Cost and cost-effectiveness of ivermectin mass drug administration for malaria control in Kwale county, Kenya: a modelling analysis of a cluster-randomised trial

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Summary

Background Malaria remains a major health burden in sub-Saharan Africa, where traditional vector control methods are hindered by insecticide resistance and evolving mosquito behaviour causing residual transmission. In the BOHEMIA cluster-randomised trial in Kenya, ivermectin mass drug administration (iMDA), delivered once a month for 3 months with approximately 64% population coverage, was shown to reduce malaria incidence by 26%. We aimed to assess the cost-effectiveness of iMDA as a supplementary vector control tool using data from the BOHEMIA trial in Kenya.

Methods We did a cost-effectiveness analysis of the BOHEMIA cluster-randomised trial done in Kwale county, Kenya, using a societal perspective to estimate the intervention costs, health system costs, direct household out-of-pocket expenses, and indirect costs from lost wages of iMDA versus a no-intervention scenario. Intervention effectiveness was measured as the number of malaria cases averted and disability-adjusted life-years (DALYs) averted. A decision tree model was developed to simulate the intervention's impact on a broader population. Deterministic and probabilistic sensitivity analyses were performed to assess the robustness of the results, and incremental cost-effectiveness ratios (ICERs) were compared with Kenya's gross domestic product (GDP)-based thresholds.

Findings The intervention cost of iMDA was US$11·83 per person. Household out-of-pocket costs averaged $5·85 for uncomplicated malaria cases and $52·23 for severe cases. Productivity loss amounted to $2·18 for uncomplicated and $8·83 for severe cases. The base-case ICER was $905·23 per DALY averted, which was below the threshold of 0·5×Kenya's GDP per capita ($974·65). In probabilistic analysis (10 000 iterations), the median ICER was $1107·51 per DALY averted (50% credible interval 770·05–1606·77).

Interpretation This study demonstrates that iMDA can be a cost-effective supplementary intervention for malaria control in settings with moderate malaria transmission and good insecticide-treated net coverage, particularly when malaria reduction is greater than 23·62% for children younger than 5 years and opportunities for reducing intervention costs can be identified.

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For more on the **BOHEMIA consortium** see https://bohemiaconsortium.org/

Introduction

Malaria remains a considerable global health challenge. In 2022, there were an estimated 249 million cases of malaria and 608 000 malaria deaths worldwide, with 94% of cases and 95% of deaths occurring in the WHO African region.[1] Vector control interventions, such as insecticide-treated nets and indoor residual spraying, have been instrumental in reducing malaria incidence, contributing to an 81% decline in cases across sub-Saharan Africa between 2000 and 2015.[2,3] However, these interventions are increasingly limited by emerging challenges, including insecticide resistance and behavioural adaptations in mosquito populations. These challenges threaten the progress made towards the targets set by the WHO Global Technical Strategy for Malaria for 2016–2030.[4]

In recognition of these challenges, the Broad One Health Endectocide-based Malaria Intervention in Africa (BOHEMIA) consortium was established to investigate the potential of ivermectin mass drug administration (iMDA) as an innovative vector control strategy. Ivermectin is an endectocide with demonstrated ability to kill mosquitoes that feed on treated individuals.

The BOHEMIA consortium implemented a phase 3, cluster-randomised, clinical trial, to assess the efficacy and safety of iMDA in curbing malaria transmission in two distinct African settings: Mopeia, Mozambique, and Kwale, Kenya.[5] In Kwale, ivermectin was administered once a month for three consecutive months to the eligible population (bodyweight ≥15 kg, excluding pregnant women and severely ill individuals). Results from the trial in Kwale showed that iMDA resulted in an incremental 26% reduction (95% CI 5–42; p=0·02) in malaria infection incidence in children aged 5–15 years, in an area of high insecticide-treated net ownership and use.[6] Although the primary efficacy outcome was determined in a cohort of

Research in context

Evidence before this study

We searched PubMed from database inception to Aug 28, 2025, to identify evidence on the cost-effectiveness of ivermectin mass drug administration (iMDA) for malaria control. We used the search terms "malaria" AND "ivermectin" AND ("cost effectiveness" OR "ICER" OR "cost benefit" OR "cost utility" OR "health economics" OR "economic burden" OR "economic evaluation"), without language restrictions. This search identified seven peer-reviewed publications, of which only four discussed cost-effectiveness in relation to iMDA for malaria control. Two studies (published in 2017 and 2018) suggested opportunities to improve the cost-effectiveness of iMDA for malaria control by leveraging ivermectin's affordability or by combining iMDA with efforts targeting other neglected diseases, although further regulatory and technical evaluations would be required. An additional 2021 study used a full factorial design to simulate the impact of iMDA on health and economic outcomes between 2023 and 2027. However, this study focused on incremental cost per case and death averted, which are not directly comparable with the WHO-recommended cost-effectiveness thresholds based on disability-adjusted life-years (DALYs) or quality-adjusted life-years. Additionally, the effectiveness evaluation was based on simulations rather than actual interventions. A 2025 study used a mathematical model and scenario-based analysis to show that iMDA could substantially reduce malaria cases and save DALYs by killing both parasites and mosquitoes. However, our search did not identify any studies that provided economic assessments based on real-world implementation of iMDA for malaria control. As a result, there is a gap in the literature on its cost-effectiveness based on field data.

Added value of this study

To our knowledge, this is the first study using data from a randomised control trial to demonstrate that iMDA can be a cost-effective supplementary intervention for malaria control in settings with moderate transmission and good insecticide-treated net coverage. Our analysis, conducted from a societal perspective, incorporates direct and indirect household costs, health system costs, and intervention costs, providing a comprehensive assessment of the economic impact of iMDA. Additionally, we offer an assessment of the cost-effectiveness of iMDA from the health-care provider perspective. By leveraging clinical trial and household-level survey data, we present evidence that iMDA is cost-effective relative to Kenya's gross domestic product-based cost-effectiveness threshold, addressing an important gap in the literature where systematic evaluations of the cost-effectiveness of iMDA for malaria control have been scarce.

Implications of all the available evidence

Our economic analysis, combined with the demonstrated clinical efficacy and safety in a separate published study, provides support for integrating iMDA as a supplementary intervention in malaria control programmes. Policy makers should consider iMDA as part of a broader strategy to address residual malaria transmission. Future research should explore iMDA efficacy in other ecoepidemiological settings and options for reducing costs associated with iMDA implementation should be prioritised.

children, it is reasonable to consider this a reflection of a community-wide effect.

Although the potential value of scaling up iMDA against malaria has been discussed,[7] the cost-effectiveness of such an approach has not yet been estimated. In this study, we aimed to estimate the incremental cost-effectiveness of iMDA delivered as a supplementary malaria vector control tool using cost data collected as part of the BOHEMIA trial in Kenya.

Methods

Study design

In this cost-effectiveness analysis, the iMDA intervention was compared with a no-intervention scenario within a population with documented high coverage and use of effective insecticide-treated nets, based on data from the BOHEMIA clinical trial conducted in Kwale, Kenya[6] (appendix 1 p 3). The cost-effectiveness analysis accounted for both societal and health-care provider perspectives on costs, using household and individual economic data collected from a longitudinal household survey embedded within the clinical trial and supplemented with previously published data (appendix 1 p 9).Effectiveness was measured as the averted number of malaria cases and disability-adjusted life-years (DALYs) calculated using trial data. A decision-analytic model was developed to simulate the population-level effect of the intervention, encompassing all age groups benefiting from iMDA. Deterministic and probabilistic sensitivity analyses were conducted, accounting for key variables and uncertainties in the model inputs.

See Online for appendix 1

Ethical approval for the health economics substudy of BOHEMIA was obtained from the Scientific and Ethics Review Unit of the Kenya Medical Research Institute (SERU 4586) and the Research Ethics Review Committee of WHO (ERC.0003623). For longitudinal household surveys, written informed consent was obtained from adult participants and from the parents or guardians of children younger than 18 years. Informed assent was obtained from adolescents aged 13–17 years. No incentives were offered to the participants.

Intervention

Data on the estimates of effectiveness were obtained from the epidemiological findings of the clinical trial, which measured malaria incidence in an efficacy cohort including 2891 children aged 5–15 years from a population of 28 932 in 84 eligible clusters over a 6-month

period.[7] All eligible individuals (bodyweight ≥15 kg, excluding pregnant women and severely ill individuals) in 42 clusters randomly assigned to the intervention group received a single oral dose of ivermectin 400 µg/kg monthly for three consecutive months, and individuals in the control group received a single 400 mg oral dose of albendazole monthly for three consecutive months. Albendazole was used as an active control to provide participants with the established deworming benefit of ivermectin, but it has no effect on mosquito survival.[8] The first dose was administered in October, 2023, coinciding with the start of the short rains and the associated increase in malaria transmission in the region. All doses were administered under directly observed therapy by field teams, who also conducted household visits to perform malaria testing on the efficacy cohort. The target coverage was 64% of the total population (approximately 80% of eligible individuals), whereas the achieved population coverage across the three monthly rounds was 66% in the ivermectin group and 73% in the control group. Full details of the BOHEMIA trial methodology, population demographics, and eligibility criteria have been described previously.[6]

Measurement of health effects

The effectiveness of the intervention was quantified using two primary metrics: (1) the reduction in the number of diagnosed malaria cases, and (2) the decrease in DALYs attributable to the intervention. We assumed that the intervention's effect size among children aged 5–15 years derived from the BOHEMIA trial[6] was consistent across all age groups. Malaria incidence in the control group was used as the base estimate for the probability of malaria infection in the absence of iMDA. Since only the incidence among children aged 5–15 years was available from the trial, we extrapolated incidence for other age groups by adapting age-specific incidence rate ratios (IRRs) from a separate study done on the Kenyan coast.[9] DALYs were calculated as per WHO methodologies.[10] The detailed health effects estimations and assumptions are available in appendix 1 (pp 3–5). The key assumptions were critically evaluated in the sensitivity analysis.

Measurement of costs

Costs were evaluated from both societal and health-care provider perspectives, incorporating intervention costs, household out-of-pocket expenses, and health system costs. Detailed breakdowns of these costs and allocation methodologies are provided in appendix 1 (p 5). Intervention costs included administrative, implementation, targeting, and training expenses, based on a retrospective cost analysis following an ingredient-based methodology. Household costs were estimated from a longitudinal health economics survey conducted among a randomly selected subset of 626 households (2728 individuals) who participated in the trial. Before the intervention, approximately 15 clusters per trial group were randomly selected to participate in the health economics survey, stratified by socioeconomic status using data from the demographic survey, which was completed before the trial.[11,12] A longitudinal household survey, administered monthly for 5 months from intervention start, collected data on 996 self-reported malaria episodes, including direct medical costs (treatment, diagnostic tests, consultations, and hospitalisation), direct non-medical costs (transportation and food), and indirect costs (value of time lost to caregiving or illness). A wage-based approach was applied to value the number of days absent from productive activities (eg, employment, education, agriculture, and domestic tasks), using the self-reported daily wage when available, or a proxy activity wage when no wage was reported or the work was as unpaid. Proxy wages were calculated using 2022 Kenya Economic Survey data,[13] with adjustments for agricultural (450·70 KES per day) and non-agricultural work (842·07 KES per day). Household out-of-pocket costs were compared across age groups using the Kruskal–Wallis test with Dunn pairwise tests and Benjamini–Hochberg adjustment. Health system costs for malaria treatment were sourced from existing literature (appendix 1 p 9) and adjusted for inflation. All costs were initially quantified in 2023 KES and subsequently converted to 2023 US$ (139·72 KES per $1). Additional details on the survey methods, wage calculations, health system cost adjustments, and statistical tests are available in appendix 1 (p 6). All cost estimates derived from the survey data, associated statistical tests, and intervention costs are provided in appendix 1 (pp 12–16).

Decision tree analysis

A decision tree model was constructed to evaluate the cost-effectiveness of iMDA strategies across an all-age population over a 6-month time horizon, consistent with the follow-up period in the trial. The population structure of the decision tree modelled a hypothetical cohort of 10 000 individuals, categorised into three age groups: (1) children younger than 5 years, (2) children aged 5–15 years, and (3) individuals older than 15 years (figure 1A). The age distribution was based on the proportions reported in the 2019 Kenya Population and Housing Census.[14] All three age groups were included in both the iMDA and control groups to capture the broader population-level effect. The bodyweight threshold for ivermectin treatment effectively excluded most children under 5. The model captured this by assigning no treatment to children under-5 in the iMDA group but included them to reflect potential indirect protection resulting from broader community coverage in the iMDA group. Within the iMDA group, the decision tree further distinguished between children aged 5–15 years and individuals older than 15 years who did and did not

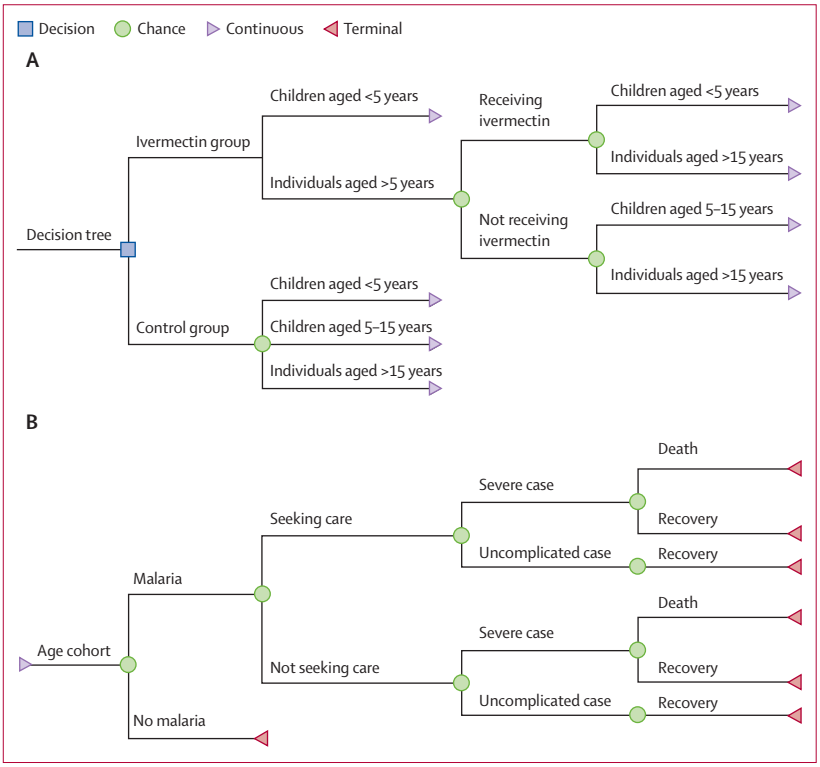

Figure 1: **The structure of the decision-tree model**
(A) Initial decision tree. The population was categorised by intervention arm and age; ivermectin treatment was only assigned to individuals eligible by bodyweight, thus excluding most children under 5 years in the ivermectin group; children aged 5–15 years and individuals older than 15 years who did not receive ivermectin reflect other eligibility criteria (eg, pregnancy) and levels of coverage. (B) Subsequent decision tree. Consistent malaria progression across all age cohorts.

	Cost (US$)	Cases or DALYs, n	Difference in cost (US$)*	Case averted or DALYs averted, n†	ICER (US$ per case)	ICER (US$ per DALY)
Societal perspective						
Cases, n						
Control	33 089·20	5103·26	..	..	..	..
iMDA	107 646·46	4203·26	74 557·26	899·99	82·84	..
DALYs	33 089·20	526·17	..	..	..	..
Control	33 089·20	526·17	..	..	..	..
iMDA	107 646·46	443·81	74 557·26	82·36	..	905·23
Health-care provider perspective						
Cases, n						
Control	20 143·98	5103·26	..	..	..	..
iMDA	97 120·89	4203·26	76 976·91	899·99	85·53	..
DALYs						
Control	33 089·20	526·17	..	..	..	..
iMDA	107 646·46	443·81	76 976·91	82·36	..	934·61

All costs are in 2023 US$. DALYs=disability-adjusted life-years. ICER=incremental cost-effectiveness ratio. iMDA=ivermectin mass drug administration. *iMDA cost minus control cost. †Effect of control minus the effect of iMDA.

Table 1: **Key findings of the base-case analysis for iMDA versus control, using a theoretical cohort of 10 000 people (all ages)**

receive ivermectin, reflecting other eligibility criteria (eg, ivermectin not given in pregnancy) and levels of participation among eligible individuals in the BOHEMIA trial in Kenya.

Each individual in the cohort was assigned a malaria risk probability based on a baseline incidence for their age group (figure 1B). Malaria cases were categorised as uncomplicated or severe, in accordance with the US Centers for Disease Control and Prevention guidelines,[15] with severe malaria defined as cases requiring hospital admission for at least one night. Thus, the model then branches according to health-care seeking behaviour, with pathways leading to outcomes of either severe or uncomplicated malaria. These pathways culminated in three potential end states: no malaria, mortality, or recovery. The decision tree model assumed that no migration, repeat infections, or mortality (other than from malaria) occurred within the 6-month timeframe. The costs considered for each branch in the decision tree model are in appendix 1 (p 7).

Cost-effectiveness analysis

The most probable parameter values for each node in the decision tree model were derived primarily from the BOHEMIA trial and its nested health economics survey, using local and national statistics when trial data were unavailable (appendix 1 pp 9–11). We conducted a base-case analysis using the model, by determining expected costs and health outcomes for the hypothetical cohort and computing the incremental cost-effectiveness ratio (ICER) for each intervention group. The ICER based on DALYs averted was compared against the cost-effectiveness threshold set at 0·5 times the 2023 Kenya gross domestic product (GDP) per capita, corresponding to US$974·65 per DALY averted for determining cost-effective interventions. This threshold was derived from the concept of willingness to pay (WTP), which represents the maximum amount a society or individual is willing to spend to gain an additional unit of health benefit (eg, one DALY averted). Previous literature has suggested 0·5×GDP per capita is a more appropriate benchmark for health-care interventions in low-income and middle-income countries, because this threshold is more closely aligned with local WTP than the 1–3×GDP per capita threshold previously recommended by WHO.[16,17]

A deterministic sensitivity analysis was conducted, examining the stability of results against variations in key parameters (appendix 1 pp 9–11). Parameter ranges were informed by the primary trial data or, when unavailable, by hypothesising a 10–30% deviation from the most likely values. Specific adjustments in the sensitivity analysis are described in appendix 1 (p 8). Additionally, a probabilistic sensitivity analysis was conducted to account for the inherent uncertainty in model inputs by incorporating probability distributions for each parameter (appendix 1 p 8). All modelling and analyses were conducted using R statistical software (version 4.4.3).

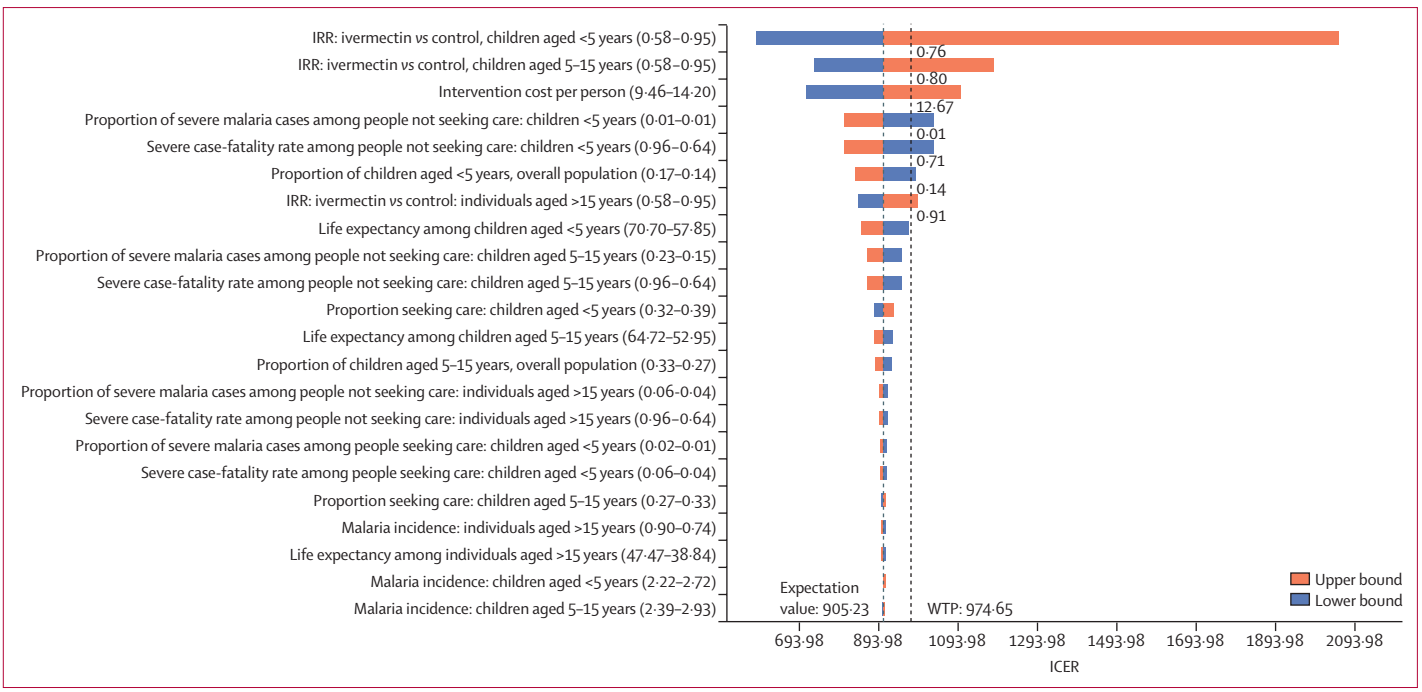

Figure 2: **Tornado diagram from univariate sensitivity analysis of iMDA versus control**
The grey dashed line denotes the cost-effectiveness threshold of US$974·65 per DALY averted (0·5×GDP per capita). The red segment shows the effect of increasing the parameter: if it extends right, ICER increases; if it extends left, ICER decreases. Numbers in parentheses are the parameter bounds and are ordered based on their effect on the ICER (decreases ICER to increases ICER). All costs are in 2023 US$. DALYs=disability-adjusted life-years. GDP=gross domestic product. ICER=incremental cost-effectiveness ratio. IRR=incidence rate ratio. WTP=willingness to pay.

Role of the funding source
The funder of the study had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Results
The results of base-case analysis indicated that although iMDA incurs a higher total cost, it was more effective in reducing the overall disease burden, as reflected by the lower number of malaria cases and DALYs in the iMDA group than the control group (table 1). The ICER for iMDA was $905·25 per DALY averted under the societal perspective and $934·61 per DALY averted under the health-care provider perspective, which was slightly lower than the cost-effectiveness threshold of $974·65 (0·5×per capita threshold). Since the two perspectives yielded similar conclusions, the societal perspective has been provided in the main text and data for the provider perspective are reported in appendix 1 (pp 17–18).

Univariate sensitivity analysis showed that the age-specific IRR between the iMDA and control groups in children under-5 was the most influential parameter, with a potential to significantly shift the ICER over the cost-effectiveness threshold of $974·65 if iMDA effectiveness was reduced to less than 25% (IRR >0·76; figure 2). Reducing the IRR in children under-5 to 0·95 increased the ICER to more than 1·0×GDP per capita (more than twice the WTP threshold), whereas the same IRR in children aged 5–15 years only increased the ICER to approximately 0·61×GDP per capita (1·2 times the WTP threshold). Other influential parameters included intervention cost per person and the proportion of patients with severe malaria who were not seeking care, although their effects are smaller. The three-way sensitivity analyses (appendix 1 pp 20–24) also confirmed that parameters related to children under-5 resulted in the largest shifts in ICER. ICER outcomes were highly sensitive to the IRR for children under-5, while changes in incidence, care-seeking, and severity among children under-5 had a greater influence than the same parameters in older age groups; however, effects were modest when compared with IRR.

In probabilistic sensitivity analyses, the mean and median of ICERs derived from probabilistic simulations slightly exceeded the cost-effectiveness threshold; the result remains close enough to justify the cost-effectiveness of iMDA, especially considering potential variability in key decision tree parameters (table 2). Across the simulations there was a wide range of estimated ICERs, highlighting uncertainty in key parameters. The central 50% of simulations clustered near the WTP threshold, indicating that iMDA is likely to be cost-effective under a wide range of plausible scenarios, while the extremes reflect uncertainty in less probable parameter combinations.

In probabilistic sensitivity analysis, the probability of each intervention being cost-effective at different WTP thresholds per DALY averted was estimated, and results showed a clear crossover point where the

	Mean (SD)	Median (50% CrI; 95% CrI)
Incremental intervention cost (2023 US$)	80 078·55 (23 983·24)	77 735·18 (62 982·39–94 765·50; 39 897·53–133 718·60)
Health system cost-savings (2023 U$)	2396·51 (686·97)	2320·54 (1898·17–2807·61; 1287·80–3946·50)
Household out-of-pocket cost-savings (2023 U$)	2355·33 (1492·90)	1974·18 (1353·98–2917·92; 646·62–6356·44)
Incremental cost (2023 US$)	75 326·71 (24 042·99)	73 019·30 (58 181·20–90 098·05; 35 038·03–128 603·40
Incremental effects		
Total cases averted	734·21 (199·67)	711·46 (583·44–872·77; 405·73–1149·80)
Deaths averted	1·14 (0·48)	1·06 (0·80–1·41; 0·44–2·29)
DALYs averted	70·11 (30·01)	65·18 (48·73–86·39; 26·16–142·49)
ICERs		
Incremental cost per case averted	111·42 (50·83)	101·71 (75·15–137·32; 41·33–234·05)
Incremental cost per DALY averted	1299·98 (808·39)	1107·51 (770·05–1606·77; 379·16–3304·50)

CrI=credible interval (quantile). DALY=disability-adjusted life-year. ICER=incremental cost-effectiveness ratio. The 50% CrIs correspond to the posterior IQR defined by the 25th and 75th percentiles, and the 95% CrIs correspond to the posterior equal-tailed interval defined by the 2·5th and 97·5th percentiles, computed from the simulated posterior distributions.

Table 2: **Probabilistic cost-effectiveness results across all 10 000 simulations, and each simulation consisted of a theoretical cohort of 10 000 people (all ages)**

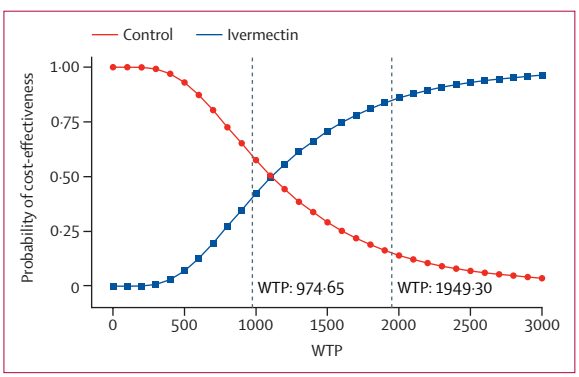

Figure 3: **Cost-effectiveness acceptability curves**
Curves show the probabilities at which iMDA and control groups are cost-effective at different WTP thresholds. The two vertical lines represent different WTP thresholds at $974·65 per DALY averted (0·5 × GDP per capita) and $1949·30 per DALY averted (1·0 × GDP per capita). All costs are in 2023 US$. DALYs=disability-adjusted life-years. GDP=gross domestic product. iMDA=ivermectin mass drug administration. WTP=willingness to pay.

cost-effectiveness of the two interventions shifted depending on the WTP value (figure 3). At thresholds lower than $1107·50 per DALY, the control group had a higher probability of being the most cost-effective option (figure 3). However, as the WTP threshold increased above this point, iMDA became increasingly likely to be the more cost-effective choice. When WTP reached $974·65 per DALY averted (equivalent 0·5×GDP per capita), the control group had the higher probability of being cost-effective (approximately 59·42%), The cost-effectiveness plots of the incremental costs and DALYs averted from the Monte Carlo simulations at a specific WTP of $974·65 per DALY are shown in appendix 1 (p 25).

Discussion

In this study, the cost-effectiveness of iMDA for malaria control in Kenya was estimated in a seasonal and moderate transmission setting, and in a population with good coverage of insecticide-treated nets and use. We used the efficacy results from a well-designed and implemented clinical trial, combined with transparent costing methods, to demonstrate that iMDA could be economically justified in Kwale, Kenya and similar settings. To date, no studies have directly evaluated the cost-effectiveness of iMDA for malaria control, underscoring the novelty of this study and the potential of iMDA to address existing gaps in malaria intervention strategies.

The delivery of iMDA in Kenya had a total annual cost of $102 583·59, with the cost per person who received ivermectin estimated at $11·83, which included administrative, training, targeting, and implementation costs. Although this cost is two to three times higher than the reported mean economic cost per insecticide-treated net distributed[18] or person targeted in indoor residual spraying programmes,[19] comparison with these other vector control measures with the intent of resource reallocation is inappropriate, because iMDA is intended to be applied in situations where current vector control tools are already in use, whereby iMDA targets mosquito biting behaviour that is not targeted by these traditional tools. Beyond the use case, the logistics and timeline for iMDA implementation also varied considerably from other vector control measures. The delivery of iMDA most closely resembles that of seasonal malaria chemoprevention programmes, where anti-malarial medications are most commonly delivered to children aged 3–59 months once a month for 3–4 months during peak malaria transmission seasons.[20] Reported costs of seasonal malaria chemoprevention implementation across seven countries in the Sahel region of Africa found that the weighted mean cost per child treated was $3·63, ranging from $2·71 in Niger to $8·20 in The Gambia.[21] Although our per-person cost exceeded the higher bound of this range, our study was implemented

within the context of a clinical trial and decisions on how best to allocate costs to programmatic activities were made to avoid underestimation. Additionally, it could be that Kenya's labour costs are higher than in countries that implement seasonal malaria chemoprevention. Considering that administrative and fieldworker labour costs contributed significantly to the overall programmatic costs, this could drive the per-person cost higher within the Kenyan context.

The household-level economic assessment highlights that the economic burden of malaria on households is substantial when considered against household annual income. For uncomplicated cases, out-of-pocket costs of $4·39 per episode can lead to annual economic costs exceeding $57·07 for a household with five children (with an incidence of 2·66 malaria infections per child per year[6]). This represents approximately 11·39% of the average annual household income of $501·07, as estimated using the BOHEMIA health economics study data. Additionally, among individuals older than 15 years, only 40·21% reported being engaged in economically productive activities (paid or unpaid), which might have lowered the overall productivity losses reported in this cohort, as compared with other studies.

The cost-effectiveness analysis generated an ICER of $905·25 per DALY averted under the societal perspective, which is lower than the cost-effectiveness threshold of $974·65. Sensitivity analyses show that results are parameter dependent, particularly on the malaria IRR in young children and the per-person intervention cost. It is reasonable to explore the potential for intervention costs to be lower, considering the clear opportunities for resource sharing across public health programmes or negotiation of ivermectin prices with economies of scale. For example, considering the overlap in timing of seasonal malaria chemoprevention programmes, costs could be reduced through integrated delivery: fieldworkers already visiting households to provide anti-malarials to young children could simultaneously administer ivermectin to eligible older family members, thereby sharing the fixed costs of personnel and transport. It might also be possible to overlap delivery of ivermectin delivered as part of a neglected tropical disease programme (eg, onchocerciasis, lymphatic filariasis, and soil-transmitted helminths) with one of the three rounds of iMDA for malaria. The detailed cost collection this study provides allows for further discussion and consideration of some of these opportunities.

Although the cost of iMDA was below the WTP threshold of 0·5×GDP, the ICER of $905·25 per DALY averted from the societal perspective was much higher than that of other currently implemented malaria control strategies, such as insecticide-treated nets, which had a median cost of $44·51 per DALY averted from a provider perspective across several sub-Saharan African settings;[22] indoor residual spraying, which from provider perspective had an ICER of US$25·16 per DALY averted in South Africa and Mozambique;[22] and seasonal malaria chemoprevention, which had a median cost of $177·34 per DALY averted from a societal perspective in Ghana.[22] Additionally, considering the WHO recommendation that countries should consider sub-national integrated approaches to malaria control,[23] it is more appropriate to consider strategies and their cost-effectiveness when delivered in various combinations, at differing scales, and across the range of eco-epidemiological contexts. In this analysis, the example of combining iMDA and seasonal malaria chemoprevention remains pertinent. iMDA is novel because by killing mosquitoes that feed on individuals receiving ivermectin, it potentially impacts individuals who do not receive ivermectin, whereas seasonal malaria chemoprevention offers protection to the most susceptible individuals who receive antimalarial medicines. By targeting different points in the malaria transmission cycle with activities that can be delivered through shared resources, a greater effect is likely to be achieved with relatively fewer costs,[24] although the effectiveness of such combinations has varied across settings.[25,26]

The evaluation of iMDA for use as part of integrated malaria control also provides an opportunity to examine its cost-effectiveness from a more holistic perspective on efficacy outcomes. Beyond its ongoing use in neglected tropical diseases programmes, ivermectin is indicated for use in people with scabies, filariae, and soil-transmitted helminthiases, and has been evaluated for its potential use for bed bugs and other parasitic diseases.[27] During the implementation of BOHEMIA in Mozambique, an 80% reduction in scabies and headlice was observed in ivermectin clusters[28,29] suggesting that the cost-effectiveness of iMDA should be considered from a broader perspective through curated delivery in populations with coendemic diseases, potentially increasing the cost-effectiveness estimates.

This study had several limitations. First, the decision tree model simplifies real-world implementation despite being informed by data from the BOHEMIA trial and estimates for the Kenyan population. For example, the base case applied a single IRR of iMDA effectiveness across ages. To assess age heterogeneity, we then specified age-specific IRRs and ran both one-way and three-way sensitivity analyses across wide ranges. The model assumes homogeneity in intervention coverage, which might not account for its variation based on differences in socioeconomic status or proximity to health-care infrastructure within the population. Second, the model was developed using data from a specific region in Kenya, which limits generalisability to other areas. The efficacy of iMDA might vary across different ecoepidemiological regions due to variations in transmission levels, baseline insecticide-treated net coverage, and other contextual factors. Any roll-out in other regions should be paired with local efficacy estimates with a site-specific economic

evaluation. Our decision tree model structure provides a flexible framework that can be adapted for such analyses by incorporating local parameter values. Third, the costs were estimated for malaria cases without comorbidities, potentially underestimating the true cost and health burden of the disease in individuals with other health conditions. Finally, the 6-month horizon might miss longer-term effects, including transmission feedback, seasonality, and possible ivermectin resistance. Future work should incorporate more granular data, richer assessments of model structural uncertainty, alternative models, longer horizons, a range of transmission settings, and potential effects on neglected tropical diseases across broader geographies.

This study provides a comprehensive evaluation of the cost-effectiveness of iMDA for malaria control in Kenya, highlighting its potential as a viable additional strategy for reducing the burden of malaria. The results provide valuable information for public health authorities involved in malaria vector control who might be considering how best to integrate the various existing and emerging strategies. Our findings suggest that realising the cost-effectiveness of iMDA is likely to depend on reducing implementation or drug costs, coordinating with other public health campaigns, and targeting geographical areas where the entomological and epidemiological profile indicates that the intervention will have the most impact.

Contributors

CR, AM, and KX conceptualised the article and were responsible for study design and data analysis. XD contributed to study design and data analysis. RO contributed to study design and data analysis, and led field investigation for the health economics substudy. The field investigation leadership team also included ASG, MK, LM, EY, and LK. IO and JM advised on software and data curation. RO, KX, and ASG accessed and verified data. KX wrote the first draft of the manuscript, with support from CR and AM. Funding was acquired by CR, MM, CC, and RR. All authors had full access to the data, reviewed and provided comments on the manuscript, and had final responsibility for the decision to submit for publication.

Equitable partnership declaration

The authors of this paper have submitted an equitable partnership declaration (appendix 2). This statement allows researchers to describe how their work engages with researchers, communities, and environments in the countries of study. This statement is part of *The Lancet Global Health*'s broader goal to decolonise global health.

See Online for appendix 2

Declaration of interests

RR is Chair and Trustee of the Sabin Vaccine Institute, a not-for-profit organisation in the USA. All other authors declare no competing interests.

Data sharing

The BOHEMIA consortium has agreed to make the data underlying each manuscript openly available on publication. The data supporting this paper can be found in the Virginia Tech Data Repository (https://doi.org/10.7294/30152659), which contains only aggregated, anonymous data that is sufficient to reproduce the analyses and results presented in the manuscript. Interested researchers can request access to the raw data directly from the BOHEMIA consortium (https://bohemiaconsortium.org/), subject to data use agreements and institutional review. The full R code used for data processing, modelling, and analysis is available in the same repository.

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References

1 WHO. World malaria report 2023. https://www.who.int/publications/i/item/9789240086173 (accessed Aug 6, 2024).
2 Basco R, Hernández-Perlines F, Rodríguez-García M. The effect of entrepreneurial orientation on firm performance: a multigroup analysis comparing China, Mexico, and Spain. *J Bus Res* 2020; **113:** 409–21.
3 Li J, Docile HJ, Zhao L, et al. Current status of malaria control and elimination in Africa: epidemiology, diagnosis, treatment, progress and challenges. *J Epidemiol Global Health* 2024; **14:** 561–79 .
4 WHO. Global Technical Strategy for Malaria 2016–2030. World Health Organization, 2015.
5 Chaccour C, Casellas A, Hammann F, et al. BOHEMIA: Broad One Health Endectocide-based Malaria Intervention in Africa-a phase III cluster-randomized, open-label, clinical trial to study the safety and efficacy of ivermectin mass drug administration to reduce malaria transmission in two African settings. *Trials* 2023; **24:** 128.
6 Chaccour C, Maia M, Kariuki M, et al. Ivermectin to control malaria–a cluster-randomized trial. *N Engl J Med* 2025; **393:** 362–75.
7 Marathe A, Shi R, Mendez-Lopez A, et al. Potential impact of 5 years of ivermectin mass drug administration on malaria outcomes in high burden countries. *BMJ Glob Health* 2021; **6:** e006424.
8 Kobylinski KC, Alout H, Foy BD, et al. Rationale for the coadministration of albendazole and ivermectin to humans for malaria parasite transmission control. *Am J Trop Med Hyg* 2014; **91:** 655–62.
9 Kamau A, Mtanje G, Mataza C, et al. Malaria infection, disease and mortality among children and adults on the coast of Kenya. *Malar J* 2020; **19:** 210.
10 WHO. WHO methods and data sources for global burden of disease estimates 2000–2019. December, 2020. https://www.who.int/docs/default-source/gho-documents/global-health-estimates/ghe2019_daly-methods.pdf (accessed Nov 28, 2025).
11 Ruiz-Castillo P, Imputiua S, Xie K, et al. BOHEMIA a cluster randomized trial to assess the impact of an endectocide-based one health approach to malaria in Mozambique: baseline demographics and key malaria indicators. *Malar J* 2023; **22:** 172.
12 Xie K, Marathe A, Deng X, et al. Alternative approaches for creating a wealth index: the case of Mozambique. *BMJ Glob Health* 2023; **8:** e012639.
13 Kenya National Bureau of Statistics. 2022 Economic Survey. https://www.knbs.or.ke/reports/2022-economic-survey/ (accessed Sept 20, 2024).
14 Kenya National Bureau of Statistics. 2019 Kenya population and housing census. Nairobi: Kenya National Bureau of Statistics, 2019.
15 US Centers for Disease Control and Prevention. Clinical features of malaria. May 9, 2024. https://www.cdc.gov/malaria/hcp/clinical-features/index.html (accessed Jan 7, 2026).
16 Iino H, Hashiguchi M, Hori S. Estimating the range of incremental cost-effectiveness thresholds for healthcare based on willingness to pay and GDP per capita: a systematic review. *PLoS One* 2022; **17:** e0266934.
17 Kazibwe J, Gheorghe A, Wilson D, Ruiz F, Chalkidou K, Chi Y-L. The use of cost-effectiveness thresholds for evaluating health interventions in low- and middle-income countries from 2015 to 2020: a review. *Value Health* 2022; **25:** 385–89.
18 Wisniewski J, Acosta A, Kolaczinski J, Koenker H, Yukich J. Systematic review and meta-analysis of the cost and cost-effectiveness of distributing insecticide-treated nets for the prevention of malaria. *Acta Trop* 2020; **202:** 105229.
19 Yukich J, Digre P, Scates S, et al. Incremental cost and cost-effectiveness of the addition of indoor residual spraying with pirimiphos-methyl in sub-Saharan Africa versus standard malaria control: results of data collection and analysis in the Next Generation Indoor Residual Sprays (NgenIRS) project, an economic-evaluation. *Malar J* 2022; **21:** 185.

20 WHO. WHO guidelines for malaria. June 3, 2022. https://iris.who.int/handle/10665/354781 (accessed Aug 30, 2025).

21 Gilmartin C, Nonvignon J, Cairns M, et al. Seasonal malaria chemoprevention in the Sahel subregion of Africa: a cost-effectiveness and cost-savings analysis. *Lancet Glob Health* 2021; **9:** e199–208.

22 Conteh L, Shuford K, Agboraw E, Kont M, Kolaczinski J, Patouillard E. Costs and cost-effectiveness of malaria control interventions: a systematic literature review. *Value Health* 2021; **24:** 1213–22.

23 WHO. High burden to high impact: a targeted malaria response. World Health Organization, 2018.

24 Dabira ED, Soumare HM, Conteh B, et al. Mass drug administration of ivermectin and dihydroartemisinin-piperaquine against malaria in settings with high coverage of standard control interventions: a cluster-randomised controlled trial in The Gambia. *Lancet Infect Dis* 2022; **22:** 519–28.

25 Somé AF, Somé A, Sougué E, et al. Safety and efficacy of repeat ivermectin mass drug administrations for malaria control (RIMDAMAL II): a phase 3, double-blind, placebo-controlled, cluster-randomised, parallel-group trial. *Lancet Infect Dis* 2025; **25:** 737–50.

26 Hutchins H, Pretorius E, Bradley J, et al. Adjunctive ivermectin mass drug administration for malaria control on the Bijagos Archipelago of Guinea-Bissau (MATAMAL): a quadruple-blinded, cluster-randomised, placebo-controlled trial. *Lancet Infect Dis* 2025; **25:** 424–34.

27 Sulik M, Antoszczak M, Huczyński A, Steverding D. Antiparasitic activity of ivermectin: four decades of research into a "wonder drug". *Eur J Med Chem* 2023; **261:** 115838.

28 Furnival-Adams J, Houana A, Nicolas P, et al. Collateral benefits of ivermectin mass drug administration designed for malaria against headlice in Mopeia, Mozambique: a cluster randomised controlled trial. *Infect Dis Poverty* 2025; **14:** 25.

29 Furnival-Adams J, Houana A, Saute F, et al. Direct and indirect protection against scabies through ivermectin mass drug administration designed for malaria in Mozambique: a cluster randomised controlled trial. *Lancet Microbe* 2025; **6:** 101189.