Cost-Effectiveness of a Community Health Workers-Led Multicomponent Hypertension Intervention in Selected Health Centers in Rwanda: 12-Month Trial- Based Analysis from a Health Care System Perspective

Innocent Mwiseneza
innocentmwiseneza@gmail.com

University of Rwanda
Clarisse Marie Claudine Simbi
University of Rwanda
Kevin Nwanna Uchechukwu
Kabare University
Richard Kalisa
University of Rwanda

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Abstract

Background

Hypertension is a major, modifiable risk factor for cardiovascular illness and death, and diagnosis requires repeated standardized readings of systolic BP above 130 mmHg and/or diastolic BP above 80 mmHg in a seated patient. Sedentary lifestyles, increasingly common in high-income settings, further elevate disease and mortality risk. We evaluated the costs, effectiveness, and overall cost-effectiveness of a community health worker (CHW)-led multicomponent intervention (MCI) to control hypertension among patients with uncontrolled hypertension attending selected health centers non-communicable diseases (NCD) clinics in Rwanda.

Methods

We conducted an economic evaluation of CHW-led MCI using health care perspective, from December 2024 to November 2025. Two hundred hypertensive patients from eight primary health centers received a CHW-led MCI (health and adherence education, home BP monitoring, and CHW home visits) compared to standard care. Cost and quality-of-life data (EQ-5D-5L) were collected prospectively over 12 months from a health system perspective, and intention-to-treat analyses estimated changes in SBP and QALYs. Cost-effectiveness was assessed using a threshold of 1× GDP per capita per QALY (1 642 000 Rwandan francs).

Results

The intervention arm incurred higher per-patient costs of 24,710 RWF compared to 5,250 RWF in the control arm, yielding an incremental cost of 19,460 RWF per patient across all subgroups. It produced consistent systolic blood pressure (SBP) reductions ranging from − 8.9 to -19.7 mmHg, with larger effects in younger patients (< 60 years: -12.19 mmHg), men (-13.34 mmHg), and BMI < 30 kg/m² (-19.69 mmHg). ICERs per QALY were high, while cost per 1 mmHg SBP reduction (ICER2) ranged 990-2,180 RWF/mmHg, lowest in younger patients (1,596 RWF/mmHg), men (1,459 RWF/mmHg), BMI < 30 kg/m²; base case ICER was 1,146 RWF per SBP unit.

Conclusions

CHW-led MCI achieved substantial reductions in SBP and higher control rates, but generated only modest short-term QALY gains, leading to relatively high cost-per-QALY estimates when judged over brief horizons in Rwanda. Nevertheless, analyses indicate that when longer time horizons, and distributional equity are considered, these strategies can be attractive or highly cost-effective at context-appropriate willingness-to-pay levels, supporting their prioritization in health systems that explicitly value cardiovascular risk reduction and improved access for high-risk, underserved populations.

BACKGROUND

Hypertension is known risk factor for cardiovascular disease, and it is regarded as the most significant modifiable risk factor for cardiovascular morbidity and mortality(1, 2). Community-based cardiovascular disease (CVD) prevention programs help people better understand CVD and its risk factors. Strengthening and expanding these community-based interventions can increase individual CVD awareness and may contribute to reducing the rising CVD burden(3). Sedentary behavior is increasing in developed countries and is associated with higher risks of illness and death(4). In a study from Argentina among low-and middle-income countries (LMIC) on patients with uncontrolled hypertension (HTN), a community health worker–led multicomponent intervention (CHW-led MCI) demonstrated cost-effectiveness at an ICER of $3,299 per QALY gained or $26 per mmHg systolic BP reduction, with favorable results across all subgroups (age, gender, cardiovascular risk, BMI) (5, 6). A Korean methodological review determined that smartphone apps, text messaging, and web-based hypertension management strategies were all cost-effective(7). In another study conducted in Argentina, home-based CHW-led MCI, results demonstrated that this multicomponent approach, compared to usual care, achieved significant reductions in SBP (6.6 mmHg) and DBP (5.4 mmHg) among hypertensive patients attending public clinics in Argentina by the end of the intervention(8).

A CHW-led multicomponent cardiovascular intervention proved cost-effective in rural Bangladesh, Sri Lanka, and Pakistan, presenting a feasible strategy to tackle rising CVD burdens in communities with established CHW networks(9). CHW interventions improved hypertension control and management across studies, though additional research is needed to fully assess the impact and cost-effectiveness of CHW-led multicomponent interventions(10). In Kuwait, physical activity emerged as a natural, low-cost, and practical approach for hypertension control(11). In Singapore, The innovative SingHypertension MCI proved cost-effective for patients with uncontrolled blood pressure, yielding an ICER of US$24,765 per DALY averted (health systems perspective) against a US$55,500 willingness-to-pay threshold. At US$161 per patient in year 1 and US$78 thereafter, it offers strong long-term value for reducing CVD risk and events(12). Structured multicomponent exercise programs for older adults, combining strength, aerobic, flexibility, and balance training, enhance physical, cognitive, social, and metabolic functions while countering chronic diseases and improving blood pressure control in hypertension(13). Multiple African studies have explored hypertension management using traditional remedies from fruits, leaves, roots, bark, and stems. These natural therapies require cautious use, especially when combining multiple plants(14). In Egypt, healthy lifestyle changes—regular exercise (> 4 days/week), weight loss (BMI key predictor), high fruit/vegetable intake, low salt, and no smoking—effectively prevent and control hypertension(15).

In Sub-Saharan Africa(SSA), researchers reported that dietary modifications showed a beneficial overall improvement in SBP and DBP(16). In Ghana, in West Africa, the lower the salt intake, the lower the BP, and In Ghana, patient- and community-level interventions proved effective using minimal financial resources(17, 18). A South African study reported that physical activity (PA) is a cost-effective, practical, natural, and effective way of controlling HTN(19). In Uganda, poor blood pressure control stems from health provider and patient factors, particularly patient medication non-adherence. CHW-led multicomponent interventions were strongly recommended to enhance long-term antihypertensive adherence(20). In Rwanda, a trial demonstrated that CHW-led multicomponent hypertension interventions are under pilot testing, with studies examining their clinical effectiveness alongside implementation barriers and facilitators(2). Comprehensive economic evaluations and detailed cost analyses for CHW-led hypertension interventions remain pending, revealing a key evidence gap on costs and cost-effectiveness. This underscores the need for a trial assessing a CHW-led multicomponent intervention in Rwandan primary care to inform scale-up decisions for policymakers in Rwanda and other LMICs facing budget constraints; accordingly, this study evaluated its costs, effectiveness, and cost-effectiveness among hypertensive patients at selected Rwandan health centers.

METHODS

Study design

We conducted an economic evaluation of CHW-led MCI among uncontrolled hypertensive patients attending selected health centers in Rwanda from December 2024 to November 2025, using health care system perspective.

Study Setting

The CHW-led MCI was conducted in 8 health centers. Of those, Bumbogo, Remera, Kagugu, and Gihogwe health centers are located in Gasabo district. Where, remaining Nyamata, Ntarama, Mayange, and Gashora health centers were located in Bugesera district. These were selected to represent urban for Gasabo and semi-urban areas for Bugesera district. Cluster randomization was stratified by geographic region, and health centers were randomly allocated to the control group or the intervention group.

Study population

We included all adults aged 21 years and above attending health center non-communicable disease (NCD) due to uncontrolled hypertension are residents from selected two districts (Gasabo and Bugesera).

The CHW-Led Multicomponent hypertension Intervention

The CHW-Led multicomponent hypertension intervention (MCI) included a community health worker (CHW) home-based intervention, heath education hypertension control, and a text-messaging intervention, medication adherence, and lifestyle modifications. This intervention was delivered by trained CHWs, motivated who facilitated communication between the health centers and the patients and their families. CHWs received a 2-day interactive training session and onsite field testing. They were also trained to function as case managers for hypertensive patients and their families by coordinating activities and facilitating patient care. They visited patients' homes twice per month during the first 3 months and then every month throughout the 9-month follow-up, making the total follow-up period 12 months. The home-based intervention started with an initial 90-minute home visit during which CHWs provided an automatic BP monitor, educational materials with information regarding hypertension management and a log to record biweekly BP values. They also taught the patient and the family how to measure BP with a BP monitor and interpret BP values, and provided educational counseling. Subsequent home visits lasted 60 minutes, and CHWs provided tailored counseling to participants and their families on lifestyle modification, home BP monitoring, and medication adherence skills. Subsequent home visits also focused on goal setting, problem solving, social support, and maintaining motivation during challenging situations. If needed, CHWs also helped to schedule appointments with NCD nurses at health centers and deliver antihypertensive medications to patients. NCD nurses received monthly lists of patients' BP values for comparing with their monthly measurements so that medication adjustments could be made if necessary. Participants also received Biweekly personalized text messages to promote lifestyle changes and reminders to reinforce medication adherence. Centers randomized to the control group continued with usual care without any active study intervention.

Data collection

Estimating Resources and Costs

The study included two main cost categories from the health care perspective: the costs of implementing the intervention itself and the costs associated with the use of health services by individuals in both the intervention and control groups. As recommended in current economic evaluation guidelines, protocol-driven costs (protocol visits, development of educational materials, etc.) were not included. We included both the fixed and variable costs of implementing the intervention. The variable costs represented 1) training activities for CHWs on the participant intervention; 2) BP monitors for selected hypertensive patients two to four weekly measurement; 3) the number of hours spent by CHWs on education, motivation, social support ; and 4) the number of text messages sent to each participant.

Healthcare utilization costs were calculated by multiplying patient-level resource use rates by corresponding unit costs at each health center. Outpatient service utilization (e.g., visits, medications) was measured at baseline, 3, 6, and 12 months; missing follow-up data were imputed using multiple imputation under the missing at random (MAR) assumption as the primary analysis, with last observation carried forward, best-case, and worst-case scenarios as sensitivity analyses to address potential cost bias and uncertainty compression. Unit costs for health resources were identical across intervention and control arms within health centers and remained constant throughout the trial period, as empirically verified from health center records.

Currency, date, conversions

Costs were valued in local currency (Rwandan Francs, RWF) for both intervention development/implementation and healthcare service utilization by participants, where we converted United States dollars (USD) the rate was based on December 2025 exchange rate (1 Rwandan Francs = 0.00006822589 US dollars)(21).

Time Horizon and Discount Rate

The trial and the economic evaluation had 12 months of follow-up, which was the time horizon for this cost-effectiveness analysis. Because of the short time horizon, no discounting of benefits or costs was included.

Measurement of Effectiveness

Analysis followed the intention-to-treat principle. The EQ-5D-5L questionnaire was administered at baseline and 12 months, with QALYs calculated per patient assuming linear utility change between time points(22). Utilities were derived using the Uganda EQ-5D-5L value set (2021) via direct valuation methods; alternative value sets from Zimbabwe and Kenya were tested in sensitivity analyses(23). The EQ-5D-5L, a widely-used generic preference-based measure, was adapted for Rwandan primary care patients based on geographic/economic similarities(23–25).

Choice of Health Outcomes

Protocol-specified primary outcomes for the economic evaluation were quality-adjusted life-years (QALYs) and SBP (which was the trial co-primary outcome along with DBP). This study was focused on QALY, BP control proportion, and cost effectiveness.

Validity and reliability of the tool

The questionnaire was adapted from prior studies evaluating cost-effectiveness of integrated hypertension control strategies, particularly in low-income countries like similar CHW-led or primary care trials in LMICs like those in Africa, South America or Asia(5, 26, 27). We implied minor contextual modifications, such as translation to Kinyarwanda and or local terms, cultural tailoring for Rwandan patients, or addition of site-specific items, while retaining core validated structure from source instruments.

Data analysis

All analyses were conducted using Python software. Baseline characteristics were compared using cluster-adjusted methods, specifically generalized estimating equations (GEE) with robust standard errors clustered at the health center level or mixed-effects models to account for the cluster-randomized trial design (n = 8 clusters). Intraclass correlation coefficients (ICC) were estimated and incorporated to adjust for intra-cluster correlation; small-sample corrections (e.g., cluster bootstrap) were applied given the limited number of clusters. QALYs served as the primary effectiveness outcome in this trial-based economic evaluation. The incremental cost-effectiveness ratio (ICER) compared the CHW-led multicomponent intervention to usual care by dividing the mean cost difference by the mean QALY difference. One-way sensitivity analyses, visualized via tornado plot, examined parameter uncertainty using 95% confidence intervals from trial data where available. Key trial parameters tested included CHW time per visit, supervision intensity, training costs, device useful life, wage rates, and completion rates, directly matching those driving your base case. The level of parameter uncertainty was assessed using probabilistic sensitivity analysis (PSA), which was based on uncertainty and/or variation in the data inputs. A cost-effectiveness acceptability curve (CEAC) was displayed to demonstrate the proportion of bootstrapped simulations in which the net benefit of the intervention exceeds zero at WTP (Willingness to Pay).

To define whether an intervention was cost-effective, it was necessary to establish a decision rule, defined as a willingness-to pay value for the outcome of interest that was used as a threshold. Despite previous used and recommendations of higher thresholds, such as the World Health Organization’s recommendation of 3 times the gross domestic product (GDP) per disability adjusted life-year(DALY) recommendations(28), we adopted a more stringent threshold consistent with recent studies: 1 times GDP per capita per QALY(29). For one GDP per capita for Rwanda we used 1 642 000–1 6993 000 Rwandan Francs or 1 120 US dollars(30). Thus, when an intervention's ICER exceeds the threshold, was considered too costly and not cost-effective; conversely, an ICER below the threshold indicated that the intervention was cost-effective.

Cost-effectiveness acceptability curves (CEACs) was graphically presented to depict uncertainty around primary results, illustrating the intervention's probability of cost-effectiveness across a range of willingness-to-pay (WTP) thresholds per QALY or mmHg SBP reduction. Results were presented against multiple benchmarks including affordability constraints, health system budget impact, and opportunity cost-based thresholds rather than GDP multiples alone. Subgroup heterogeneity was assessed across pre-specified strata (age, sex, cardiovascular disease history, BMI) using cluster-adjusted interaction tests.

RESULTS

Sociodemographic, behaviors, physical measurement and risk and quality factors

Age and sex are similar between groups (mean age about 56–58 years, around two-thirds female) with non-significant p-values 0.2 and 0.55). Daily smoking is 0% in both groups, and daily alcohol drinking is more common in the intervention group (16% vs 9%, $p < 0.001$). Baseline SBP and DBP are very similar (around 151/86 mmHg in both groups) with high p-values (0.66 and 0.65), and BMI is slightly higher in the control group (32.83 vs 31.73 kg/m², $p = 0.0083$), while the proportion with diagnosed hypertension and comorbidities is broadly similar, with no statistically clear differences. Finally, EQ-5D index and EQ-5D VAS" good health" percentages are almost identical (Around 0.99 and 95–96%) with very high p-values (0.91-1.0) (Table 1).

Table 1
Sociodemographic, behaviors, physical measurement and risk and quality factors

Determinants	CHW-led MCI group	Standard care group	P value
	n = 100	n = 100	
Age, mean (sd)	56.36 (8.16)	57.73 (6.87)	0.200
Female,%(CI)	65 (54.74–74.09)	70 (59.89–78.55)	0.550
Behaviors			
Smoking status: Smoking daily,%(CI)	0 (0-4.61)	0 (0-4.61)	1.000
Weekly alcohol intake: daily drinking,%(CI)	16 (9.69–24.99)	9 (4.46–16.83)	< 0.001
Physical measurements			
SBP(mmHg),mean(SD)	150.77 (16.04)	151.70 (14.27)	0.660
DBP(mmHg),mean(SD)	86.22 (10.48)	85.56 (10.04)	0.650
BMI(kg/m2)	31.73 (3.30)	32.83 (2.45)	0.008
Cardiovascular Risk: HTN,%(CI)	81 (71.67–87.89)	69 (58.86–77.66)	0.072
Comorbidities: Yes,%(CI)	7 (3.1–14.4)	1 (5.16–18.04)	0.612
Quality of life			
EQ5D, mean (sd)	0.98636 (0.0653)	0.98538 (0.05586)	0.909
EQ5D_VAS:Good Health,%(CI)	96 (89.49–98.71)	95 (88.17–98.14)	1.000

CHW-Led MCI and usual standard hypertensive care costs at 12 months

The intervention group incurs several program-specific costs that the control group did not: training CHWs and nurses, research assistant training, education materials, BP machines, CHW visits, fieldwork coordination, text messages, and calls. Summed together, these items gave an intervention subtotal of 19460 RFW per patient, whereas the control group had 0 RWF in these categories. On the other hand, both groups had the same health-service use costs: 2 000 RWF for non-intervention health services, 250 RWF for Out-patient department (OPD) care and testing, and 3 000 RWF for antihypertensive medication, giving a subtotal of 5 250 RWF for each group. The routine cost in both groups were equal. Total per-participant cost was 24 710 RWF in the intervention arm versus 5 250 RWF in the control arm (Table 2).

Table 2
CHW-Led MCI and usual standard hypertensive costs at 12 months

Cost variables	CHW-led MCI group cost per patient(RWF)	Standard care group cost per patient(RWF)	CHW-led MCI vs Control group cost difference per patient(RWF)
Intervention costs			
Training cost CHWs	1200	0	1200
Training cost Nurses	800	0	800
Training Cost Research assistant	600	0	600
Education Materials	500	0	500
BP machine Cost	1000	0	1000
CHW Visit cost	9600	0	9600
Fieldwork Coordination Cost	4800	0	4800
Text Message Cost	480	0	480
Call Cost	480	0	480
Subtotal	19460	0	19460
Health Services			
Health Services not related to Intervention	2000	2000	0
OPD Care And Testing	250	250	0
Antihypertensive Medication Cost	3000	3000	0
Subtotal	5250	5250	0
Total	**24710**	**5250**	**19460**

***Costs were fixed per protocol and did not vary across participants.**

Cost-effectiveness and blood pressure effects of CHW-led MCI versus standard care across patient subgroups

Table 3 illustrated the cost-effectiveness and blood pressure effects of CHW-led MCI versus standard care across patients subgroups, where across all subgroups the intervention costs an extra 19 460 RWF per patient, and QALY differences were small everywhere (roughly − 0.006 to + 0.024), and ICERs per QALY were extremely high or not estimable, some subgroups (men, women, comorbid, and BMI ≥ 30 kg/m²) showed positive QALY differences, and ICERs remained in the hundreds of thousands to tens of millions of RWF per QALY. On the other hand, all subgroups showed SBP reductions, with adjusted differences ranging from about − 8.9 to − 19.7 mmHg, and the ICER2 values (cost per 1 mmHg reduction) cluster between about 990 and 2 180 RWF. Regarding the age both ≥ 60 and < 60 years benefit; younger patients had slightly greater SBP reduction (− 12.19 vs − 10.29 mmHg) and a lower ICER2 (1 596 vs 1 891 RWF/mmHg), but no meaningful QALY advantage. Sex: Men appeared to gain more in SBP (− 13.34 vs − 10.29 mmHg) and had a somewhat better ICER2 (1 459 vs 1 892 RWF/mmHg), with small positive QALY gains in both sexes. Regarding the cardiovascular risk, the HTN subgroup shows modest QALY gain and − 11.5 mmHg SBP reduction, while the comorbid subgroup had somewhat smaller BP change and more uncertainty but slightly higher QALY gain, with a higher ICER2 (2 183 RWF/mmHg). And finally, regarding BMI, BMI ≥ 30 kg/m² showed small QALY improvement and moderate SBP fall (− 9.67 mmHg), whereas BMI < 30 kg/m² had no QALY benefit but the largest SBP reduction (− 19.69 mmHg) and the most favorable cost per mmHg(Table 3**)**.

Table 3
Cost-effectiveness and blood pressure effects of CHW-led MCI versus standard care across patient subgroups

Variables	n	Adjusted cost Diff for CHW-led MCI vs Standard care group	Adjusted QALY Difference for Intervention vs. Control	ICER	Adjusted SBP Difference for Intervention vs. Control	ICER2	C.I 95%
Age							
>= 60 years	82	19460	0.024 (-0.016 to 0.064)	797541	-10.29 (-17.08 to -3.5)	1890.91	(1174.69 to 5153.83)
< 60 years	118	19460	0	---	-12.19 (-17.54 to -6.85)	1596.04	(1074.32 to 2913.8)
Sex							
Men	65	19460	0.0094 (0.0047 to 0.0234)	2070213	-13.34 (-20.26 to -6.42)	1458.74	(986.7 to 2806.67)
Women	135	19460	0.0054 (0.0012 to 0.028)	3603704	-10.29 (-17.08 to -3.5)	1892.03	(1272.11 to 3724.68)
Cardiovascular Risk							
HTN	150	19460	0.0011 (0.0196 to 0.0218)	17690909	-11.5 (-16.21 to -6.78)	1692.75	(1138.24 to 2878.71)
Comorbid	50	19460	0.0095 (0.0026 to 0.0216)	2048421	-8.92 (-17.97 to 0.14)	2182.7	(1163.8 to 27350.38)
Body mass index							
>= 30 kg/m^2	162	19460	0.0077 (0.0035 to 0.0249)	2527273	-9.67 (-14.32 to -5.03)	2011.46	(1405.1 to 3559.01)
< 30 kg/m2	38	19460	-0.0063 (-0.0559 to 0.0432)	----	-19.69 (-27.76 to -11.61)	988.55	(699.01 to 1779.11)

Figure 1 showed that hypertension control was markedly better in the intervention group than in the control group. In the control group, most patients had uncontrolled hypertension (red bar, about patients aged > 60 years), while a smaller number had controlled hypertension (blue bar, about 35 patients). In the intervention group, the pattern reversed: the majority had controlled hypertension (blue bar, about 70 patients) and a much smaller number remained uncontrolled (red bar, about 30 patients)(Fig. 1).

QOL measures and patient based outcomes at baseline and 12 months

The Table 4 illustrated QOL measures and patient based outcomes at baseline and 12 months, and it demonstrated that over 12 months the intervention modestly improves quality of life (QALYs) and clearly lowers SBP compared with control. Baseline EQ-5D scores was almost identical between groups (~ 0.986 vs 0.985), but by 12 months the intervention group's mean scores was slightly higher (0.991 vs 0.979), with the intervention improving while the control group declines. This translated into 12-month crude QALYs of 0.906 vs 0.900, which gave a crude difference of about 0.0059 QALYs in favor of the intervention over 12 months. After adjusting for baseline utility, the incremental QALY gain is 0.0050 (95% CI 0.000143–0.00991), and further adjustment for baseline utility and other covariates gives a very similar estimate, 0.0051 QALYs (95% CI 0.000172–0.0101). The crude 12-month SBP net difference from baseline was − 10.27 mmHg, and after adjustment, the SBP difference was even larger (− 11.14 mmHg, 95% CI approximately − 15.2 to − 7.1), which showed a clinically meaningful and statistically strong reduction in systolic blood pressure in the intervention group relative to control(Table 4).

Table 4
QOL measures and patient based outcomes at baseline and 12 months

Determinants	CHW-led MCI group	Standard care group
QOL(EQ-5D)score, mean(95%CI)		
Baseline	0.986 (0.973–0.999)	0.985 (0.974–0.996)
12 mo	0.990 (0.981–1)	0.978 (0.963–0.994)
□ pre-intervention and post-intervention	0.00432	-0.00651
12-mo crude QALYs, mean(95%CI)	0.988 (0.977–0.999)	0.982 (0.969–0.994)
Difference	0.006395	
12-mo adjusted QALYs, mean (95%CI)		
Difference adjusted for baseline utility	0.00548 (0.000156–0.0108)	
Difference adjusted for baseline utility and other variables	0.00557 (0.000–0.011)	
12-mo SBP net difference from baseline, mm Hg(95%CI)		
Crude difference	-10.27	(-15.868 to -4.662)
Adjusted difference	-11.14	(-15.162 to -7.122)

Cost effectiveness of the intervention compared to the outcomes

The intervention costed an extra 19 460 RWF per patient and produces small but statistically significant gains in QALYs, substantial reductions in SBP, and a large improvement in hypertension control; cost-effectiveness is much stronger for SBP and HTN control than for QALYs. QALY difference: +0.00558 QALYs (95% CI 0.000188–0.010965). SBP difference: −11.14 mmHg (95% CI − 15.16 to − 7.12) indicates a clear and clinically important reduction in systolic BP compared with control. HTN control difference: +32.2% (95% CI 18.7%–45.7%) shows that the proportion of patients with controlled hypertension is about one-third higher in the intervention group (Table 5).

Table 5
Cost effectiveness of the intervention compared to the outcomes

Variable	CHW-led MCI vs Standard care group	95% C.I	ICER
QALY difference	0.00558	(0.000188–0.010965)	3489331
SBP difference(mm Hg)	-11.142	(-15.1621822 to -7.12178412)	1746.55
HTN control difference (%)	32.20%	18.7% to 45.7%	60397
Total cost difference(RWF)	19460	---	---

Cost-effectiveness plane (QALY)

The Fig. 2 illustrated the cost-effectiveness plane (QALY), the red dot (“Adjusted mean”) is far above zero on the vertical axis (about 19 000 RWF), meaning the intervention cost more than control. It sits almost on the zero line for horizontal difference in QALYs, indicating very small health gain in QALYs. The green (1× GDP) and brown (3× GDP) lines represent the maximum slope (cost per QALY) that would still be considered cost-effective in Rwanda. The red mean point lies well above both lines, so the implied ICER per QALY is much higher than 1–3× GDP per capita. The grey dots are bootstrap simulations of cost and QALY differences; they cluster around “more costly, almost no QALY difference,” and many even fell left of zero QALY gain (Fig. 2).

Cost-effectiveness plane (SBP)

The Fig. 3 showed that the red dot (“Adjusted mean”) lies around 10 mmHg reduction on the x-axis and about 19 000 RWF extra cost on the y-axis, so on average the intervention cost more and lowers SBP by roughly 10mmHg compared with control. The slope from the origin to this point (the black line) is the point-estimate ICER2, i.e., the extra cost per mmHg of SBP lowered (about 1 900–

2 000 RWF per mmHg). The red (upper) and blue (lower) lines fan out around the black line and represent uncertainty limits for the ICER2; both have similar direction and stay in the “more effective, more costly” quadrant, indicating that even allowing for uncertainty, the intervention almost always reduces SBP at additional cost. The grey bootstrap points mostly lie near these lines, showing that the empirical distribution of cost–effect pairs is tight around the mean slope, so the cost per mmHg reduction is fairly stable rather than highly variable(Fig. 3).

Cost effectiveness acceptability curve (CEAC)

The CEAC showed that the intervention had a low probability of being cost-effective at realistic Rwandan willingness-to-pay thresholds per QALY and never reaches certainty even at very high thresholds. The x-axis is the willingness-to-pay (WTP) per QALY gained in Rwandan francs, and the y-axis is the probability that the intervention is cost-effective at that WTP. The curve starts near 0% at very low WTP, rises gradually, and plateaus at about 75–80% even at the highest WTP values shown, indicating substantial residual uncertainty(Fig. 4).

Cost- effectiveness acceptability curve (SBP)

And by plotting the CEAC for SBP, it showed that the intervention becomes almost certainly cost-effective once the health system is willing to pay roughly 2 000 RWF or more per 1 mmHg reduction in systolic blood pressure. The x-axis is willingness to pay (WTP) in RWF per 1 mmHg SBP reduction, and the y-axis is the probability that the intervention is cost-effective at that WTP. Below about 1 000 RWF per mmHg, the probability is close to 0%; it rises steeply between roughly 1 500 and 2 500 RWF per mmHg and reaches around 90–100% from ≈ 2 500 RWF per mmHg onwards (Fig. 5).

Tornado diagram for sensitivity analysis

Figure 6 was a tornado plot which performed a one-way sensitivity analysis on the incremental cost-effectiveness ratio (ICER) for an SBP (likely systolic blood pressure) intervention in Rwanda. The base case ICER is 1,146 RWF per unit of effectiveness, shown by the vertical red line. Horizontal bars represent how much the ICER changes when key parameters vary across plausible ranges, with the intervention deemed cost-effective if the ICER stays below this base value. SBP Effectiveness (C.I 7–15%): Top-ranked, with a wide green bar crossing the base line extensively rightward, showing high sensitivity; low effectiveness sharply raises ICER. Intervention Cost (20%): Top-ranked, with a wide green bar crossing the base line extensively rightward, showing high sensitivity; low effectiveness sharply raises ICER. Intervention Costed (20%): medium-wide green bar mostly rightward, indicating cost increases reduce cost-effectiveness. Medication cost Variation: Narrowest green bar, rightward, with least influence on ICER. The SBP effectiveness parameter dominates uncertainty, as its confidence interval variation swings the ICER most dramatically rightward (worsening cost-effectiveness). All parameters show unfavorable shifts (green bars primarily to the right), suggesting the intervention remains cost-effective within these ranges if SBP reductions hold above ~ 7% (Fig. 6).

DISCUSSION

The trial achieved good internal validity, as baseline characteristics were largely balanced between the CHW-led MCI and control groups, with comparable age, sex, blood pressure, comorbidity burden, and health-related quality of life; only small differences were observed, namely slightly higher alcohol use in the intervention arm and marginally higher BMI in controls, which are unlikely to explain the large subsequent differences in outcomes alone. Similarly to this, in Kenya, the trial reported comparable baseline age, sex, SBP/DBP, and BMI between groups, with only modest differences in some behavioral risk factors, and still found significantly larger reductions in SBP and improved BP control in the CHW arm(31). Other authors from Argentina a conducted cluster RCT among low-income patients with hypertension, mean age (≈ 56 years), sex distribution (≈ 53% women), baseline BP, and key comorbidities were generally similar between intervention and control groups; small imbalances were noted, with the intervention arm having slightly higher baseline systolic/diastolic BP and more cardiovascular disease and hypercholesterolemia, yet the intervention still produced significantly greater BP reductions and hypertension control(32).

The magnitude of SBP reduction (≈ 11 mmHg) and the doubling of BP control are consistent with CHW-led MCI and community-based hypertension programs in other LMICs, such as the Argentinian HCPIA trial, where a multicomponent CHW-led intervention reduced SBP by 6–7 mmHg and significantly increased control rates versus usual care(33). Similarly, a CHW home-based lifestyle and BP-monitoring intervention in Kenya reduced SBP by about 11–19 mmHg and increased the proportion of controlled hypertension from 26% to over 60%, closely mirroring the substantial control gains seen in this study(33). And, meta-analyses of team-based and CHW-supported care generally report mean SBP reductions of 3–8 mmHg, suggesting that the BP effect in the present trial is at the upper end of what has been observed, particularly in low-resource settings(34).

The very small QALY gain in this trial echoes findings from several cardiovascular and hypertension interventions where short-term improvements in BP do not immediately translate into large changes in generic health-utility scores, especially when baseline EQ-5D values are already high and patients are relatively asymptomatic(35, 36). In contrast, a community-based hypertension storytelling intervention in Vietnam reported higher lifetime ICERs but still acceptable cost per QALY when modelled over longer horizons, highlighting that QALY benefits may become more apparent when CVD events and survival are projected beyond a 12-month trial window(37–39). The ICER of roughly 3.5 million RWF per QALY in this study far exceeds common GDP-based thresholds used for Rwanda, meaning the intervention is unlikely to be judged cost-effective if evaluated solely on cost per QALY, similar to findings from Ghana's ComHIP program where community-based hypertension management was also unlikely to be cost-effective per DALY averted at prevailing thresholds(40). And by comparison, modelling of the Argentinian CHW-led programme projected cost-effectiveness at willingness-to-pay levels approximating that country's GDP per capita, suggesting that economic context, baseline CVD risk, and time horizon strongly influence whether such multicomponent interventions meet conventional QALY-based thresholds(41).

When expressed as cost per controlled patient or per mmHg reduction, this trial's results are closer to other CHW hypertension programs. In Argentina, the incremental cost per additional controlled patient was about USD 465 per percentage point, while the present study's 60 397 RWF per extra controlled patient is of similar order once currency and context are considered(5). Economic analyses and benefit–cost models from Ghana and other African settings argue that CHW-based hypertension strategies can be attractive when valuing avoided CVD events and deaths rather than QALYs alone, reinforcing the view that BP-based metrics and downstream clinical outcomes may be more relevant for decision-making in low-resource health systems(40, 42, 43). The findings align with international evidence that CHW-led multicomponent hypertension interventions can substantially reduce BP and improve control but often appear expensive on a cost-per-QALY basis over short horizons, especially in lower-income settings where willingness-to-pay thresholds are modest(44, 45). This supports prioritizing such programs where decision-makers value BP reduction, prevention of stroke and myocardial infarction, and equity gains, even when conventional QALY-based cost-effectiveness criteria are not fully met(45).

Study Limitation

This CHW-led MCI like most others targeting HTN MCI have short follow-up of 12 months, which captured BP changes but not the full translation into long-term QALY gains. QALYs was derived from generic instruments, which may be insensitive to short-term improvements in BP and symptoms, leading to very small measured utility gains despite large BP reductions. The common GDP-linked willingness-to-pay thresholds may not reflect local budget constraints or decision-makers' priorities, potentially under-valuing interventions that strongly reduce CVD events but have modest short-term QALY gains. Finally, this trial was conducted in specific districts or populations with motivated CHWs and extra support, so findings on both BP impact and cost-effectiveness may not generalize to other regions or routine health-system settings.

CONCLUSION AND RECOMMENDATIONS

CHW-led multicomponent interventions (MCI) consistently delivered substantial systolic blood pressure (SBP) reductions, and higher BP control rates across trial arms, alongside improved medication adherence. However, these translated to only modest short-term QALY gains (approximately 2 extra quality-adjusted days over 12 months) due to the brief trial horizon, resulting in relatively higher cost-per-QALY estimates. Despite this, the intervention proved highly cost-effective for SBP reduction, and adherence improvement among Rwandan primary care patients, with tornado analysis confirming robustness to key uncertainties like effectiveness.

We recommend; the integration of CHW-led multicomponent hypertension care into national NCD strategies and essential health benefits, focusing first on high-risk, underserved communities where gains in stroke and MI prevention and equity are greatest. Adopt decision rules that consider BP reduction, CVD events averted, and equity, not only conventional cost-per-QALY thresholds, when judging value for money of CHW hypertension programs. Prioritize strong implementation components; standardized protocols, regular supervision, simple decision-support tools, and reliable medicine and BP-device supply chains to maximize BP reductions and long-term CVD benefits. When evaluating such programs, use longer time horizons and CVD-event-based models rather than relying solely on 6–12-month trial QALY differences, which tend to be small. Include distributional cost-effectiveness or equity-impact analyses where possible, to quantify how CHW-led hypertension programs reduce disparities in access and outcomes between poorer and better-off populations.

Abbreviations

BP
Blood Pressure
CHWs
Community health workers
CMHS
College of Medicine and Health Sciences
CVD
Cardiovascular Diseases
GDP
Gross Domestic product
HTN
Hypertension
LMICs
Low- and middle-income countries
MCI
Multicomponent intervention
NCD
Non-communicable disease
IRB
Institutional Review Board
PI
Principal Investigator
QALY
Quality-Adjusted Life Year
RCT
Randomized Controlled Trial
UR
University of Rwanda.

Declarations

Ethical approval and consent to participate

Participation was voluntary, with participants able to withdraw at any time without penalty. Privacy was protected using patient codes instead of names, private data collection areas, locked storage for paper forms, and password-protected electronic files per UR-CMHS IRB standards. Data collectors received ethics training and explained study aims, indirect benefits (improved HTN management), and no direct compensation (except travel reimbursement). Signed consent forms were obtained after participants asked questions. The trial was approved by; University of Rwanda-College of medicine and Health sciences Institutional Review Board (UR-CMHS IRB): Initial approval No. 695/CMHS IRB/2024; renewed No. 614/CMHS IRB/2025 and Rwanda Ministry of Health: CHW permission No. 20/5179/DPMEHF/2024 (19 Nov 2024). Formal letters were presented to health centers. The study adhered to the Declaration of Helsinki, ensuring informed verbal explanations and signed consent for all participants.

Consent to publish

Not Applicable

Conflict of interest

The authors declare no conflicts of interest.

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Author Contribution

IM, KN, CMCS, and RK contributed to the study conception, design, data collection, data analysis, and manuscript refinement. All authors read and approved the final manuscript.

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Data Availability

All data relevant to this study are included in the article

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Figures

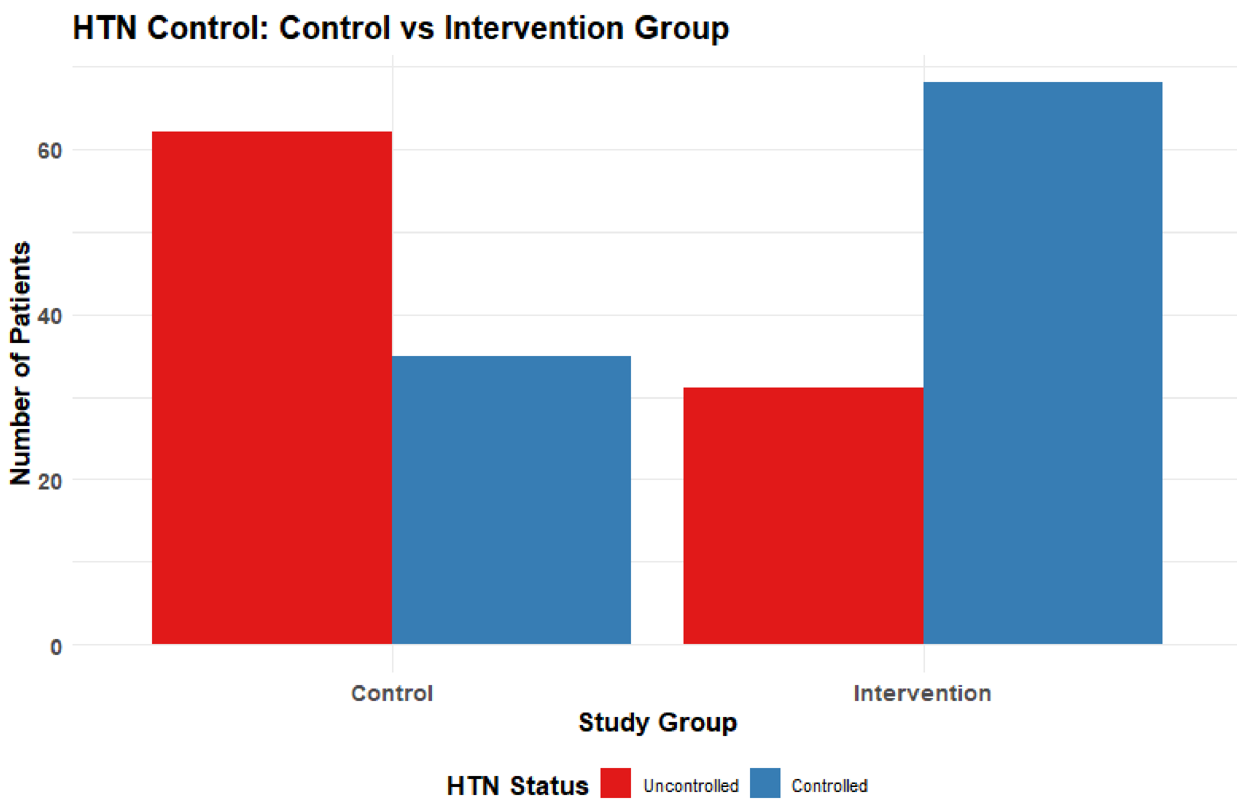

Figure 1

Hypertension control in the CHW-led MCI vs Control group

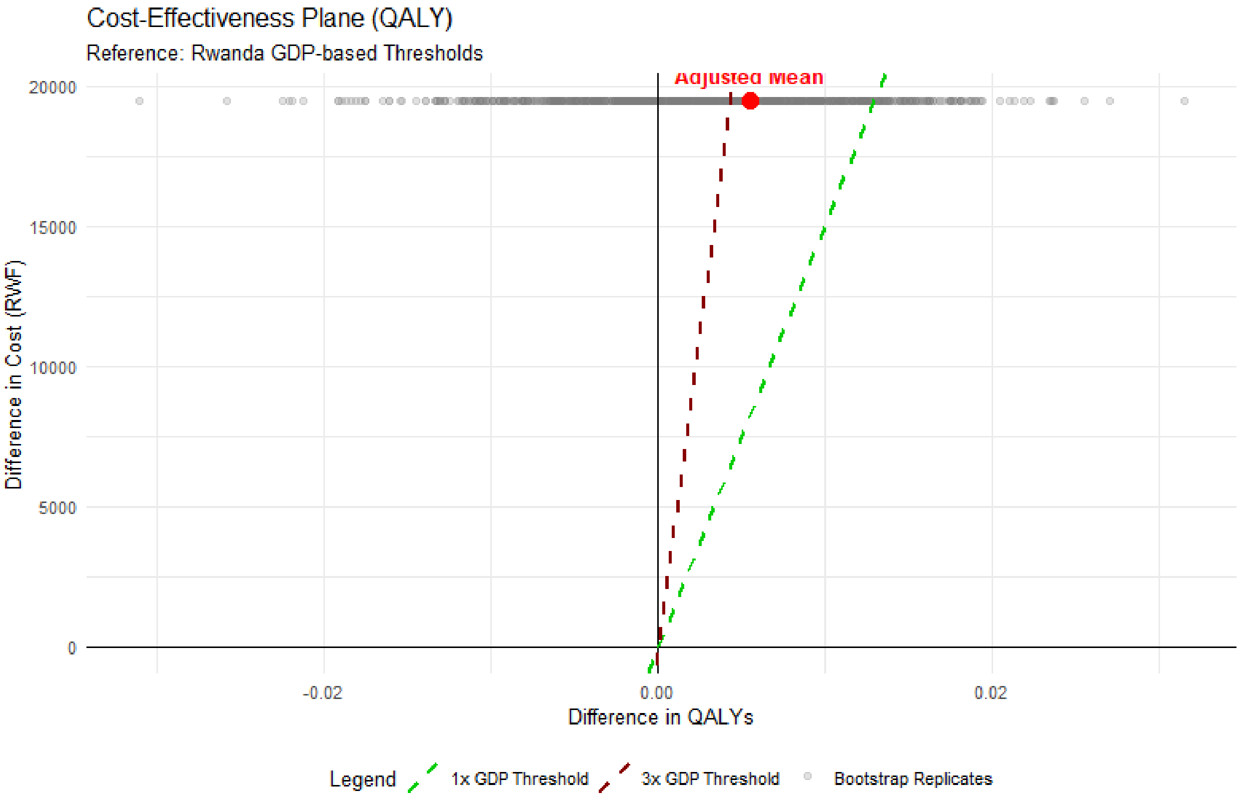

Figure 2

Hypertension control in the CHW-led MCI vs Control group

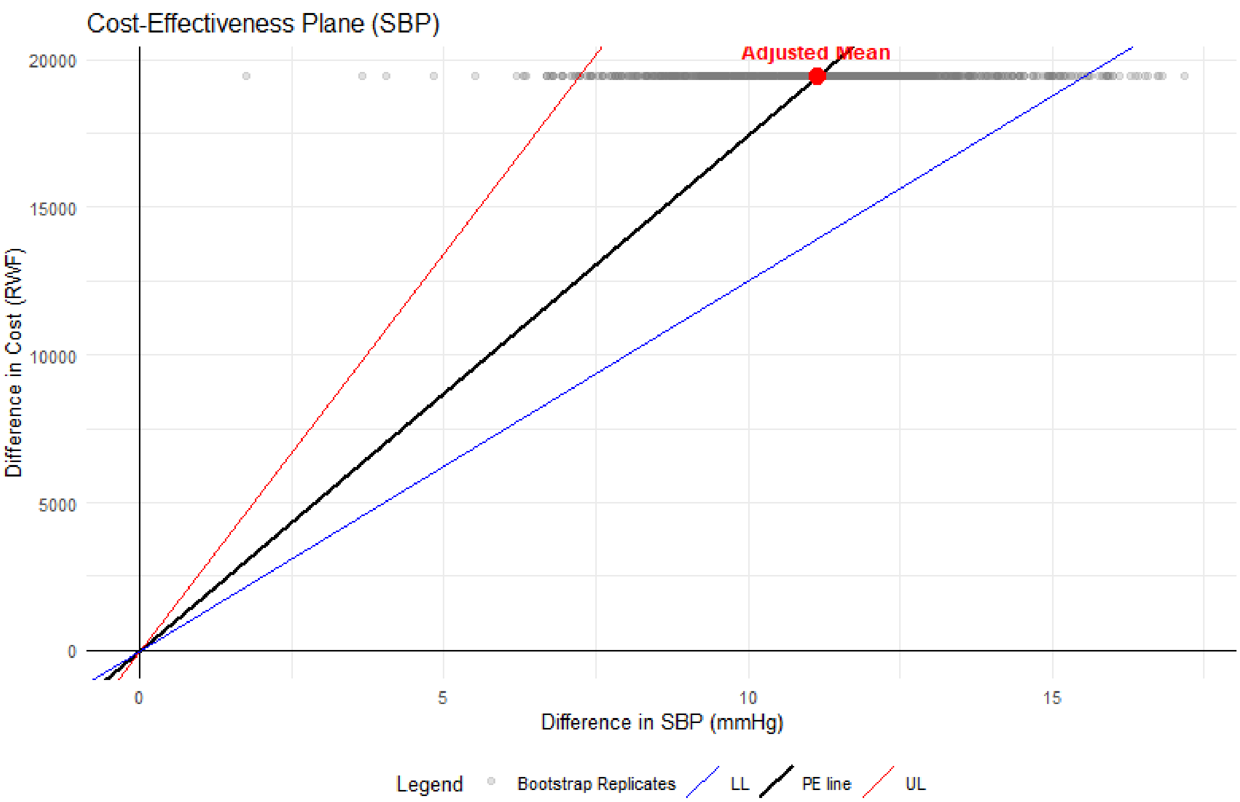

Figure 3

Cost-effectiveness plane (SBP)

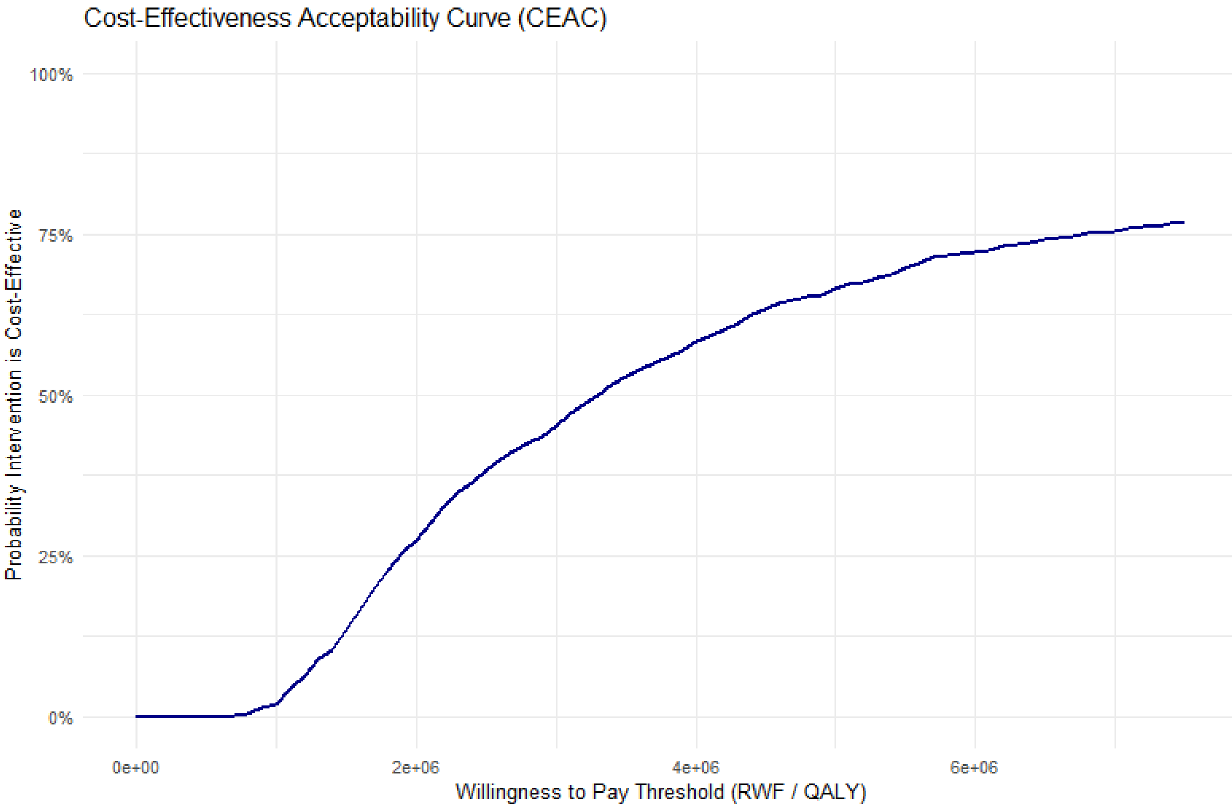

Figure 4

Cost effectiveness acceptability curve (CEAC)

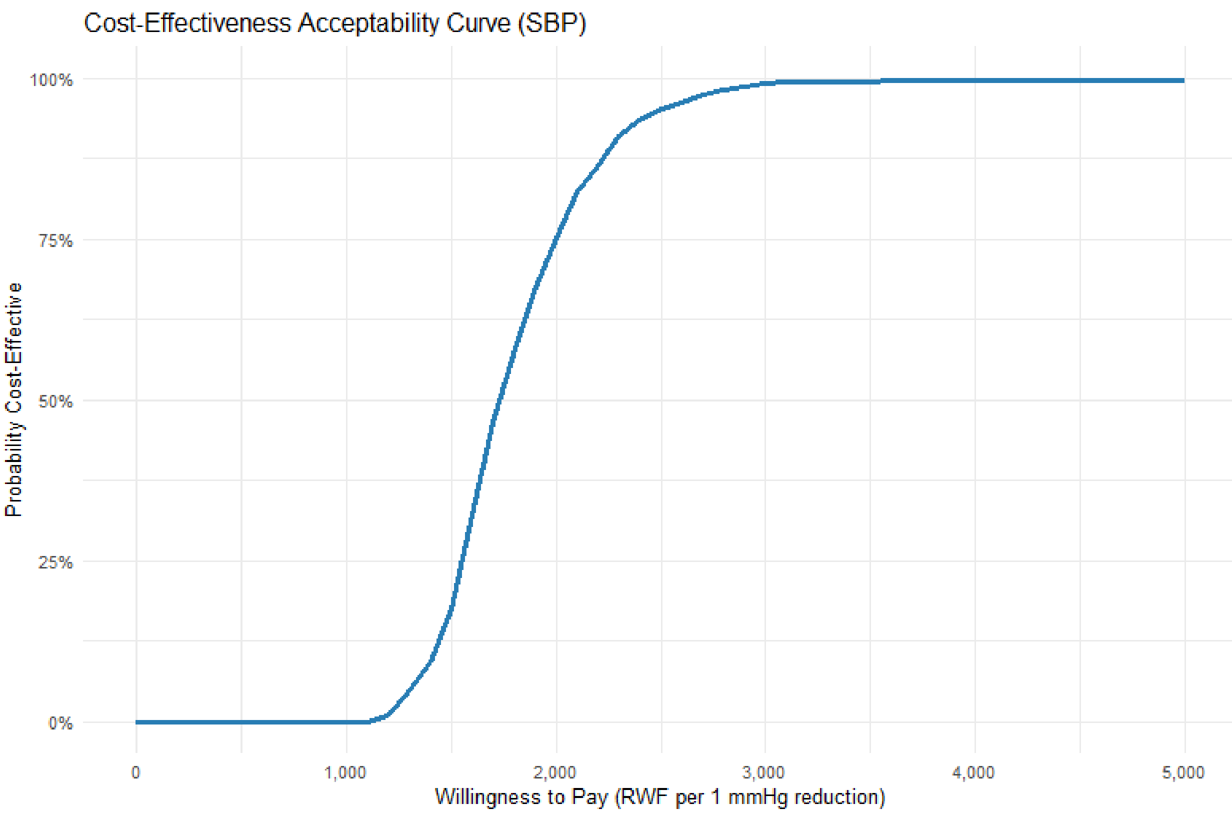

Figure 5

Cost-effectiveness acceptability curve (SBP)

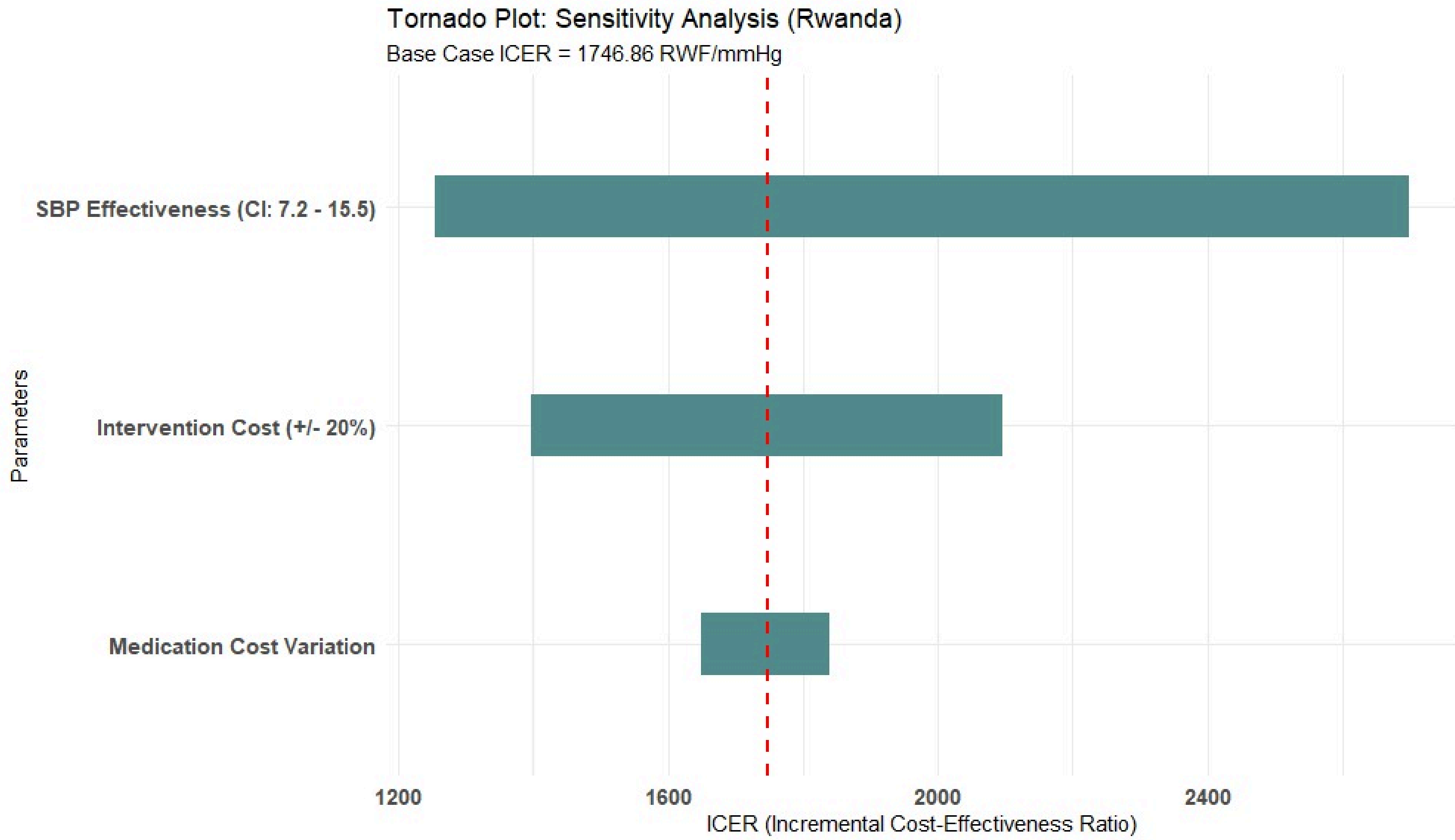

Figure 6

Tornado diagram for sensitivity analysis