Audibert *et al. Malaria Journal* (2025) 24:124
https://doi.org/10.1186/s12936-025-05355-0

Malaria Journal

RESEARCH

Open Access

Projected uptake of sulfadoxine–pyrimethamine for perennial malaria chemoprevention in children under 2 years of age in nine sub-Saharan African countries: an epidemiologically-based 5-year forecast analysis

Céline Audibert[1*], Pierre Hugo[1], Roly Gosling[2], Charlotte Eddis[3], Meredith Center[3] and André Marie Tchouatieu[1]

Abstract

Background Perennial malaria chemoprevention (PMC) with sulfadoxine–pyrimethamine (SP) is recommended for children under 2 years of age living in areas of perennial malaria transmission. Initially delivered through the Expanded Programme of Immunization (EPI), recent pilot studies explored PMC delivery via the vitamin A supplementation programme or community health workers (CHWs). Understanding SP demand across the various delivery channels is key to implementing PMC.

Methods A 5-year epidemiologically-based forecasting model was developed to estimate SP volumes required for nine sub-Saharan countries based on seven different scenarios considering the EPI, vitamin A or CHWs delivery channels, alone or in combination. Model inputs were secondary data sources, enhanced with information from a field survey conducted among 40 national decision-makers and 176 healthcare providers. Projected SP volumes were estimated based on expected coverage and uptake within the eligible population. The efficiency of meeting the need versus demand was calculated for each scenario. A sensitivity analysis was performed for base, low and high estimates of the coverage and uptake rates. The forecasting period was 2023 to 2027.

Results The eligible population in the study countries was estimated at 21 million children in 2023. Estimated demand in 2027 ranged from 17.8 million SP doses for EPI to 49.6 million when combining all delivery channels. These results were highly dependent on the coverage and uptake rate of each delivery channel. The sensitivity analysis showed that uncertainty around the estimates ranged from twofold (Vitamin A), to 3.4-fold (CHWs). EPI was the most efficient channel overall (53%), but the efficiency of each scenario varied by country depending on local contexts.

Conclusions The model provides a tool to anticipate SP needs and demand for PMC under various scenarios, aiding manufacturers, donors, partners, governments, and procurement organizations in effective planning for PMC implementation.

Keywords Perennial malaria chemoprevention, Malaria, Sulfadoxine–pyrimethamine, Demand forecasting

*Correspondence:
Céline Audibert
audibertc@mmv.org
Full list of author information is available at the end of the article

Background

Malaria remains a major public health issue, with an estimated 263 million cases and 597,000 deaths reported in 2023, primarily in sub-Saharan Africa (SSA) [1]. Nearly 80% of malaria-related deaths in SSA involve children under 5 years of age [1]. Key measures to reduce malaria burden in this group include vector control, preventive chemotherapies, and vaccines [2]. Although seasonal malaria chemoprevention (SMC) protected around 53 million children in 2023, those in areas with perennial malaria transmission lack routine chemoprevention and depend on vector control methods like insecticide-treated bed nets and indoor residual spraying [1, 3].

Perennial malaria chemoprevention (PMC) involves administering a full course of antimalarial medication at set intervals, regardless of infection status, to prevent illness in moderate to high transmission settings [2]. Initially, PMC was known as intermittent preventive treatment in infants (IPTi) and was delivered through immunization services to infants at approximately 10 weeks, 14 weeks, and 9 months of age, aligning with the expanded programme on immunization (EPI) [2]. Studies indicated that using sulfadoxine–pyrimethamine (SP) for PMC was safe, cost-effective, and well-accepted, leading to a 27% reduction in clinical malaria cases and fewer instances of anaemia, parasitaemia, and hospital admissions [4]. However, uptake was limited, with Sierra Leone being the only country to implement the intervention widely before 2023. Potential explanations for this include concerns about SP-resistant *Plasmodium falciparum*, moderate efficacy, synchronization challenges with EPI, and gaps in coverage [5].

In 2022, the updated WHO malaria guidelines extended PMC to children beyond the first year of life in moderate-to-high-burden areas [2]. Restrictions based on the prevalence of molecular markers of SP resistance were lifted, as there was limited evidence that PMC efficacy was affected [2]. The guidelines also encouraged flexible dosing to target vulnerable children, enabling countries to adapt PMC based on local factors [2, 6]. It was anticipated that these modifications would increase PMC feasibility and acceptance in affected countries. Several pilot studies were initiated in perennial malaria settings, exploring different delivery methods for PMC, such as through the vitamin A supplementation programme, community health workers (CHWs), as well as the EPI [7–10]. Children in these pilots received up to eight SP doses. The effectiveness, feasibility, and cost of these approaches are still under evaluation, with countries expected to choose strategies that fit their specific contexts [6].

PMC addresses a critical public health need by protecting children in perennial malaria areas. Given the affordability of SP, PMC-SP has the potential to be a cost-effective intervention to protect children against malaria. As Africa prepares to adopt and expand this intervention, ensuring a steady supply of medicines is essential. Accurately projecting future demand for SP is required for donors, partners, governments, and pharmaceutical manufacturers to plan and allocate resources effectively. Given the diversity of potential PMC delivery approaches, and the need to work effectively across different health programmes within each country, it is important to understand the data reporting needs that will support accurate demand forecasting. A deterministic model framework was developed to forecast SP demand based on the various delivery methods tested during the PMC pilots using currently available data. The model aimed to identify the data and reporting needs for each channel and provide a template which can be updated and used by the countries conducting PMC pilots to inform scale up and support implementation.

Methods

Geographic focus and study setting

SP demand for PMC was estimated for the eight countries where PMC pilots were ongoing or planned at the time of the study in early 2022: Benin, Cameroon, Côte d'Ivoire, Democratic Republic of Congo (DRC), Mozambique, Nigeria, Sierra Leone, and Togo. Zambia was also included since a pilot was initially planned, but later abandoned. Table 1 outlines the interventions planned in each country at the time of the study, including delivery channel, child age ranges, and the number of SP doses. These data were incorporated into the forecast model to ensure all piloted delivery methods and schedules were considered.

Model design and data

To project future demand for SP for PMC, an epidemiology-based approach was chosen over consumption- or morbidity-based methods. The epidemiology-based model was appropriate because PMC is a risk-based intervention, relying on country-level transmission risks and child population projections. A consumption-based approach was not suitable due to the lack of data, as PMC had only been used in pilots, and does not consider the ambition to reach the entire eligible population. The morbidity-based model, which focuses on projected disease burden and future incidence, was also inappropriate for an intervention aimed at preventing disease [11]. Figure 1 summarizes the model framework. The first part of the model involved estimating the eligible population using secondary data (Fig. 1, Table 2) [1, 12–15].

Table 1 PMC pilot implementations ongoing in selected countries at the start of the study

Country	Delivery channel	Child age range	Target number of SP doses
Benin	EPI + CHWs	Up to 2 years old	Up to eight doses
Cameroon	EPI + CHWs	Up to 2 years old	Up to eight doses
Côte d"Ivoire	EPI + CHWs	Up to 2 years old	Up to five doses
DRC	To be determined by pre-pilot investigation		
Mozambique	EPI + CHWs + vitamin A	Up to 2 years old	Up to four doses
Nigeria	EPI	Up to 15 month old	Unspecified
Sierra Leone	EPI + vitamin A	Up to 2 years old	Up to six doses
Togo	EPI + vitamin A	Up to 2 years old	Up to six doses
Zambia	None	None	None

CHWs community health workers, *DRC* Democratic Republic of Congo, *EPI* expanded programme of immunization, *PMC* perennial malaria chemoprevention, *SP* sulfadoxine–pyrimethamine, *vitamin A* vitamin A supplementation programme

Eligible children were aged under 2 years old, living in moderate to high malaria transmission areas in the study countries, and estimated using World Bank and WHO data [1, 12]. As the entire population in the sample countries lived in such areas, no corrections were needed for malaria transmission [1]. Children receiving SMC were excluded because SMC is for seasonal malaria areas, whereas PMC is for perennial malaria areas; thus, there should be no overlap between the interventions. SMC data were available from the Ministries of Health for the included countries. Children receiving cotrimoxazole for HIV were excluded as PMC with SP should not be given to those on sulfa-based medications [2]. UNAIDS and UNICEF data were used to estimate the number of children infected with or exposed to HIV and receiving cotrimoxazole [13, 16]. No adjustment was needed for the prevalence of SP molecular markers of drug resistance as this is no longer a consideration within the updated World Health Organization (WHO) malaria guidelines [2]. All population parameters in the model were modifiable, and the model was designed to be adaptable to potential changes in eligibility criteria, including the emergence of clinically relevant parasite resistance to SP, or for example, should DRC implement SMC. Forecast dynamics included population growth for children under two determined from World Bank growth projections [12], with other factors remaining constant year over year.

The second part of the model involved considering the frequency of administration for each delivery channel in each country and estimating the expected coverage and uptake of PMC (Fig. 1). Coverage rate refers to the percentage of the total population that has access to PMC, while uptake rate indicates the percentage of the population that has adopted the intervention. These rates were estimated using primary data from PMC implementation for Sierra Leone and secondary sources for other countries, including Ministry of Health publications, Demographic and Health Surveys reports, WHO's Global Health Observatory, and UNICEF data [14, 17, 18]. For the EPI vaccination programme, coverage and uptake rates for three immunizations were considered independently: the diphtheria-pertussis-tetanus second and third vaccinations at 3 and 4 months of age, and the measles vaccine at 9 months of age. The model focused on these three exposures only in order to reflect the original delivery schedule for PMC. This scenario was used as a reference point and depicted what would happen if countries were to implement PMC as it was originally designed. The model allows to vary the number of exposures, if relevant. For the vitamin A and the CHWs channel, data were not available to assess each SP dosing opportunity independently, so the coverage and uptake values were constant for all dosing opportunities. However, the model does allow for coverage and uptake rate assumptions to be adjusted per dose as additional data become available. There was no adjustment for potential changes year-on-year in coverage or uptake for any channel, but this can be adjusted in the model with updated information. The model presented here assumed there were no synergies between channels, though this is also modifiable. The model also does not account for two interventions being distributed simultaneously, for example EPI and vitamin A being jointly distributed. There was not enough systematic and reliable data on the uptake and coverage of these combinations at the time of the survey to model these interactions.

Field survey

To support the coverage and uptake estimates, a field survey was conducted to validate and complement secondary data with insights from national decision-makers and healthcare workers involved in malaria care. Participants were recruited through purposive and snowball sampling and contacted by phone or email. Screening questions ensured participants had sufficient knowledge of malaria

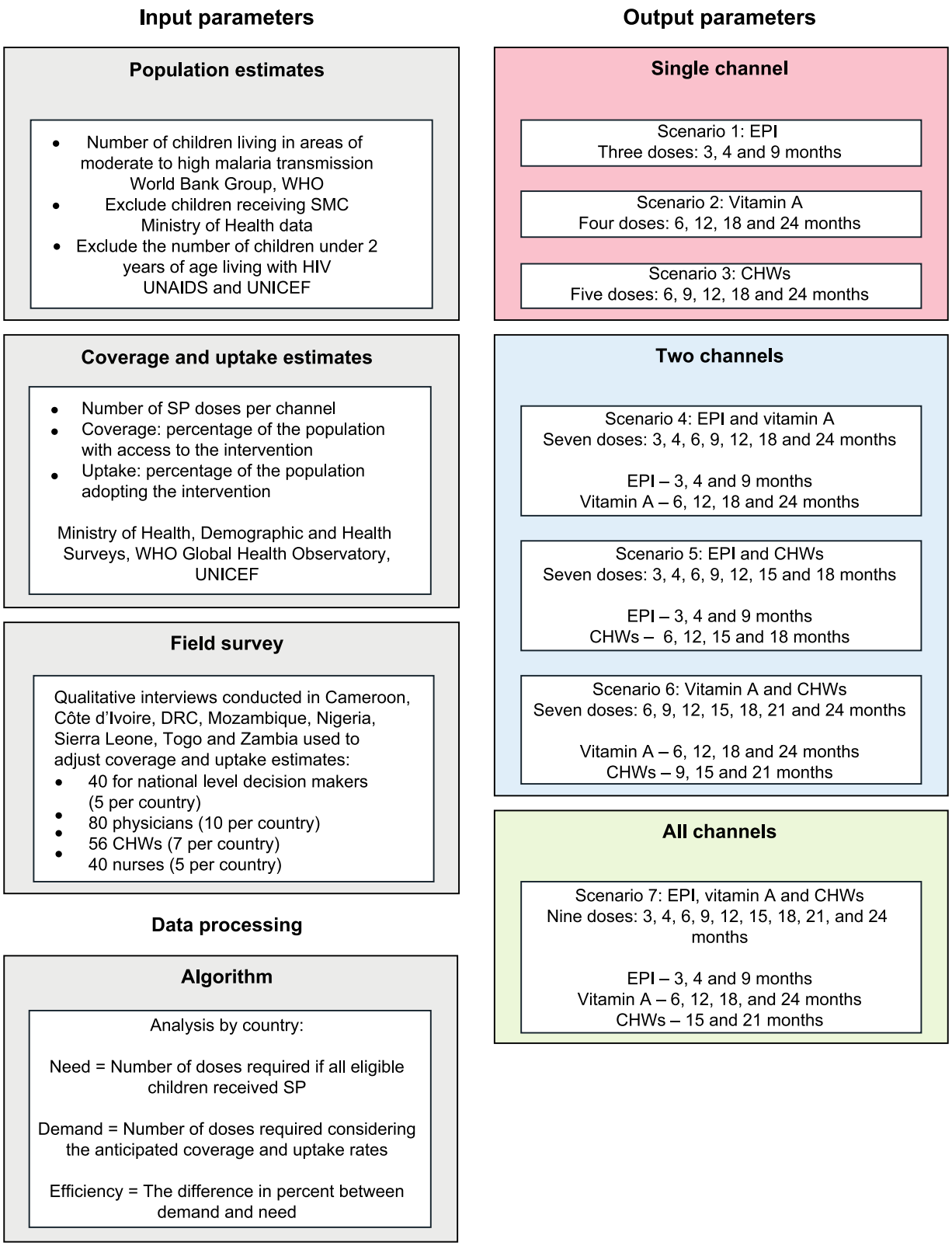

Fig. 1 Overview of the PMC delivery model. *CHWs* community health workers, *EPI* expanded programme of immunization, *PMC* perennial malaria chemoprevention, *vitamin A* vitamin A supplementation programme

Table 2 Forecast model inputs to estimate the number of children eligible for PMC in 2023 and growth projections

Country	Children under 2 years of age	Moderate to high transmission areas, %	Receiving cotrimoxazole, %	Receiving SMC, %	PMC eligible children	Population growth factor, %			
						2023–2024	2024–2025	2025–2026	2026–2027
Benin	836,737	100	0.16	2.5	814,472	1.9	1.8	1.9	1.5
Cameroon	1,767,234	100	0.29	17.0	1,461,599	1.5	1.5	1.5	1.3
Côte d'Ivoire	1,806,624	100	0.18	0.00	1,803,422	1.6	1.6	1.6	1.6
DRC	6,990,181	100	0.16	0.00	6,978,928	2.0	1.9	1.9	1.5
Mozambique	2,282,002	100	2.30	3.0	2,161,149	1.8	1.7	1.7	1.5
Nigeria	14,752,292	100	0.08	61.0	5,741,254	0.3	0.3	0.4	0.5
Sierra Leone	484,116	100	0.11	0.00	483,562	1.6	1.6	1.7	1.4
Togo	525,624	100	0.38	35.8	335,446	2.0	2.0	2.0	1.7
Zambia	1,311,086	100	1.60	0.00	1,290,145	3.1	2.7	2.6	1.1

PMC perennial malaria chemoprevention, *SMC* seasonal malaria chemoprevention

and involvement in the provision of malaria services. The discussion guide was tailored to respondent types and included questions about eligible populations, the EPI programme, the vitamin A programme, current malaria interventions, experience with SMC, experience with PMC, and CHWs roles and functions (Additional file 1). Some questions were omitted if irrelevant or unfamiliar to respondents at the investigators' discretion. The guide was piloted with a sub-set of respondents to refine the interview process. Data from the survey were compared with secondary sources, and a workshop held to review the findings.

Outcomes

Model outputs considered seven PMC delivery scenarios, including the EPI vaccination programme, the vitamin A supplementation programme, CHWs, and combinations of these channels (Fig. 1). The model allowed for a minimum of three and a maximum of nine SP doses. The simulation assumed the same delivery schedules were applied in each country for ease of comparison. The model allows to adapt the number and timing of exposures for each delivery channels to run country specific simulations in case a deep dive on any country included in the survey would be relevant. For CHWs and vitamin A delivery mechanisms, the number of contacts were derived from what was planned in the various pilots. The need, defined as the number of SP doses that would be required if the whole eligible population had unlimited and full access to PMC, and estimated demand for SP, accounting for the coverage and uptake rate of each delivery channel and representing the number of SP doses that are actually reaching the eligible population, were projected annually over a 5 years period (2023 to 2027). The ratio of need versus demand identified which delivery channel, or combination of channels, were the most efficient at reaching the eligible population.

Statistical methods

The model was formulated in Microsoft Excel.

The need in terms of the planned doses (P) for the eligible population (E) was calculated as:

$$P = \left(\frac{E}{2}\right) \times N$$

where N is the total number of doses for any scenario. Because the target population for PMC are children aged from zero to 2 years old, the eligible population (E) was divided by two to annualize the population, assuming an even split between the number of children aged zero to 1 year old and those 1 to 2 years old. This follows an annual birth cohort approach and assumes that children were either zero to 12 months old or 1 to 2 year old at the beginning of each year. This approach was selected for ease of modelling.

Demand was based on the actual doses (A), considering coverage (C) and uptake (U), and was calculated as:

$$A = \frac{E}{2} \sum_{i=1}^{n} (C_i \times U_i)$$

where n is the number of doses, C_i is the coverage for dose i, and U_i is the uptake for dose i.

Percentage efficiency of each channel (F) was calculated as:

$$F = \left(\frac{A}{P}\right) \times 100$$

Model results were presented in estimated numbers of SP doses. The model assumed that all countries implemented PMC simultaneously, that any eligible child would receive PMC regardless of whether they had received previous doses, and that all children were eligible for all doses. Thus, the model did not follow a cohort approach, nor did it consider children's age distribution.

Sensitivity analysis

In order to evaluate the uncertainty of this deterministic model, a sensitivity analysis was performed by varying the uptake and coverage rates of each delivery channels. A base case as well as lower and higher limits were determined for each exposures and specific to each country. The values for the base, low and high limits were derived from the findings of the desk research and field survey. No statistical analysis was performed.

Ethics statement

Separate local ethics clearances were obtained for each country. In Benin, authorization was delayed and no field data were collected. Before each interview, the study's objective was explained, and written informed consent was obtained. Confidentiality was maintained, and permission for recording confirmed. The study did not involve patient data, so no institutional review board approval was necessary.

Role of the funding source

UNITAID was not involved in the design or conduct of the study or in the development of this publication.

Results

The eligible population across the nine SSA countries comprised 21,069,977 million children in 2023 (Table 2). A total of 40 qualitative interviews were conducted between May to October 2022 with national decision-makers, including representatives from National Malaria Control Programmes, in-country funding partners, and global health agencies (five interviews per country). Additionally, 176 quantitative interviews were conducted with end-users such as physicians, nurses and CHWs (10, 5, and 7 interviews per country, respectively) (Fig. 1). The survey data were used to refine the assumptions about coverage and uptake rates for inclusion in the forecast model. The base case as well as the low and high limits were defined based on the findings from the research, and were specific to each exposures for each country. The low and high limits were established based on extreme values identified through the desk research and the interviews with experts, while the base case values were derived from those mentioned most frequently. This resulted in estimations of a base case and upper and lower limits to reflect potential inaccuracies in the estimates (Additional file 2).

Figure 2A shows the estimated SP demand in 2027 for each delivery channel and for the three sensitivity cases, expressed as the number of SP doses that are actually reaching the eligible population. Focusing on the base case, delivery through the EPI programme generated the lowest demand, totalling 17.8 million doses in 2027. This lower demand was anticipated since this scenario includes the fewest SP doses (3 per year) (Fig. 1). The vitamin A or CHWs delivery channels used independently, returned a higher demand for SP than the EPI programme alone, reaching 21.6 million and 25.6 million doses, respectively, by 2027. Combining any two delivery channels resulted in similar demand levels: 36.9 million doses for CHWs and vitamin A, 38.9 million for EPI and CHWs, and 39.4 million for EPI and vitamin A in 2027. However, using all three channels resulted in a demand of nearly 49.7 million doses in 2027. The growth rate for the period 2023 to 2027 remained constant, as no changes in coverage and uptake over time were included and population growth was considered the only driver.

To estimate forecast uncertainty, lower and upper boundaries were estimated for uptake and coverage rates for each delivery channel (Additional file 2). The uncertainty is shown in Fig. 2A as the percentage difference in the variation between the lower and upper boundaries in 2027. Uncertainty in the estimates ranged from less than twofold (196%) with the vitamin A channel, to around 3.4-fold (343%) with CHWs (Fig. 2A).

Figure 2B illustrates the gap between the estimated need if the entire eligible population had full access to PMC and the demand for SP doses for each delivery channel considering coverage and uptake rates by 2027. Comparing the need and demand identifies the most efficient delivery channel or combination of channels. The EPI delivery channel was the most efficient, delivering 53% of the needed SP doses by year 5 and the CHWs channel was the least efficient, delivering 45% of the needed SP doses (Fig. 2B). The remaining scenarios were between 47 and 50% efficient.

Country-level analysis showed that the most efficient delivery channels varied per country (Fig. 3). The EPI programme was the most efficient single channel in Benin, Côte d'Ivoire, and Mozambique, meeting 75%, 76% and 82% of the need, respectively. However, it was the least efficient in Sierra Leone, with only 41% of the need being met. The vitamin A programme was most efficient in DRC, Sierra Leone, Togo, and Zambia, with 45%, 77%, 86% and 80% of the need being met, respectively. The CHWs channel was most efficient in Cameroon and Nigeria, meeting 57% and 62% of the SP

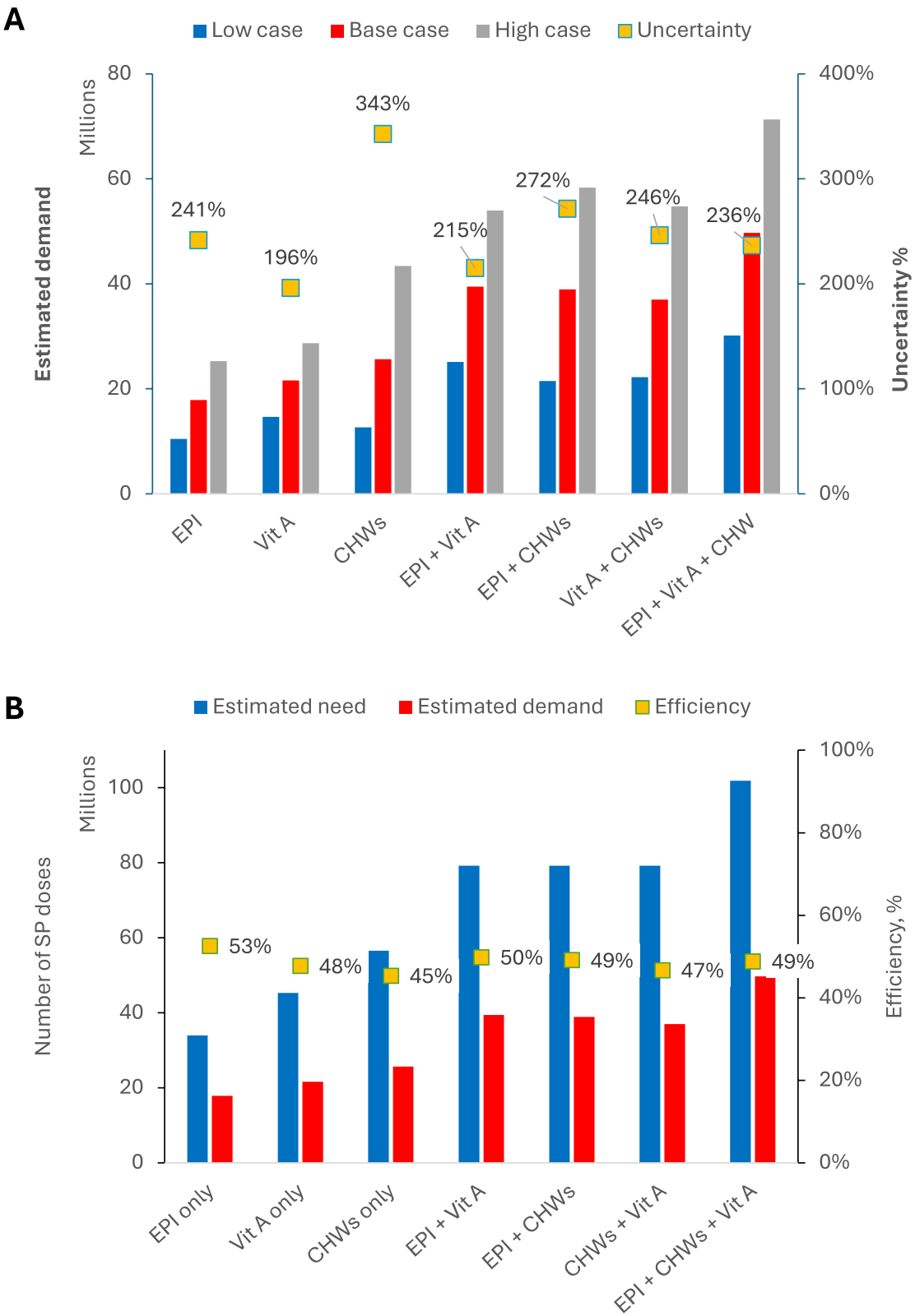

Fig. 2 PMC delivery model outputs by channel. **A** Analysis of uncertainty for the actual dose estimates based on a low and high limits around the base case for each scenario in 2027. **B** Channel efficiency comparing the need for SP in the entire eligible population versus the demand for SP considering coverage and uptake rates in 2027. *CHWs* community health workers, *EPI* expanded programme of immunization, *PMC* perennial malaria chemoprevention, *Vit A* vitamin A supplementation programme

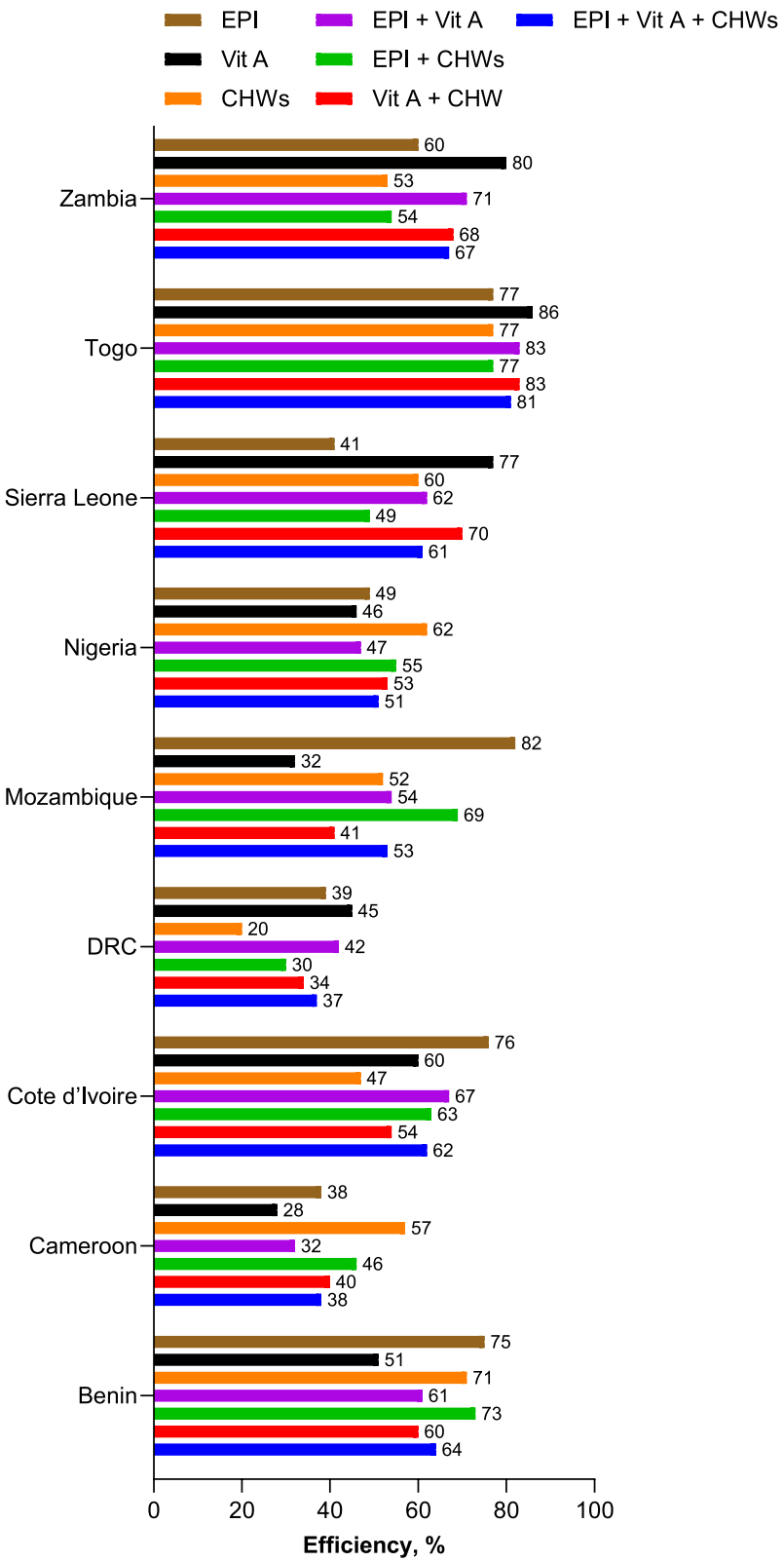

Fig. 3 Country analysis of PMC delivery channel efficiency. Channel efficiency comparing the need for SP in the entire eligible population versus the demand for SP considering coverage and uptake rates by country in 2027. *CHWs* community health workers, *EPI* expanded programme of immunization, *PMC* perennial malaria chemoprevention, *Vit A* vitamin A supplementation programme

need, respectively. Combining delivery channels did not improve efficiency beyond what each could achieve alone, as no synergistic effects were included in the model. However, combining channels did cover more children, as shown in Fig. 1. The analysis also highlighted disparities across countries, such as Togo's consistent demand versus need ratio across all channels, while other showing greater variation between channels.

Discussion

This forecast model examined the effects of various PMC delivery channels on SP need and demand across nine SSA countries. By 2027, SP demand could range from 17.8 million doses if delivered solely through the EPI programme to 49.6 million doses if delivered via a combination of EPI, Vitamin A, and CHWs channels. Although delivery of PMC through the EPI channel in the first year of life would reach fewer children, it is estimated to be the most efficient, delivering 53% of the needed doses.

Uptake and coverage rates were critical assumptions, significantly affecting SP demand. As the data from the PMC pilot studies was not yet available, coverage and uptake estimates were adjusted using feedback from an extensive field survey to model the effect of the uncertainty in the data. However, different channels had different levels of uncertainty, for example, SP demand could increase by 3.4-fold between low and high scenarios for the CHWs channel versus twofold for the vitamin A channel. This analysis emphasizes the importance of developing standard and routine reporting mechanisms to capture data on coverage and uptake rates for each channel to improve data reliability and reduce uncertainty, particularly where community-based delivery is contemplated. As the model allows for adjustment of coverage and uptake rates, it can also be used to estimate the effects of changes in these rates that may occur through strengthening any specific delivery channel. This supports manufacturers, funders and policymakers to understand the potential impact of initiative to increase uptake and coverage rates [11]. Although we did not consider channel synergies in this analysis, these could also be factored into the model where there is scope for integration of the different channels.

Efficiency considers the degree to which the need for PMC is met via each scenario. From an implementation perspective, while the EPI channel was the most efficient, it would still reach only just over half of eligible children. Studies show that timely, full vaccination rates are especially low among children from the poorest households, rural areas, and those whose mothers have low educational levels [19, 20]. Therefore, improving access to vaccination programmes in these underserved population could increase the delivery of PMC through the EPI channel. In addition, a study in Sierra Leone, the only country with a national PMC scale-up at the time of this study, showed that PMC coverage through the EPI was lower than vaccination rates at the same EPI contacts, with declining coverage as children age [21]. The reasons for this decline need to be investigated further in order to design supportive measures. Potential causes for this decline include out of stock situation, reluctance to use PMC, insufficient training on PMC administration, or lack of awareness. According to Fombah et al. [21], about half the children attending the immunization programme received all three PMC doses. This is slightly higher than our estimated 41%, indicating a conservative model approach. These findings suggest that effective PMC delivery through the EPI channel requires strengthening of delivery strategies such as outpost and mobile delivery, to improve acceptability and access among hard-to-reach populations and ensure full attendance at all EPI visits.

The vitamin A channel was estimated to achieve 48% of the demand compared to the need for PMC. A recent study in Mozambique, Senegal, Sierra Leone, and Tanzania found that routine vitamin A delivery approaches were insufficient for public health impact and suggested intensive outreach efforts to increase coverage, especially in resource-poor settings [22]. More evidence is needed to understand the resources required for routine versus outreach approaches and their suitability for PMC delivery. The current model assumes that PMC would be largely distributed through routine vitamin A supplementation, which might need adjustment if a mix of routine and outreach approaches is developed. Scaling up the vitamin A channel may not be cost-effective in all settings due to the lower prevalence of vitamin A deficiency among children [23]. However, the potential for PMC to enhance the cost-effectiveness of vitamin A distribution by providing malaria protection at the same time requires investigation.

PMC delivery through the CHWs channel was the least efficient (45%), while reaching the most children. CHWs'broad reach is due to their provision of various health services, including education, status improvement and disease prevention [24–26]. However, health worker shortages in the areas of most need and multilevel contextual barriers may limit the efficiency of CHWs in delivering PMC [27–29]. Despite these limitations, CHWs have increased malaria prevention uptake in pregnant women [30], so adaptations for PMC delivery could similarly increase uptake and coverage. The model assumed that CHWs would deliver PMC directly and did not consider their potential role in encouraging EPI attendance or participation in the vitamin A programme,

so there is the potential for synergy with other channels. However, most SSA countries do not currently use CHWs to deliver routine malaria prevention interventions to young children, highlighting the need for capacity-building strategies to support scale-up.

The input flexibility of the model ensures that it is highly generalizable across the settings in which PMC is recommended. It could also be adapted to the sub-national level. However, there are some key limitations. Coverage and uptake data were obtained through secondary resources, with some primary data coming from PMC delivery programme reports in Sierra Leone. Combining primary and secondary data may have led to misaligned results, given the different design considerations. The model also employed simplifying assumptions that do not consider the following: the impact of malaria vaccines on PMC opportunities, population changes due to migration, country-specific incidence rates of malaria, drug expiry and wastage, and contextual factors impacting uptake and coverage, such as access to healthcare and CHW availability. A further consideration is that the age profile of children aged under 2 years was not considered within the model which assumed children were eligible for all PMC doses in any year. As a consequence, the outcomes of the model should be seen as illustrative. Given the uncertainty around some variables, the results should be interpreted as directional.

As more data become available, more complex models can be developed. However, to provide a more accurate assessment of SP demand and need for the malaria programme, reporting and monitoring systems must capture the necessary information to refine assumptions. Up-to-date data on eligible populations, disaggregated by age group, as well as data on children receiving SMC or cotrimoxazole, are needed to improve national estimates. Accurate projections of population growth and migration trends are also required. Since coverage and uptake rates drive demand, understanding changes over time and potential regional differences is key. Also, information on the potential synergistic effects of combining delivery channels could reveal added benefits. In terms of outputs, contextual factors such as logistical challenges, healthcare worker availability, infrastructure, and community acceptance could explain varying channel performance. Data on the costs and feasibility of each scenario will also be needed to support cost-effectiveness models.

The analysis highlights the importance of considering each country's unique context, as local factors influence SP dose delivery efficiency through different channels and combinations. PMC success depends on countries' willingness to scale up, manufacturers' confidence in global demand, and funders' and governments' ability to estimate demand based on potential public health benefits and affordability. Identifying the most effective delivery channels allows for targeted strengthening to maximize the PMC intervention. Additionally, the model can be used to look more closely at why specific channels are performing well in certain countries, providing opportunities for shared learning and regional support between countries implementing PMC. This work needs to be complemented by a thorough cost effectiveness analysis of the various delivery channels to guide how to efficiently implement and scale up PMC.

Conclusions

In conclusion, this forecast model estimated the annual SP doses required for PMC and compared different potential delivery channels. Despite the data limitations, this study provides valuable guidance for policymakers, funders, and manufacturers in identifying the key drivers of PMC need, demand and efficiency. It also indicates the reporting and monitoring mechanisms required to obtain the necessary data to inform policy. Overall, the model allows exploration of the factors impacting the scale up of PMC delivery in SSA to maximize the public health benefits.

Abbreviations

CHWs	Community health workers
DRC	Democratic Republic of Congo
EPI	Expanded programme on immunization
HIV	Human immunodeficiency virus
IPTi	Intermittent preventive treatment in infant
PMC	Perennial malaria chemoprevention
SMC	Seasonal malaria chemoprevention
SP	Sulfadoxine pyrimethamine
SSA	Sub-Saharan Africa
UNICEF	United Nations Children's Fund
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12936-025-05355-0.

Additional file 1. Discussion guide, provided as Wordfile. Provides the list of questions that were used in the survey

Additional file 2. Coverage and uptake rates assumptions per country and for each delivery channel, shown as a Wordfile. Provides low, base and high assumptions for the coverage and uptake rates, based on the results from the desk research and field survey

Acknowledgements

The authors thank IQVIA for their valuable contributions to the survey. Naomi Richardson (Magenta Communications Ltd) provided editorial and graphics support and was funded by Medicines for Malaria Venture

Author contributions

CA, PH and AMT conceptualised the study. CA, PH, MC and AMT curated the key population survey databases. CA, PH, MC and AMT reviewed the

secondary source documents and extracted data. CA, PH, RG, CE, MC, AMT analysed the data, CA wrote the first draft of the manuscript. All authors contributed to interpretation of the results and edited the manuscript for intellectual content. All authors read and approved the final version of the manuscript for submission.

Funding
The funder, UNITAID, was not involved in the design or conduct of the study or in the development of this publication.

Availability of data and materials
All data generated or analysed during this study are included in this published article and its supplementary information files. The excel based model can not be made publicly available but outcome of simulations can be shared by the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
The study did not involve patients and did not collect patient characteristics. The purpose of the study was to collect experts' professional opinions and insights and did not collect personal data or sensitive information. As such, there was no institutional review board involved in approving the research. Separate local ethics clearances were obtained for each country. Written informed consent was obtained from each participant.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

Author details
[1]Medicines for Malaria Venture (MMV), Route de Pre-Bois 20, 1215 Meyrin, Switzerland. [2]London School of Hygiene & Tropical Medicine, London, UK. [3]Population Service International, Abidjan, Côte d'Ivoire.

Received: 20 December 2024 Accepted: 28 March 2025
Published online: 16 April 2025

References

1. WHO. World malaria report 2024. Geneva: World Health Organization; 2024. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2023. Accessed 15 ember 2024.
2. WHO. Guidelines for malaria. Geneva: World Health Organization; 2023. https://www.who.int/publications/i/item/guidelines-for-malaria. Accessed 27 Aug 2024.
3. Ashley EA, Poespoprodjo JR. Treatment and prevention of malaria in children. Lancet Child Adolesc Health. 2020;4:775–89.
4. Esu EB, Oringanje C, Meremikwu MM. Intermittent preventive treatment for malaria in infants. Cochrane Database Syst Rev. 2019;12: CD011525.
5. Audibert C, Tchouatieu AM. Perception of malaria chemoprevention interventions in infants and children in eight sub-Saharan African countries: an end user perspective study. Trop Med Infect Dis. 2021;6:75.
6. Menendez C, Saute F, Greenwood B, Schellenberg D, Snow R, Alonso PL. Avoiding another lost decade in reducing malaria burden in African infants and young children. Lancet Glob Health. 2022;10:e1385–6.
7. The PLUS Project. Reducing morbidity and mortality due to malaria and anemia in children under 2; 2023. https://www.psi.org/plusproject/home/ Accessed 27 Aug 2024.
8. PATH, Malaria Consortium. Scaling IPTi-SP in DRC and Nigeria: a scoping report 2022. .https://files.givewell.org/files/DWDA%202009/PATH/PATH_and_Malaria_Consortium_Scaling_IPTi_SP_in_DRC_and_Nigeria_A_scoping_report_2022.pdf. Accessed 27 Aug 2024.
9. Multiply. Implementation of perennial malaria chemoprevention (PMC) within the MULTIPLY project started in Mozambique; 2022. https://multiplyipti.net/implementation-of-perennial-malaria-chemoprevention-pmc-within-the-multiply-project-started-in-mozambique-2-december-2022-2-2-2/. Accessed 27 Aug 2024.
10. Malaria Consortium. Reducing malaria morbidity in infants through perennial malaria chemoprevention in Nigeria: Investigating clinical effectiveness and operational feasibility. 2021. https://www.malariaconsortium.org/media-download-file/202405201142/pbpmcnigeria.pdf. Accessed 27 Aug 2024.
11. Subramanian L. Effective demand forecasting in health supply chains: emerging trend, enablers, and blockers. Logistics. 2021;5:12.
12. World Bank Group. Population estimates and projections. 2023. https://databank.worldbank.org/source/population-estimates-and-projections. Accessed 27 Aug 2024.
13. Joint United Nations Programme on HIV/AIDS. The path that ends AIDS: UNAIDS Global AIDS Update 2023. https://thepath.unaids.org/wp-content/themes/unaids2023/assets/files/2023_report.pdf. Accessed 27 Aug 2024.
14. UNICEF. Immunization; 2024. https://data.unicef.org/topic/child-health/immunization/. Accessed 17 Aug 2024.
15. WHO. World malaria report 2021. Geneva: World Health Organization; 2021. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021. Accessed 27 Aug 2024.
16. UNICEF. HIV/AIDS data: Global and regional trends; 2024. https://data.unicef.org/topic/hivaids/global-regional-trends/. Accessed 27 Aug 2024.
17. Demographic and Health Surveys Program. Publications by country; 2024. https://dhsprogram.com/Publications/Publications-by-Country.cfm. Accessed 27 Aug 2024.
18. WHO. The Global Health Observatory. Geneva: World Health Organization; 2022. https://www.who.int/data/gho/indicator-metadata-registry/imr-details/69. Accessed 27 Aug 2024.
19. Fenta SM, Biresaw HB, Fentaw KD, Gebremichael SG. Determinants of full childhood immunization among children aged 12–23 months in sub-Saharan Africa: a multilevel analysis using Demographic and Health Survey Data. Trop Med Health. 2021;49:29.
20. Mutua MK, Mohamed SF, Porth JM, Faye CM. Inequities in on-time childhood vaccination: evidence from sub-Saharan Africa. Am J Prev Med. 2021;60(Suppl 1):S11–23.
21. Fombah AE, Chen H, Owusu-Kyei K, Quinto L, Gonzalez R, Williams J, et al. Coverage of intermittent preventive treatment of malaria in infants after four years of implementation in Sierra Leone. Malar J. 2023;22:145.
22. Janmohamed A, Doledec D, Dissieka R, Jalloh UH, Juneja S, Beye M, et al. Vitamin A supplementation coverage and associated factors for children aged 6 to 59 months in integrated and campaign-based delivery systems in four sub-Saharan African countries. BMC Public Health. 2024;24:1189.
23. Kannan A, Tsoi D, Xie Y, Horst C, Collins J, Flaxman A. Cost-effectiveness of Vitamin A supplementation among children in three sub-Saharan African countries: An individual-based simulation model using estimates from Global Burden of Disease 2019. PLoS ONE. 2022;17: e0266495.
24. Olaniran A, Smith H, Unkels R, Bar-Zeev S, van den Broek N. Who is a community health worker ?—a systematic review of definitions. Glob Health Action. 2017;10:1272223.
25. World Health Assembly. Community health workers delivering primary health care: opportunities and challenges; 2019. https://iris.who.int/handle/10665/329264. Accessed 27 Aug 2024.
26. WHO. Guideline on health policy and system support to optimize community health worker programmes. Geneva: World Health Organization; 2018. https://www.who.int/publications/i/item/9789241550369. Accessed 27 Aug 2024.
27. Ahmat A, Okoroafor SC, Kazanga I, Asamani JA, Millogo JJ, Illou MM, et al. The health workforce status in the WHO African Region: findings of a cross-sectional study. BMJ Glob Health. 2022;7(Suppl 1): e008317.
28. Gebremeskel AT, Omonaiye O, Yaya S. Multilevel determinants of community health workers for an effective maternal and child health programme in sub-Saharan Africa: a systematic review. BMJ Glob Health. 2022;7: e008162.
29. Kok MC, Broerse JEW, Theobald S, Ormel H, Dieleman M, Taegtmeyer M. Performance of community health workers: situating their intermediary

position within complex adaptive health systems. Hum Resour Health. 2017;15:59.
30. Gonzalez R, Manun'Ebo MF, Meremikwu M, Rabeza VR, Sacoor C, Figueroa-Romero A, et al. The impact of community delivery of intermittent preventive treatment of malaria in pregnancy on its coverage in four sub-Saharan African countries (Democratic Republic of the Congo, Madagascar, Mozambique, and Nigeria): a quasi-experimental multicentre evaluation. Lancet Glob Health. 2023;11:e566–74.

Publisher's Note