	8	8	8
o HEWs		0	0	0	0	0
LCU to USD exchange rate	BIRR/USD	43.73	43.73	43.73	43.73	43.73
"Safety stock" required to be on hand for medicines	Percent	0.03	0.03	0.03	0.03	0.03
Number of health providers in need of training						
Counsel patients to change behavior	Persons	13	5	5	13	13
Assess patients' total CVD risk	Persons	13	5	5	13	13
Training to counsel patients to change behavior (5A's)*						
Classroom size	Persons	10	5	5	10	10
Hours of training needed	Hours	18	18	18	18	18
Training to screen/diagnosis/treat patients Hypertension/CVD patients						
Classroom size	Persons	10	5	5	10	10
Hours of training needed	Persons	21	21	21	21	21
Number of Trainers						
Professional trainer(s)	Persons	2	2	2	2	2
Administrative staff	Persons	1	1	1	1	1
Input costs for training						
Hourly wage						
Professional trainer	BIRR/hour	125	125	125	125	125
Administrative staff	BIRR/hour	40	40	40	40	40
Per unit cost of materials						
Instructive handbooks	BIRR/book	10	10	10	10	10
Agenda	BIRR/day	10	10	10	10	10
Pen	BIRR/day	10	10	10	10	10
Paper	BIRR/day	40	40	40	40	40
Additional costs						
Facility rental for training (one day)	BIRR/day	1500	1500	1500	1500	1500
Refreshments	BIRR/day	180	180	180	180	180
Meals	BIRR/day	260	260	260	260	260
Per diem for staff	BIRR/day	650	650	650	650	650
Per diem and/or salary of trainees	BIRR/day	650	650	650	650	650
Transportation stipend for staff	BIRR/day	150	150	150	150	150
Transportation stipend for trainees	BIRR/day	150	150	150	150	150
Pharmacological treatment for hypertension[b]						
Protocol Step #1 (Amlodipine 5 mg*, 1 per day, 365 days)*						
% of all individuals with high blood pressure who receive this treatment regimen	Percent	55%	55%	55%	55%	55%
Protocol Step #2 (Amlodipine 10 mg*, 1 per day, 365 days)*						
% of all individuals with high blood pressure who receive this treatment regimen	Percent	40%	40%	40%	40%	40%
Protocol Step #3 (Amlodipine + Hydrochlorothiazide 25 mg*, 1 per day, 365 days)*						
% of all individuals with high blood pressure who receive this treatment regimen	Percent	5%	5%	5%	5%	5%
Pharmacological treatment for diabetes[b]						
Protocol Step #1 (metformin 500 mg*, 1 per day, 365 days)*						
% of all individuals with diabetes who receive this treatment regimen	Percent	50%	50%	50%	50%	50%
Protocol Step #2 (metformin 500 mg*, 2 per day, 365 days)*						
% of all individuals with diabetes who receive this treatment regimen	Percent	40%	40%	40%	40%	40%
Protocol Step #3 (metformin 1000 mg + *Glibenclamide* 5 mg*, 1 per day, 365 days)*						
% of all individuals with diabetes who receive this treatment regimen	Percent	10%	10%	10%	10%	10%
Pharmacological treatment for high cholesterol (default regimens)[b]						
Protocol Step #1 (low intensity, simvastatin 20 mg*, 1 per day, 365 days)*						
– % of all individuals with high cholesterol who receive this treatment	Percent	55%	55%	55%	55%	55%

(*continued on next page*)

Appendix Table 1 (*continued*)

Input Description	Units	Amhara Baherdar Addis Alem Hospital	Diredawa Dechatu Health Center	Oromia Modjo Health Center	Oromia Wolenchity Hospital	Sidama Daye Hospital
Protocol Step #2 (moderate intensity, atorvastatin 20mg1 per day, 365 days)						
– % of all individuals with high cholesterol who receive this treatment	Percent	40%	40%	40%	40%	40%
Protocol Step #3 (high intensity, atorvastatin 40mg1 per day, 365 days)						
– % Percent of all individuals with high cholesterol who receive this treatment	Percent	5%	5%	5%	5%	5%

Note: [a] Ethiopian Public Health Institute. (2016). Ethiopia STEPS report on risk factors for non-communicable diseases and prevalence of selected NCDs. [b] Patient distributions by protocol steps are obtained from key informant interviews and local physician consultations.

Appendix Table 2
Hypertension control: estimated health provider and non-health personnel time

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Total	
	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	**Minutes**	**Converted to FTE**
Health Personnel												
Doctor	609436	4.9	198056	1.6	192931	1.5	700159	5.6	632048	5.1	2332630	19
Nurse	609436	4.9	198056	1.6	192931	1.5	700159	5.6	632048	5.1	2332630	19
HEW	40925	0.3	12902	0.1	12028	0.1	30713	0.2	26268	0.2	122836	1
Non-health Personnel												
Program Director	24960	0.2	24960	0.2	24,960	0.2	24,960	0.2	24,960	0.20	**124800**	**1**
Program Manager	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	**624000**	**5**
Administrative Assistant	37440	0.3	37440	0.3	37,440	0.3	37,440	0.3	37,440	0.30	**187200**	**2**
Clerical Officer	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	**624000**	**5**
Statistician	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	**624000**	**5**

Note: FTE (full-time equivalent) is the estimated number of hypothetical staff needed to perform program activities full time under the model assumptions.

Appendix Table 3
Integrated CVD risk control: estimated health provider and non-health personnel time

	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Total	
	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	Converted to FTE	Minutes	**Converted to FTE**
Health Personnel												
Doctor	682561	5.5	221885	1.8	216219	1.7	785659	6.3	705173	5.7	2611497	21
Nurse	682561	5.5	221885	1.8	216219	1.7	785659	6.3	705173	5.7	2611497	21
HEW	40925	0.3	12902	0.1	12028	0.1	30713	0.2	26268	0.2	122836	1
Lab technician	438750	3.5	142979	1.1	139725	1.1	513000	4.1	292500	2.3	1526954	12
Non-health Personnel												
Program Director	24960	0.2	24960	0.2	24,960	0.2	24,960	0.2	24,960	0.20	124800	**1**
Program Manager	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	624000	**5**
Administrative Assistant	37440	0.3	37440	0.3	37,440	0.3	37,440	0.3	37,440	0.30	187200	**2**
Clerical Officer	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	624000	**5**
Statistician	124800	1.0	124800	1.0	124,800	1.0	124,800	1.0	124,800	1.00	624000	**5**

Appendix Table 4
Sensitivity analysis: Total Cost per adult (18+ age) who present in health facility

Sensitivity analysis scenarios	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Average	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	**Birr**	**USD**
Panel 1: Hypertension management program												
Baseline estimate[s]	219	5.0	310	7.1	312	7.1	159	3.6	168	3.8	**234**	**5.3**
Scenario 1: Medicine price (+10%; −10%)[b]	(229; 210)	(5.2; 4.8)	(321; 301)	(7.3; 6.9)	(323; 304)	(7.4; 6.9)	(165; 153)	(3.8; 3.5)	(174; 162)	(4.0; 3.7)	**(242; 226)**	**(5.5; 5.2)**

(*continued on next page*)

Appendix Table 4 (*continued*)

Sensitivity analysis scenarios	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Average	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	**Birr**	**USD**
Scenario 2: Hypertension prevalence rate (+10%; −10%)	(229; 210)	(5.2; 4.8)	(321; 301)	(7.3; 6.9)	(323; 304)	(7.4; 6.9)	(165; 153)	(3.8; 3.5)	(174; 162)	(4.0; 3.7)	**(242; 226)**	**(5.5; 5.2)**
Scenario 3: Provider time (+10%; −10%)[c]	(224; 214)	(5.1; 4.9)	(316; 307)	(7.2; 7.0)	(318; 309)	(7.3; 7.1)	(163; 154)	(3.7; 3.5)	(172; 164)	(3.9; 3.7)	**(239; 230)**	**(5.4; 5.2)**
Scenario 4: Number of visits for high-risk CVD (+1; −1)[d]	(221; 218)	(5.1; 5.0)	(312; 309)	(7.2; 7.1)	(315; 311)	(7.2; 7.1)	(160; 157)	(3.7; 3.6)	(170; 166)	(4.0; 3.8)	**(236; 232)**	**(5.4; 5.3)**
Panel 2: Integrated hypertension, diabetes, and cholesterol management program												
Baseline estimate	851	19.5	891	20.4	893	20.4	732	16.7	860	19.7	845	**19.3**
Scenario 1: Medicine price (+10%; −10%)	(872; 830)	(19.9; 19.0)	(908; 876)	(20.8; 20.0)	(911; 878)	(20.8; 20.1)	(744; 720)	(17.0; 16.5)	(872; 848)	(19.9; 19.4)	**(861; 830)**	**(19.7; 19)**
Scenario 2: Hypertension, diabetes, and Cholesterol prevalence rates (+10%; −10%)	(872; 830)	(20.0; 19.0)	(908; 876)	(20.8; 20.0)	(911; 878)	(20.8; 20.1)	(744; 720)	(17.0; 16.5)	(872; 848)	(19.9; 19.4)	**(861; 830)**	**(19.7; 19)**
Scenario 3: Provider time (+10%; −10%)	(857; 845)	(20.0; 19.3)	(897; 887)	(20.5; 20.3)	(899; 890)	(20.6; 20.3)	(737; 727)	(16.8; 16.6)	(865; 855)	(19.8; 19.6)	**(851; 841)**	**(19.5; 19.2)**
Scenario 4: Number of visits for high-risk CVD (+1; −1)	(852; 849)	(19.5; 19.4)	(893; 890)	(20.4; 20.4)	(896; 893)	(20.5; 20.4)	(733; 730)	(16.8; 16.7)	(862; 858)	(19.7; 19.6)	**(847; 844)**	**(19.4; 19.3)**

Note: [a] The baseline estimates are the assessed cost presented in the main content. [b] Prices of medicines used in the treatment protocol were increased/decreased by 10% from the baseline prices. [c] Activity based provider time (in minutes) for screening, counselling, physical exam, and follow-up visits were increased/decreased by 10% from the baseline values. [d] Number of visits for high-risk CVD group was increased/decreased by one from the baseline number of 4 visits.

Appendix Table 5
Sensitivity analysis – annual medication costs per person

Sensitivity analysis scenarios	Amhara Baherdar Addis Alem Hospital		Diredawa Dechatu Health Center		Oromia Modjo Health Center		Oromia Wolenchity Hospital		Sidama Daye Hospital		Average	
	Birr	USD	Birr	USD	Birr	USD	Birr	USD	Birr	USD	**Birr**	**Birr**
Cost per person treated with medications for hypertension												
Baseline	394	9.0	394	9.0	394	9.0	394	9.0	394	9.0	**394**	**9.0**
Hypertension medicine price (+10%; −10%)	(434; 355)	(9.9; 8.1)	(434; 355)	(9.9; 8.1)	(434; 355)	(9.9; 8.1)	(434; 355)	(9.9; 8.1)	(434; 355)	(9.9; 8.1)	**(434; 355)**	**(9.9; 8.1)**
Cost per person treated with medications for diabetes												
Baseline	672	15.4	672	15.4	672	15.4	672	15.4	672	15.4	**672**	**15.4**
Diabetes medicine price (+10%; −10%)	(739; 604)	(16.9; 13.8)	(739; 604)	(16.9; 13.8)	(739; 604)	(16.9; 13.8)	(739; 604)	(16.9; 13.8)	(739; 604)	(16.9; 13.8)	**(739; 604)**	**(16.9; 13.8)**
Cost per person treated with medications for cholesterol												
Baseline	670	15.3	670	15.3	670	15.3	670	15.3	670	15.3	**670**	**15.3**
Cholesterol medicine price (+10%; −10%)	(737; 603)	(16.9; 13.8)	(737; 603)	(16.9; 13.8)	(737; 603)	(16.9; 13.8)	(737; 603)	(16.9; 13.8)	(737; 603)	(16.9; 13.8)	**(737; 603)**	**(16.9; 13.8)**

Abbreviations

CVD Cardiovascular disease
NCD Non-communicable disease
EHCI Ethiopia Hypertension Control Initiative
HEW Health extension worker
PHC Primary healthcare centre
USD United States dollar
WHO World Health Organization
EPSA Ethiopian Parametrical Supply Agency
CDC Centers for Disease Control and Prevention

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