

Impact of enhanced malaria surveillance processes and data feedback on data comprehensiveness and malaria case management in Arba Minch Zuriya District, Ethiopia: a pre-post implementation study

Tamiru Shibiru Degaga

`tamiru.degaga@menzies.edu.au`

College of Medicine and Health Sciences, Arba Minch University

Samuel Alemu Bamboro

College of Medicine and Health Sciences, Arba Minch University

Tedla Teferi Tego

Arba Minch General Hospital

Kalkidan Muluneh Mengistu

College of Medicine and Health Sciences, Arba Minch University

Hellen Mnjala

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Grant Lee

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Robert J Commons

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Kamala Thriemer

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Ric N Price

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Nicholas M Douglas

Global and Tropical Health Division, Menzies School of Health Research and Charles Darwin University

Research Article

Keywords: Malaria, Surveillance, Continuous quality improvement, CQI, Data completeness, Dosing accuracy, Weight-based dosing, South Ethiopia

Posted Date: October 18th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10990781/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Good quality malaria care requires comprehensive clinical data collection and prescription of appropriate antimalarial regimens based on specific patient attributes such as weight and species of infection. We evaluated whether introduction of enhanced routine malariometric data collection combined with a Continuous Quality Improvement (CQI) programme could improve data completeness and adherence to recommended antimalarial treatment and dosing in southern Ethiopia.

Methods

We conducted a longitudinal, pre-post implementation study at two public health centres in Arba Minch Zuriya district, Southern Ethiopia, from March 2023 to March 2026. The implementation package (introduced in September 2024) included enhanced data collection and checking processes combined with presentation of automatically generated data reports to clinic staff at regular CQI meetings to identify gaps in malaria case management and data comprehensiveness and formulate locally appropriate corrective actions. Routine malaria records from the pre-CQI period were compared with prospectively collected data during the transition period and after three CQI cycles. Baseline malaria epidemiology, surveillance data comprehensiveness, antimalarial regimen selection, and weight-based drug dosing accuracy were assessed.

Results

During the study period, 59,394 patients were tested for malaria, and 22.8% (13,530) were positive by microscopy. Clinical records were available for 90.5% (12,243) of these patients, and *Plasmodium* species information was available for 99.2% (12,145). *Plasmodium vivax* accounted for 54.1% (6,566) of infections, and 59.8% (7,262) of the patients were male. Overall surveillance data completeness improved from 87.5% (5,351/6,119) pre-CQI to 97.2% (5,951/6,124) post-CQI. Among patients eligible for primaquine anti-relapse treatment, primaquine prescription (at any dose) increased from 81.9% (2,778/3,394) pre-CQI to 99.8% (553/554) in the third CQI cycle ($p < 0.0001$). The proportion of patients with *P. vivax* malaria receiving the recommended 14-day primaquine regimen increased from 96.7% to 99.3%, while inappropriate single-dose primaquine use declined from 3.3% to 0.7% over the same time period. Incorrect weight-based chloroquine dosing reduced from 19.5% to 4.0% (risk reduction 15.5%, 95% confidence interval (CI): 11.7–19.2; $p < 0.001$), while incorrect weight-based 14-day primaquine dosing reduced from 15.6% to 3.3% (risk reduction 12.3%, 95% CI: 9.0–15.6; $p < 0.001$).

Conclusions

Implementation of enhanced malaria surveillance, integrated with CQI, was associated with substantial improvements in data completeness, adherence to recommended antimalarial treatment, and weight-based dosing accuracy at two health centres in southern Ethiopia. The progressive improvements across CQI cycles suggest that routine data review, feedback, and locally driven corrective actions provide a feasible approach to strengthening malaria case management, including *P. vivax* anti-relapse treatment.

Introduction

Malaria remains a major global public health problem, with an estimated 282 million cases and over 610,000 deaths reported worldwide annually (1). Sub-Saharan Africa continues to bear a disproportionately high burden of malaria, accounting for approximately 94% of global cases and 95% of deaths (1). The region faces myriad persistent challenges, including high transmission intensity, limited healthcare resources, and variability in the quality of diagnosis and treatment. In this context, ensuring effective delivery of malaria interventions at the primary healthcare level is critical for reducing malaria morbidity and mortality and for achieving long-term malaria control and elimination goals. Despite substantial progress in reducing the burden of malaria since the early 2000s, gains have plateaued in many countries (1).

In Ethiopia, malaria remains an important public health concern, with approximately 60–70% of the population living in malaria-endemic areas. Transmission varies by altitude, season, and ecological factors (2). Both *Plasmodium falciparum* (*P. falciparum*) and *Plasmodium vivax* (*P. vivax*) are co-endemic, with *P. falciparum* accounting for 70% of cases (2). Transmission of malaria parasites in Arba Minch Zuria Woreda occurs year-round, and the ratio of *P. falciparum* to *P. vivax* infections is similar to the national average (3).

Ethiopian national malaria control strategies emphasise prompt diagnosis, effective treatment, and strengthened surveillance systems as key pillars for malaria elimination (4). National malaria guidelines in Ethiopia recommend species-specific treatment, including artemether-lumefantrine and single-dose 0.25 mg/kg primaquine for *P. falciparum* and chloroquine plus 14-day 0.25 mg/kg/day primaquine (total 3.5 mg/kg) anti-relapse therapy for *P. vivax* (“radical cure”) (5). Implementation of these guidelines in routine clinical practice is often suboptimal due to challenges such as incomplete clinical data collection, inconsistent diagnostic practices, and drug stockouts.

Recent evidence from health systems strengthening initiatives has demonstrated that enhancing routine malaria surveillance through improved data collection, regular data feedback, and continuous quality improvement (CQI) processes can substantially improve both data completeness and adherence to treatment guidelines (6–8).

Robust surveillance data enables timely detection of cases, monitoring of trends, and evaluation of intervention effectiveness (1). In Ethiopia, malaria surveillance is primarily conducted through the national Health Management Information System (HMIS) (9), in which data are collected routinely at health facilities and aggregated at district, regional, and national levels. However, like many routine

health information systems in low-resource settings, challenges persist, including incomplete documentation, data inaccuracies, and limited use of data for decision-making at the facility level (9). High-quality clinical documentation is particularly important for malaria case management, where treatment decisions depend on accurate diagnosis, patient characteristics (such as age, weight, and pregnancy status), and adherence to national treatment guidelines (2).

To address shortcomings in malaria surveillance and guideline-concordant treatment, the SHEPE study (Strengthening Health Systems for Effective Primaquine Radical Cure in Ethiopia) was conducted. This before-versus-after longitudinal prospective implementation study involved the introduction of enhanced malariometric surveillance and CQI strategies at two health centres, Shelle and Lante, in the Arba Minch Zuriya district of southern Ethiopia. The aims were to determine the epidemiology of malaria at these two clinics and the impact of the intervention on data quality and concordance of treatment with national guidance. Findings from this work are expected to inform strategies for improving malaria surveillance and case management in Ethiopia and similar settings.

Methods

This was a longitudinal, before-versus-after implementation study conducted at two public health centres in Arba Minch Zuriya district, Ethiopia.

Study settings

Arba Minch is located in the Gamo Zone of the South Ethiopia Regional State, about 500 kilometers south of Addis Ababa, at an elevation of 1,285 meters above sea level. It is the largest town in Gamo Zone, surrounded by Arba Minch Zuria Woreda (district), which is one of the middle administrative classes in the surroundings of Arba Minch town. Shelle Health Centre and Lante Health Centre are two of the five health centres in the woreda. Based on the 2007 Census conducted by the Central Statistical Agency (CSA), the woreda has a total population of 164,529 people (10).

Baseline data collection processes

Prior to the introduction of enhanced malariometric surveillance, routine data collection processes for malaria patients at Shelle and Lante Health Centres involved documentation of the following variables in paper-based clinic registers: date of presentation, medical record number (MRN), address, sex, age, and clinical diagnosis. Clinic staff also recorded whether the current malaria-related presentation was a repeat visit (defined as a visit within 1 month of a previous presentation). In the clinics' laboratory registers, the following data were recorded: the date of presentation, name, address, sex, age, as well as the microscopy/RDT results (positive/negative) and the species identification. In the pharmacy registers, the date of presentation, MRN, name, age, sex, diagnosis, and treatment (only drug name, no dose) were recorded.

Intervention: continuous quality improvement and implementation of enhanced malariometric surveillance

The intervention consisted of strengthening routine malaria surveillance through improved data collection, three-monthly automated data reporting and three-monthly CQI workshops using the automated reports to provide feedback and foster ongoing improvements in both clinical practice and data accuracy. The workshops were attended by the heads of the health centres, healthcare providers involved in diagnosing and treating patients with malaria, malaria programme officers, and the head of the disease prevention and control section in the Woreda Health Office. CQI processes followed the Plan-Do-Study-Act (PDSA) (11) approach to assist healthcare staff at the two study clinics to identify problems, set achievable goals, implement plans, and reassess improvements.

In August 2024, prior to data collection, a one-day orientation was delivered at both health centres which included explanations of the study procedures, standardised data recording, and the enhanced surveillance system. Prospective data collection commenced in September 2024 and included all patients presenting to the participating health centres with malaria.

The routine paper-based clinic register does not capture some variables required to evaluate the quality of malaria treatment implementation. Therefore, a supplementary surveillance logbook was developed and introduced alongside the routine register. In addition to the standard clinical and laboratory information, the enhanced surveillance recorded the following details: patient weight, pregnancy status, breastfeeding status, antimalarial treatment prescribed and dose (number of tablets prescribed), drug dispensing status, whether counselling was provided at the time of treatment, stock availability, and any subsequent adverse events reported until 21 days after treatment was initiated. This enhanced surveillance system enabled prospective recording of case management practices, treatment quality, and patient safety while complementing the existing routine malaria surveillance system.

Retrospective and prospective data entry and management

The study included both retrospective and prospective data collection. The retrospective data refers to the baseline (pre-CQI) period; two trained research nurses extracted data from routine clinic and laboratory registers and patients' medical records. Patient medical record numbers were used to retrieve individual charts from the health centres' archives when additional clinical information was required. Data extracted from these hard-copy sources were entered directly into a secure Research Electronic Data Capture (REDCap) database hosted by Menzies School of Health Research.

Prospective data collection began at the start of the CQI phase, during which data were collected from the enhanced malariometric surveillance system. Healthcare workers recorded patient information in the supplementary surveillance logbook during routine clinical care, and trained data clerks subsequently transcribed these data into the REDCap database using standardised data entry procedures.

To ensure data fidelity, the REDCap instrument incorporated validation and consistency checks during data entry, including range checks, mandatory fields, and internal logic rules. Two months after data entry commenced, routine data quality assessments were undertaken by generating data queries to identify missing, inconsistent, or implausible values. These were verified against the source documents and corrected where necessary. Final data cleaning and completeness checks were completed before statistical analysis.

Case diagnosis and management of malaria

As per routine procedures, patients presenting with fever or history of fever to the emergency room, outpatient department, youth friendly service unit, or under-five clinics were advised to go to the centre's laboratory to have a thick blood film for *Plasmodium* parasite identification, speciation, and quantification. Additional tests were also ordered at the attending health staff's discretion to rule out alternative conditions resembling malaria. The parasite load was assessed by quantifying the number of malaria parasites per 500 white blood cells on thick film. In the absence of electricity, the health centres used multi-species RDTs (MERISCREEN Malaria Pf/Pan Ag, Malaria Ag Pf/Pv (pLDH/pLDH, MALARIA PV/PF TEST KIT)) capable of detecting both *P. falciparum* and *P. vivax* (although this is a local pragmatic solution rather than guideline concordant practice).

National antimalarial guidelines recommend that parasitologically confirmed uncomplicated *P. falciparum* malaria should be treated with six doses of artemether-lumefantrine over three days, with the dose administered according to the patient's body weight, together with a single 0.25 mg/kg dose of primaquine. Patients with uncomplicated *P. vivax* malaria should be treated with weight-based chloroquine and 0.25 mg/kg/day primaquine radical cure for 14 days, without prior glucose-6-phosphate dehydrogenase (G6PD) testing. Patients with mixed *P. falciparum* and *P. vivax* infections are treated with artemether-lumefantrine plus 14-day primaquine at the same dose as used for *P. vivax* mono-infections. Artemether-lumefantrine is used as an alternative to treat *P. vivax* infection when chloroquine is not available (Table S1-4). Guidelines also stipulate that health workers provide education to patients receiving primaquine radical cure regarding symptoms suggestive of haemolysis (such as coca cola-coloured urine) and the need to stop treatment and return to the health facility should these side effects occur. All patients with severe malaria are referred to Arba Minch General Hospital.

Automated reporting and feedback mechanisms

As part of the CQI implementation, an automated report was generated every 3 months, which collated and presented data on malaria epidemiology, data integrity, and prescribing accuracy from the REDCap database using STATA version 17 (Stata Corp, Texas, USA). Once generated, these reports were shared with clinical staff at both clinics to provide feedback on data quality and case management. Delivery of the reports was followed by an in-person, structured meeting at each clinic to discuss areas and targets for improvement. Data were classified as missing if no entry was provided or if the value was recorded as unknown. Prescribing accuracy for antimalarial medicines was assessed by evaluating concordance

with national malaria treatment guidelines (Table S1-4). Doses of chloroquine, artemether-lumefantrine, or primaquine that fell outside of weight-based dosing categories were classified as guideline discordant.

Statistical analysis

Baseline demographic, clinical, and epidemiological characteristics are summarised using descriptive statistics. Categorical variables are presented as frequencies and percentages, while continuous variables are presented as means with 95% confidence intervals (95% CIs) or medians with interquartile ranges (IQRs), as appropriate.

Differences in categorical outcomes were assessed using Pearson's chi-square or Fisher's exact tests. Weight-based dosing accuracy was classified according to the Ethiopian national malaria treatment guidelines as correct, underdosed, or overdosed (Table S1-4). All statistical tests were two-sided, and a p -value < 0.05 was considered statistically significant. All analyses were conducted using STATA statistical software (Version 17, Stata Corp, Texas, USA).

The impact of the quality improvement intervention was assessed by comparing outcomes across five predefined study periods: 1) the pre-CQI period (18 months – 18 March 2023 to 18 September 2024), 2) the transition period (3 months – 19 September 2024 to 18 December 2024), 3) the first CQI cycle (6 months - December 2024 to May 2025), 4) the second CQI cycle (6 months - June 2025 to November 2025), and 5) the third CQI cycle (4 months - December 2025 to March 2026). The primary comparison was between the pre-CQI and post-CQI periods, with the latter encompassing the transition period and all three CQI cycles. Outcomes were also compared across the individual post-CQI periods to assess changes over successive CQI cycles.

Results

Malaria epidemiology in Arba Minch Zuriya

Between March 2023 and March 2026, 59,394 patients presented to the two clinics and were tested for malaria. Microscopically confirmed malaria was diagnosed in 22.8% (13,530) of patients, and 0.04% (23) of patients were diagnosed by RDT. The overall slide positivity rate (SPR) was 22.8% (13,530/59,394) (Table S5). Clinical records were available from the clinic register for 90.5% (12,243) of patients, of whom 99.2% (12,145) had a *Plasmodium* species recorded. The latter patients are included in the subsequent baseline epidemiological analyses (Table 1).

Overall, 54.1% (6,572) of malaria patients presented to Lante Health Centre and 45.9% (5,573) to Shelle Health Centre. In total, 59.8% (7,262) were male, and 93.6% (5,688) were of Gamo ethnicity. The median age of the patients was 17.0 years (interquartile range [IQR] 9.0–25.0). There was a greater proportion of children younger than 15 years at Shelle Health Centre (53.9%, 2,899/5,374) compared with Lante Health Centre (32.0%, 2,094/6,553) (Table S6). Infants younger than six months accounted for 0.4% (44/12,145)

of the study population. In total, 58.0% (2,774/4,781) of women were of reproductive age, and of those women with available data, 11.5% (149/1,297) were pregnant, and 5.3% (69/1,301) were breastfeeding.

Overall, 44.6% (5,420) of malaria cases were due to *P. falciparum* monoinfection, 54.1% (6,566) to *P. vivax* monoinfection, and 1.3% (159) were mixed infections. *Plasmodium vivax* was the predominant species of infection at both centres, with *P. vivax* monoinfection accounting for 58.6% (3,266/5,573) of malaria at Shelle and 50.2% (3,300/6,572) at Lante (Table S6). Over the course of the study, the proportion of *P. vivax* infections decreased from 56.5% (3,432/6,069) in the pre-CQI period to 51.6% (3,134/6,076) during the post-CQI period, whereas the proportion of infections due to *P. falciparum* monoinfection increased from 41.7% (2,531/6,069) to 47.5% (2,889/6,076). Mixed infections remained relatively stable (1.7% vs 0.9%) (Table S7).

Adults aged ≥ 15 years accounted for 57.1% (6,934) of all patients with malaria. Among children, *P. vivax* caused the largest proportion of malaria cases, comprising 59.9% (2,075/3,464) of cases among those aged 5–<15 years and 65.5% (1,002/1,529) among children aged < 5 years. In adults aged ≥ 15 years, *P. falciparum* and *P. vivax* accounted for 50.3% (3,487/6,934) and 48.2% (3,342/6,934) of cases, respectively (Table 1, Fig. 1).

Table 1
Baseline demographic characteristics of all patients between 2023 and 2026

Category	Species			Total ^a
	<i>P. falciparum</i>	<i>P. vivax</i>	Mixed Infections	
	N = 5,420	N = 6,566	N = 159	N = 12,145
Shelle Health Centre	2,284 (41.0%)	3,266 (58.6%)	23 (0.4%)	5,573 (45.9%)
Lante Health Centre	3,136 (47.7%)	3,300 (50.2%)	136 (2.1%)	6,572 (54.1%)
Study period				
Pre-CQI	2,531 (41.7%)	3,432 (56.5%)	106 (1.7%)	6,069 (50.0%)
Post-CQI	2,889 (47.5%)	3,134(51.6%)	53 (0.9%)	6,076 (50.0%)
Age groups, n (%)				
< 1 year	31 (27.4%)	82 (72.6%)	0 (0.0%)	113 (0.9%)
1–<5 year	480 (33.9%)	920 (65.0%)	16 (1.1%)	1,416 (11.7%)
5– <15 year	1,352 (39.0%)	2,075 (59.9%)	37 (1.1%)	3,464 (28.5%)
≥ 15 year	3,487 (50.3%)	3,342 (48.2%)	105 (1.5%)	6,934 (57.1%)
Unknown	70 (32.1%)	147 (67.4%)	1 (0.5%)	218 (1.8%)
Weight in kg by age group, mean (SD)				
< 1 year	7.8 (3.0)	7.3 (1.8)		7.4 (2.2)
1– <5 year	12.6 (3.1)	12.5 (3.1)	12.3 (1.2)	12.5 (3.1)
5– <15 year	29.0 (10.4)	28.2 (10.3)	28.6 (10.5)	28.5 (10.4)
≥ 15 year	58.7 (10.3)	58.5 (10.4)	57.1 (11.3)	58.6 (10.3)
Unknown	41.9 (22.4)	36.1 (19.9)	-	38.4 (21.0)
Sex, n (%)				
Male	3,346 (46.1%)	3,809 (52.5%)	107 (1.5%)	7,262 (59.8%)
Female	2,044 (42.8%)	2,685 (56.2%)	52 (1.1%)	4,781 (39.4%)
Missing	30 (29.4%)	72 (70.6%)	0 (0.0%)	102 (0.8%)
^a 98 patients did not have a <i>Plasmodium</i> species recorded				
^b Only recorded in the post-CQI period				

Category	Species			Total ^a
	<i>P. falciparum</i>	<i>P. vivax</i>	Mixed Infections	
Pregnancy status, n (%) ^b				
No	597 (52.0%)	545 (47.5%)	6 (0.5%)	1,148 (80.8%)
Yes	70 (47.0%)	77 (51.7%)	2 (1.3%)	149 (10.5%)
Missing	46 (37.1%)	76 (61.3%)	2 (1.6%)	124 (8.7%)
Breast feeding status, n (%) ^b				
No	636 (51.6%)	589 (47.8%)	7 (0.6%)	1,232 (86.7%)
Yes	33 (47.8%)	35 (50.7%)	1 (1.5%)	69 (4.9%)
Missing	44 (36.7%)	74 (61.7%)	2 (1.7%)	120 (8.4%)
Ethnicity, n (%) ^b				
Gamo	2,748 (48.3%)	2,896 (50.9%)	44 (0.8%)	5,688 (93.6%)
Wolaita	9 (60.0%)	6 (40.0%)	0 (0.0%)	15 (0.3%)
Amhara	3 (37.5%)	5 (62.5%)	0 (0.0%)	8 (0.1%)
Tigray	1 (33.3%)	2 (66.7%)	0 (0.0%)	3 (0.1%)
Other	30 (28.6%)	75 (71.4%)	0 (0.0%)	105 (1.7%)
Missing	98 (38.1%)	150 (58.4%)	9 (3.5%)	257 (4.2%)
^a 98 patients did not have a <i>Plasmodium</i> species recorded				
^b Only recorded in the post-CQI period				

Temporal trends

Malaria cases varied with season, with the highest average monthly burden occurring in July, followed by June and August. In total, 29.8% (3,619/12,145) of all malaria cases were recorded between June and August, and this proportion was similar for *P. falciparum* monoinfection (30.4%, 1,647/5,420) and *P. vivax* monoinfection (29.3%, 1,925/6,566) (Fig. 2 and Figure S1).

Data completeness

In the pre-CQI period, 87.5% (5,351/6,119) of clinic records were complete, including MRN, age, sex, parasite species, schizontocidal and primaquine treatment, and dose. The highest proportion of missing

data was for schizontocidal treatment, which was missing in 11.7% (713/6119) of records, followed by primaquine treatment (3.3%, 198/6,100 missing) and age (2.0%, 121/6,119 missing). MRN, chloroquine dose, and primaquine dose recording were already near-complete, with < 0.1% of records missing during the pre-CQI period (Table 2). Weight and pregnancy status (in women aged 14–50 years) were only recorded in the prospective phase. The proportion of records with missing weight fell from 15.6% (219/1,407) in the transition period to 0.5% (11/2,101) in the second CQI cycle and 0.2% (2/992) in the third CQI cycle ($p < 0.001$). The proportion of records with missing pregnancy status fell from 16.5% (58/351) during the transition period to 6.6% (30/458) during the second cycle and 2.4% (6/246) during the third CQI cycle ($p < 0.001$) (Table 2).

Table 2
Missing Data in the five periods

Variable	Pre-CQI	Transition period	1st CQI	2nd CQI	3rd CQI
	N = 6,119	N = 1,407	N = 1,624	N = 2,101	N = 992
Medical record number	3/6,119 (0.1%)	0/1,407 (0.0%)	0/1,624 (0.0%)	1/2,101 (0.1%)	0/992 (0.0%)
Age	121/6,119 (2.0%)	91/1,407 (6.5%)	5/1,624 (0.3%)	4/2,101 (0.2%)	0/992 (0.0%)
Sex	101/6,119 (1.7%)	1/1,407 (0.1%)	1/1,624 (0.1%)	2/2,101 (0.1%)	0/992 (0.0%)
Parasite species	50/6,119 (0.8%)	25/1,407 (1.8%)	10/1,624 (0.6%)	7/2,101 (0.3%)	6/992 (0.6%)
Adherence counseling [†]	-	219/ 1,407 (15.6%)	37/1,624 (2.3%)	11/2,101 (0.5%)	2/992 (0.2%)
Schizontocidal stock [†]	-	219/1,407 (15.6%)	38/1,624 (2.3%)	11/2,101 (0.5%)	2/992 (0.2%)
Weight [†]	-	219/1,407 (15.6%)	37/1,624 (2.3%)	11/2,101 (0.5%)	2/992 (0.2%)
Pregnancy [†]	-	58/351 (16.5%)	33/379 (8.7%)	30/458 (6.6%)	6/246 (2.4%)
Breast feeding [†]	-	57/351 (16.2%)	32/379 (8.4%)	27/458 (5.9%)	7/246 (2.8%)
Schizontocidal treatment	713/6,119 (11.7%)	17/1,407 (1.2%)	1/1,624 (0.1%)	2/2,101 (0.1%)	0/992 (0.0%)
Chloroquine dose	2/2,415 (0.1%)	0/683 (0.0%)	0/624 (0.0%)	0/789 (0.0%)	0/403 (0.0%)
Artemether-lumefantrine dose	10/2,983 (0.3%)	1/707 (0.1%)	0 /999 (0.0%)	0/1,310 (0.0%)	0/589 (0.0%)
Primaquine treatment [£]	198/6,100 (3.3%)	17/1,363	1 /1,548	2/2,003	0/947

Variable	Pre-CQI	Transition period	1st CQI	2nd CQI	3rd CQI
	N = 6,119	N = 1,407	N = 1,624	N = 2,101	N = 992
		(1.3%)	(0.1%)	(0.1%)	(0.0%)
Primaquine dose [£]	3/4,792 (0.1%)	0/1,315 (0.0%)	0/1,538 (0.0%)	0/1,935 (0.0%)	0/946 (0.0%)

† Recorded only in the post-CQI period; £ restricted to primaquine eligible

After CQI implementation, the proportion of missing data related to drug prescriptions and dosing dropped to zero except for schizontocidal and primaquine prescriptions which fell to 0.1% in both first and second CQI cycles (Table 2). Data completeness improved substantially at both health centres. The greatest improvements were observed in clinical and treatment-related variables, particularly at Lante Health Centre.

Table 3
Proportion of patients receiving antimalarial treatment by malaria species and CQI period

Species	Drug	Pre-CQI	Transition period	1st CQI	2nd CQI	3rd CQI
P. vivax monoinfection	Chloroquine	2,399/3,043 (78.8%)	678/728 (93.1%)	620/764 (81.2%)	783/1,066 (73.4%)	400/572 (69.9%)
	Artemether-lumefantrine	639/3,043 (21.0%)	50/728 (6.9%)	144/764 (18.8%)	283/1,066 (26.5%)	172/572 (30.1%)
	Other treatment ^c	5/3,043 (0.2%)	0/728 (0.0%)	0/764 (0.0%)	0/1,066 (0.0%)	0/572 (0.0%)
	14-day primaquine	2,606/2,696 (96.7%)	685/690 (99.3%)	708/724 (97.8%)	967/984 (98.3%)	540/544 (99.3%)
	Primaquine single dose	90/2,696 (3.3%)	5/690 (0.7%)	16/724 (2.2%)	17/984 (1.7%)	4/544 (0.7%)
Mixed infection	Chloroquine	1/90 (1.1%)	0/17 (0.0%)	0/13 (0.0%)	0/13 (0.0%)	0/10 (0.0%)
	Artemether-lumefantrine	89/90 (98.9%)	17/17 (100.0%)	13/13 (100.0%)	13/13 (100.0%)	10/10 (100.0%)
	14-day primaquine	73/82 (89.0%)	16/17 (94.1%)	9/11 (81.8%)	12/12 (100.0%)	9/9 (100.0%)
	Primaquine single dose	9/82 (11.0%)	1/17 (5.9%)	2/11 (18.2%)	0/12 (0%)	0/9 (0%)
P. falciparum monoinfection	Chloroquine	12/2,262 (0.5%)	0/632 (0.0%)	2/836 (0.2%)	4/1,014 (0.4%)	0/404 (0.0%)
	Artemether-lumefantrine	2,247/2,262 (99.3%)	632/632 (100.0%)	834/836 (99.8%)	1,010/1,014 (99.6%)	404/404 (100.0%)
	Other treatment ^c	3/2,262 (0.1%)	0/632 (0.0%)	0/836 (0.0%)	0/1,014 (0.0%)	0/404 (0.0%)
	Primaquine single dose	1,931/2,006 (96.3%)	590/595 (99.2%)	784/794 (98.7%)	920/933 (98.6%)	386/387 (99.7%)

Species	Drug	Pre-CQI	Transition period	1st CQI	2nd CQI	3rd CQI
	14-day primaquine	75/2,006 (3.7%)	5/595 (0.8%)	10/794 (1.3%)	13/933 (1.4%)	1/387 (0.3%)
P. vivax monoinfection OR Mixed infection	Any primaquine	2,778/3,394 (81.9%)	707/719 (98.3%)	735/742 (99.0%)	996/1,027 (96.9%)	553/554 (99.8%)
	14-day primaquine	2,679/2,778 (96.4%)	701/707 (99.2%)	717/735 (97.6%)	979/996 (98.3%)	549/553 (99.3%)
	Primaquine single dose	99/2,778 (3.6%)	6/707 (0.9%)	18/735 (2.5%)	17/996 (1.7%)	4/553 (0.7%)

Denominators for specific primaquine regimens are restricted to patients with prescription and dose data available who were at least 6 months of age and who were not pregnant or breastfeeding.

^cartemether and/or artesunate were given.

Adherence to antimalarial guidelines

Overall, 54.1% (6,566/12,145) of patients presented with uncomplicated *P. vivax* monoinfection, of whom 94.0% (6,173/6,566) had the prescribed schizontocidal treatment recorded. Of the 3,043 vivax malaria patients in the pre-CQI period in whom treatment was recorded, 78.8% (2,399) were treated with chloroquine, 21.0% (639) were treated with artemether-lumefantrine, and the remainder with intravenous artesunate or artemether monotherapy. The proportion treated with artemether-lumefantrine rose to 30.1% (172/572) in the third CQI period (Table 3). All mixed infections were treated with artemether-lumefantrine except for one patient in the pre-CQI period who was erroneously treated with chloroquine (Table 3).

Of the 44.6% (5,420) of patients with *P. falciparum* monoinfection, 95.0% (5,148/5,420) had their schizontocidal treatment recorded. Of these, 99.3% (2,247/2,262) were treated with AL in the pre-CQI period. 0.5% (12/2,262) of patients with *P. falciparum* malaria were erroneously treated with chloroquine during the pre-CQI cycle, 0.4% (4/1,014) during the second CQI cycle, and 0% (0/404) during the third CQI cycle. Treatment with artemether-lumefantrine rose to 100% in the third CQI period (Table 3).

In total, 97.7% (6,571/6,725) of patients with *P. vivax* monoinfection or mixed infections were 6 months of age or older, were not pregnant, and were not breastfeeding and thus eligible for primaquine radical cure. In the pre-CQI period, 81.9% (2,778/3,394) of patients eligible for primaquine were recorded as being prescribed primaquine, and this rose to 99.0% (735/742) after the first CQI and 99.8% (553/554) after the third CQI ($p < 0.0001$) (Table 3). Of the 2,778 patients eligible for radical cure in the pre-CQI period, 3.6% (99) were inadvertently treated with single dose primaquine, reducing to 0.7% (4/553) in the third CQI cycle (Table 3).

A total of 149 pregnant women were identified in the post CQI period. One of these patients (0.7%) at Lante Health Centre in the second CQI cycle was inadvertently treated with primaquine. Of the 69 lactating women, 43.5% (30) were inadvertently treated with primaquine (22 at Shelle Health Centre and 8 at Lante Health Centre) (Table S8).

In the transition period, 19.5% (114/586) of patients treated with chloroquine were prescribed the incorrect weight-based dose, of whom 2.2% (13) were underdosed and 17.2% (101) were overdosed. Incorrect dosing of chloroquine decreased to 4.0% (16/401) by the third CQI cycle (risk reduction: 15.5%, 95% CI: 11.7%–19.2%; $p < 0.001$) (Table 4). In the transition period, 3.3% (20/597) of those treated with artemether-lumefantrine were prescribed the incorrect weight-based dose, of whom 1.2% (7) were underdosed and 2.2% (13) were overdosed. The proportion of incorrect artemether-lumefantrine doses fell to 2.4% (14/578) during the third CQI cycle (risk reduction: 0.9%, 95% CI: –1.0%–2.9%; $p = 0.343$) (Table 4). In the transition period, 15.6% (93/596) of patients treated with 14-day primaquine were prescribed the incorrect dose. Incorrect primaquine dosing decreased to 3.3% (18/547) in the third CQI period (risk reduction: 12.3%, 95% CI: 9.0%–15.6%; $p < 0.001$). Overdosing occurred in 9.4% (56/596) in the transition period, decreasing to 1.5% (8/547) in the third CQI cycle (Table 4).

Among the 263 patients who were ineligible for primaquine (pregnant, breastfeeding and infants younger than six months), 14.1% (37/263) were inadvertently prescribed primaquine, ranging from 15.8% (3/19) in the pre-CQI period to 9.1% (4/44) in the third CQI cycle (Table S8).

Of the patients prescribed single dose primaquine, 12.6% (336 /2,657) were treated with the incorrect dose. The proportion receiving an incorrect dose was 19.6% (105/535) in the transition period, declining to 6.9% (27/391) in the third CQI (risk reduction: 12.8%, 95% CI: 8.5%–16.9%; $p < 0.001$) (Table 4).

Incorrect weight-based dosing of chloroquine was highest in children aged 1 to < 5 years while incorrect dosing for primaquine and artemether-lumefantrine was highest in 5 to < 15 years-old. By centre, incorrect dosing was consistently more common at Lante Health Centre than at Shelle, particularly for chloroquine and single dose primaquine (Table S9).

Counseling on adherence and signs and symptoms of drug-related adverse events was provided for 84.4% (1,187/1,407) of patients in the transition period, rising to 99.6% (988/992) in the third CQI cycle (Table 2). No patients were documented to have had an adverse event.

Table 4
Prescription accuracy by study period

Drug	Dose	Transition period	1st CQI	2nd CQI	3rd CQI
Chloroquine	Correct	472/586 (80.6%)	535/601 (89.0%)	732/785 (93.2%)	385/401 (96.0%)
	Underdose	13/586 (2.2%)	11/601 (1.8%)	11/785 (1.4%)	6/401 (1.5%)
	Overdose	101/586 (17.2%)	55/601 (9.1%)	42/785 (5.3%)	10/401 (2.5%)
Artemether-lumefantrine	Correct	577/597 (96.6%)	930/968 (96.1%)	1,253/1,286 (97.4%)	564/578 (97.6%)
	Underdose	7/597 (1.2%)	16/968 (1.6%)	14/1,286 (1.1%)	9/578 (1.6%)
	Overdose	13/597 (2.2%)	22/968 (2.3%)	19/1,286 (1.5%)	5/578 (0.9%)
14-day primaquine	Correct	503/596 (84.4%)	629/703 (89.5%)	923/985 (93.7%)	529/547 (96.7%)
	Underdose	37/596 (6.2%)	33/703 (4.7%)	29/985 (2.9%)	10/547 (1.8%)
	Overdose	56/596 (9.4%)	41/703 (5.8%)	33/985 (3.4%)	8/547 (1.5%)
Primaquine single dose	Correct	430/535 (80.4%)	690/798 (86.5%)	837/933 (89.7%)	364/391 (93.1%)
	Underdose	7/535 (1.3%)	22/798 (2.8%)	23/933 (2.5%)	8/391 (2.1%)
	Overdose	98/535 (18.3%)	86/798 (10.7%)	73/933 (7.8%)	19/391 (4.9%)

Data are restricted to patients with records completed for weight and associated dose.

Malaria recurrence

Overall, 8.7% (250/2,882) of patients had a recent history of malaria in the pre-CQI period compared to 8.5% (210/2,485) of patients in the post-CQI period ($p = 0.770$). The corresponding figures for patients presenting with *P. falciparum* were 2.0% (46/2,320) and 1.9% (46/2,484), respectively ($p = 0.741$).

Following treatment for *P. vivax* malaria, 9.5% (303/3,182) of the patients in the pre-CQI period re-presented to the clinic within 120 days with another episode of *P. vivax*, compared to 9.0% (256/2,851) in the post-CQI period. The corresponding risk of recurrent *P. falciparum* within 42 days of initial treatment of *P. falciparum* was 3.0% (73/2,448) in the pre-CQI period and 1.9% (49/2,655) in the post-CQI period (Table S10)

Discussion

Ethiopia has made significant progress towards the elimination and control of malaria, but faces significant challenges in sustaining these gains, with emerging threats from artemisinin resistant parasites, *HRP2* deletions (12) and the spread of *Anopheles stephensi* (13). To tackle these threats, it is critical that the national malaria program maintains robust malariometric surveillance, and that the health system is strengthened to ensure early diagnosis and optimal treatment of patients with malaria. In this context we undertook a program to enhance reporting of malaria at two health centres in southern Ethiopia, with repeated rounds of CQI to improve the guideline concordance of uncomplicated malaria treatment. The study highlights a high burden of malaria in this area with more than 12,000 cases reported from two clinics over a 3-year period, with similar proportions due to *P. falciparum* and *P. vivax*. Over the implementation period, the program was associated with marked improvements in the completeness of clinical records and adherence to national antimalarial guidelines and weight-based antimalarial dosing. Improvements generally progressed with each successive CQI cycle, with the greatest gains made in chloroquine and primaquine dosing accuracy.

Comprehensive epidemiological and clinical data are crucial for guiding appropriate allocation of local, regional, and national resources for malaria control activities. Surveillance data also facilitate quality assurance activities, such as audits of guideline concordance. In resource-limited settings, routine health facility data are often the primary source of information available to program managers (14). At the start of the study, most patients with malaria were recorded in clinic registers, but the lack of data on weight, pregnancy, and breastfeeding precluded assessment of treatment accuracy. From September 2024, these variables were included as part of enhanced malariometric surveillance processes. Subsequent CQI workshops reported clinic data back to the staff and encouraged data completeness which quickly improved to almost 100% within 3–6 months.

In resource-limited settings, routine surveillance systems can be undermined by staff shortages, competing workloads, and limited resources (15). Incorporating support for surveillance and CQI does not necessarily require substantial additional infrastructure but can have a significant impact on data quality, healthcare delivery and potential clinical outcomes (6). The core CQI activity in our study was intermittent presentation of an automated report to healthcare staff, that provided regular opportunities for clinic staff to review their data and identify locally appropriate actions to address gaps identified. Subsequent similar reports allowed staff to monitor the effect of their corrective actions. Similar low-budget approaches have been taken in Uganda and Ghana with both studies showing improvements in data completeness, reliability, and use in decision-making (7, 8).

Our study was modeled on a similar project in Papua, Indonesia, which also evaluated health-system strengthening approaches to improve malaria case management and, specifically, *P. vivax* radical cure. Both studies used CQI strategies to address gaps in adherence to recommended treatment practices within routine health services. The findings of the Indonesian study were broadly consistent with this study with antimalarial prescribing errors reduced from 17% to less than 6% for dihydroartemisinin-piperaquine (DHP) and from 17% to less than 4% for primaquine (6). Young children are particularly vulnerable to repeat episodes of malaria and associated morbidity and mortality (16–18). In both the Ethiopian and Indonesian studies, children were also found to be at high risk of errors in dosing of antimalarial drugs. Indonesian children younger than 1 year had 2.5-fold higher odds of receiving an incorrect DHP dose than adults, a likely reflection of the complexity of weight-based dosing and the limited availability of paediatric formulations (6). In our study, only half of the children aged 1–<5 years received the correct dose of chloroquine, of whom 44% were overdosed. Dosing errors for primaquine were most frequent among older children (aged 5 to 15 years). These findings highlight the importance of accurate weight measurement, age-specific formulations, and routine dose verification within malaria case management. Similar to our findings, the Indonesian study also reported frequent (25.6%) erroneous use of single-dose primaquine instead of 14-day regimens for patients with vivax malaria before the introduction of CQI processes. Previous studies in Ethiopia have highlighted challenges in delivering radical cure for patients with *P. vivax* malaria particularly incomplete adherence to a complete 14-day course of primaquine (19). Our findings indicate that the challenge begins even earlier, at the time the healthcare provider selects the most appropriate treatment regimen.

In our study, guideline concordance of species-specific antimalarial treatment generally improved across CQI cycles, although the use of artemether-lumefantrine instead of chloroquine for patients with *P. vivax* monoinfections continued into the third CQI period. Although the Ethiopian national malaria guideline permits artemether-lumefantrine as an alternative treatment for *P. vivax* malaria when chloroquine is not available, drug stockouts during the study period did not explain the excessive use of artemether-lumefantrine. Across the entire post-CQI period, only 21 patients' records specifically noted chloroquine unavailability (Table 2). Hence, the use of artemether-lumefantrine for *P. vivax* is likely to be due to other factors that warrant further study. Reassuringly artemether-lumefantrine was appropriately used for almost all *P. falciparum* and mixed infections throughout the study.

Incorrect treatment and suboptimal drug dosing are key drivers of the emergence and spread of multidrug resistant malaria (20). The emergence and spread of *P. falciparum* with reduced susceptibility to artemisinin poses a huge threat for malaria control on the African subcontinent (21). Recent reports have highlighted the presence of *P. falciparum* *kelch13* mutations in Ethiopia, with prevalence rising rapidly (20, 22, 23). The WHO strategy for combating artemisinin resistance recommends a four-pillar approach: strengthening surveillance of antimalarial drug efficacy and resistance; optimising and better regulating the use of diagnostics and therapeutics to limit drug pressure; limiting the spread of resistant parasites where resistance has emerged; and stimulating research and innovation to improve existing tools and develop new ones (21). A single low dose of primaquine administered to patients with *P. falciparum* sterilises gametocytes and reduces the risk of subsequent transmission (24) and is well

tolerated and safe, even in patients with G6PD deficiency (24–26). Greater use of this single dose primaquine regimen has been proposed as a complementary strategy to slow the spread of artemisinin resistant parasites (27). Recent studies from Africa, including Ethiopia, have shown very low implementation of this strategy (< 5%) (20). In this context the findings in Arba Minch are reassuring since > 95% of patients with *P. falciparum* malaria were treated with artemether-lumefantrine plus single low dose primaquine and no apparent adverse events were reported. These findings highlight that with appropriate training and supply chains, single dose primaquine can be included routinely in the case management of malaria.

This study has several strengths, including the documentation of a large number of patients with malaria over a three-year period at two independent clinics. Implementation of the quality improvement intervention within routine healthcare demonstrates that the approach is feasible and is relevant to real-world practice. The intervention also provided an opportunity for greater collaboration between clinical staff within health centres, and ownership of quality improvement processes. Importantly, fostering local ownership, embedding CQI activities into routine clinical practice, and engaging existing healthcare staff may help sustain these improvements beyond the study period.

Our study also has several limitations. First, the pre-post implementation study design cannot establish a direct cause-and-effect relationship, hence the observed improvements may partly reflect natural temporal variability, greater provider awareness, staffing changes, medication availability or other unknown factors. Second, the transition period included healthcare worker orientation sessions, which may have influenced both documentation and prescribing practices before the formal CQI cycles began. Third, the study health centres were from the same region, and this may limit the generalisability of the findings to other settings in Ethiopia. Finally, due to the lack of proactive patient follow-up, the risks of recurrence presented were likely subject to substantial attrition bias, and assessments of treatment adherence could not be made. It was therefore not possible to infer the impact of radical cure prescribing and treatment adherence on the likelihood of subsequent relapse.

In conclusion, the implementation of quality improvement processes and their integration into routine malaria surveillance can provide a feasible, scalable approach for Ethiopian health facilities to improve data quality, species-specific antimalarial prescriptions, and weight-based drug dosing. Embedding regular data review and feedback into existing systems has potential to strengthen case management, optimise resource allocation, slow the emergence of antimalarial drug resistance and support Ethiopia's ongoing malaria control and elimination efforts.

Abbreviations

CI

Confidence interval

CQI

Continuous quality improvement

CSA
Central Statistical Agency
DHP
Dihydroartemisinin-piperaquine
G6PD
Glucose-6-phosphate dehydrogenase
HMIS
Health Management Information System
IQR
Interquartile range
MRN
Medical record number
P. falciparum
Plasmodium falciparum
P. vivax
Plasmodium vivax
PDSA
Plan-Do-Study-Act
RDT
Rapid diagnostic test
REDCap
Research Electronic Data Capture
SD
Standard deviation
SHEPE
Strengthening Health Systems for Effective Primaquine Radical Cure in Ethiopia
WHO
World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval to conduct this study was provided by the College of Medicine and Health Sciences, Arba Minch University Institutional Review Board (approval number IRB/440/12) and the Human Research Ethics Committee of the Northern Territory Department of Health and Menzies School of Health Research (HREC-2024-4883). Support letters to the district health department were also obtained from the College of Medicine and Health Sciences, Arba Minch University, to proceed with data collection activities at the health centres. Patient confidentiality was maintained by de-identifying data prior to analysis.

Consent for publication

All authors of the study have granted permission for publication.

Competing interests

The authors declare no competing interests.

Funding

This research was funded in part by the Wellcome Trust (200909) and an Australian Leadership Grant (GNT1194702) to RJC. KT and RNP are funded by Australian NHMRC Leadership Investigator Grants (GNT2033264, 2008501). RJC is supported by the Royal Australasian College of Physicians (RACP) Cottrell Research Establishment Fellowship from the RACP Foundation and Dr Jack Dinham Cottrell.

Author Contribution

TSD, KT, RNP and NMD conceptualised the study and developed the methodology. GL, TSD and SAB constructed data collection instruments. TSD, RNP, NMD, SAB, TTT, and KMM oversaw data collection. TSD, GL, and SAB verified, curated, and cleaned the data. TSD, NMD, and RNP conducted statistical analysis. TSD, KT, RJC, NMD, and RN interpreted the analytical findings. TSD drafted the first version of the manuscript. KT, RNP, NMD, GL, RJC, SAB, KMM, and TTT reviewed and edited the final draft

Acknowledgements

We sincerely thank all the healthcare workers at the two health centres who participated in the data collection and CQI meetings. We would like to express special appreciation to the Arba Minch Zuriya District Health Department, Shelle Health Centre, and Lante Health Centre management staff for facilitating the study.

Data Availability

Data is available upon reasonable request to the corresponding author, subject to institutional and ethical approvals.

References

1. World malaria. report 2025 [Internet]. [cited 2026 Mar 26]. Available from: <https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2025>

2. Public E, Institute H, Ababa A. Ethiopia Service Provision Assessment 2021-22 Final Report [Internet]. 2023 [cited 2025 Dec 26]. Available from: <http://www.ephi.gov.et>
3. Dana DD, Belay MM, Ango TS, Zegene GM, Getachew S, Deressa W. Epidemiological investigation of a possible malaria outbreak in Arba Minch town, Gamo Zone, Southern Ethiopia, 2023. *Malar J.* 2026;25(1):29. 10.1186/s12936-025-05714-x . PubMed PMID: 41530820.
4. Ethiopia. Malaria Elimination Strategic plan: 2021–2025 [Internet]. [cited 2025 Dec 27]. Available from: https://ict.moh.gov.et/elibrary/public_documents
5. National. Malaria Guidelines, fifth edition, August 2022 [Internet]. [cited 2025 Dec 26]. Available from: https://ict.moh.gov.et/elibrary/public_documents
6. Fransisca L, Burdam FH, Kenangalem E, Rahmalia A, Ubra RR, van den Boogaard CHA, et al. Enhanced data quality to improve malaria surveillance in Papua, Indonesia. *Malar J.* 2025;24(1). 10.1186/s12936-025-05358-x . PubMed PMID: 40468325.
7. Westercamp N, Staedke SG, Maiteki-Sebuguzi C, Ndyabakira A, Okiring JM, Kigozi SP, et al. Effectiveness of in-service training plus the collaborative improvement strategy on the quality of routine malaria surveillance data: results of a pilot study in Kayunga District, Uganda. *Malar J.* 2021;20(1). 10.1186/S12936-021-03822-Y PubMed PMID: 34187489.
8. Asiedu A, Haws RA, Mohammed W, Boye-Doe J, Agblanya C, Ntumy R, et al. Coaching visits and supportive supervision for primary care facilities to improve malaria service data quality in Ghana: An intervention case study. *PLOS global public health.* 2025;5(6). 10.1371. /JOURNAL.PGPH.0003649 PubMed PMID: 40478884.
9. HMIS Data Recording Procedures Manual. | PDF | Health Informatics | Information [Internet]. [cited 2026 Mar 26]. Available from: <https://www.scribd.com/document/606025751/HMIS-Procedures-Facilitators-Manual-FINAL-July242018>
10. Statistical Report On Population And Housing Census Country Level. 2007 | Ethiopian Statistics Services [Internet]. [cited 2026 Sep 7]. Available from: https://ess.gov.et/download/population-and-housing-census-2007-national_statistical/
11. Worksheet P-D-S-A. Directions, and Examples | Agency for Healthcare Research and Quality [Internet]. [cited 2026 Sep 7]. Available from: <https://www.ahrq.gov/health-literacy/improve/precautions/tool2b.html>
12. Letebo A, Vanheer LN, Engdaw M, Ejigu LA, Hailu Alemayehu D, Deressa JD, et al. Genomic surveillance reveals co-occurrence of Plasmodium falciparum drug resistance variants across diverse transmission settings in Ethiopia. *Nat Microbiol* 2026. 2026;1–12. 10.1038/s41564-026-02420-5 . PubMed PMID: 42557356.
13. Tadesse FG, Ashine T, Teka H, Esayas E, Messenger LA, Chali W, et al. Anopheles stephensi Mosquitoes as Vectors of Plasmodium vivax and falciparum, Horn of Africa, 2019. *Emerg Infect Dis.* 2021;27(2):603. 10.3201/EID2702.200019 PubMed PMID: 33496217.
14. Malaria surveillance, monitoring and evaluation: a reference manual, second edition [Internet]. [cited 2026 Aug 23]. Available from: <https://www.who.int/publications/i/item/9789240112476>

15. Hoxha K, Hung YW, Irwin BR, Grépin KA. Understanding the challenges associated with the use of data from routine health information systems in low- and middle-income countries: A systematic review. *Health Inform Manage J.* 2022;51(3):135–48.
;JOURNAL:JOURNAL:HIMD;WGROU:STRING:PUBLICATION PubMed PMID: 32602368.
16. Biset G, Tadess AW, Tegegne KD, Tilahun L, Atnafu N. Malaria among under-five children in Ethiopia: a systematic review and meta-analysis. *Malar J.* 2022;21(1):338. 10.1186/S12936-022-04370-9 .
PubMed PMID: 36384533.
17. Patriani D, Arguni E, Kenangalem E, Dini S, Sugiarto P, Hasanuddin A, et al. Early and late mortality after malaria in young children in Papua, Indonesia. *BMC Infect Dis.* 2019;19(1):922.
10.1186/S12879-019-4497-Y . PubMed PMID: 31666012.
18. Ogbuanu IU, Otieno K, Varo R, Sow SO, Ojulong J, Duduyemi B, et al. Burden of child mortality from malaria in high endemic areas: Results from the CHAMPS network using minimally invasive tissue sampling. *J Infect.* 2024;88(3):106107. .JINF.2024.01.006 PubMed PMID: 38290664.
19. Tsega EA, Lakew AM, Tegegne HA, Getahun GA, Zeleke EG. Adherence to 14-day primaquine treatment for radical cure of *Plasmodium vivax* and mixed malaria patients treated at health centers in Yilmana Densa district, Ethiopia: a community-based cross-sectional study. *Malar J.* 2026 Jun;24. 10.1186/S12936-026-05982-1 . PubMed PMID: 42343401.
20. Chala B, Platon L, Tibiri YNG, Strubel PE, Thiebaut L, Wade A, et al. Clinical, molecular, and in vitro evidence of artemisinin partial resistance in Ethiopian *Plasmodium falciparum*: a prospective, multisite, surveillance study. *Lancet Infect Dis.* 2026. 10.1016/S1473-3099(. 26)00301-4 PubMed PMID: 42551453.
21. W.H.O. Strategy to respond to antimalarial drug resistance in Africa. Geneva: World Health Organization. 2022;(June):102.
22. Fola AA, Feleke SM, Mohammed H, Brhane BG, Hennelly CM, Assefa A, et al. *Plasmodium falciparum* resistant to artemisinin and diagnostics have emerged in Ethiopia. *Nat Microbiol* 2023. 2023;8(10):10. 10.1038/s41564-023-01461-4 . PubMed PMID: 37640962.
23. Alemayehu AA, Castañeda Mogollón D, Belay SG, Tesfa H, Mohon AN, Balasingam N, et al. Expansion of the *Plasmodium falciparum* Kelch13 R622I Mutation in Northwest Ethiopia. *Open Forum Infect Dis.* 2025;12(6). 10.1093. /OFID/OFAF279 PubMed PMID: 40463829.
24. White NJ, Qiao LG, Qi G, Luzzatto L. Rationale for recommending a lower dose of primaquine as a *Plasmodium falciparum* gametocytocide in populations where G6PD deficiency is common. *Malaria Journal* 2012 11:1. 2012;11(1):418-. 10.1186/1475-2875-11-418 PubMed PMID: 23237606.
25. Yilma D, Stepniewska K, Bousema T, Drakeley C, Eachempati P, Guerin PJ, et al. Safety and efficacy of single-dose primaquine to interrupt *Plasmodium falciparum* malaria transmission in children compared with adults: a systematic review and individual patient data meta-analysis. *Lancet Infect Dis.* 2025;25(9):965–76. 10.1016/S1473-3099. (25)00078-7 PubMed PMID: 40286803.
26. Dysoley L, Kim S, Lopes S, Khim N, Bjorges S, Top S, et al. The tolerability of single low dose primaquine in glucose-6-phosphate deficient and normal *falciparum*-infected Cambodians. *BMC*

Infect Dis. 2019;19(1). 10.1186/S12879-019-3862-1 . PubMed PMID: 30871496.

27. White NJ. Primaquine to prevent transmission of falciparum malaria. Lancet Infect Dis. 2013;13(2):175–81. 10.1016/S1473-3099(. 12)70198-6 PubMed PMID: 23182932.

Figures

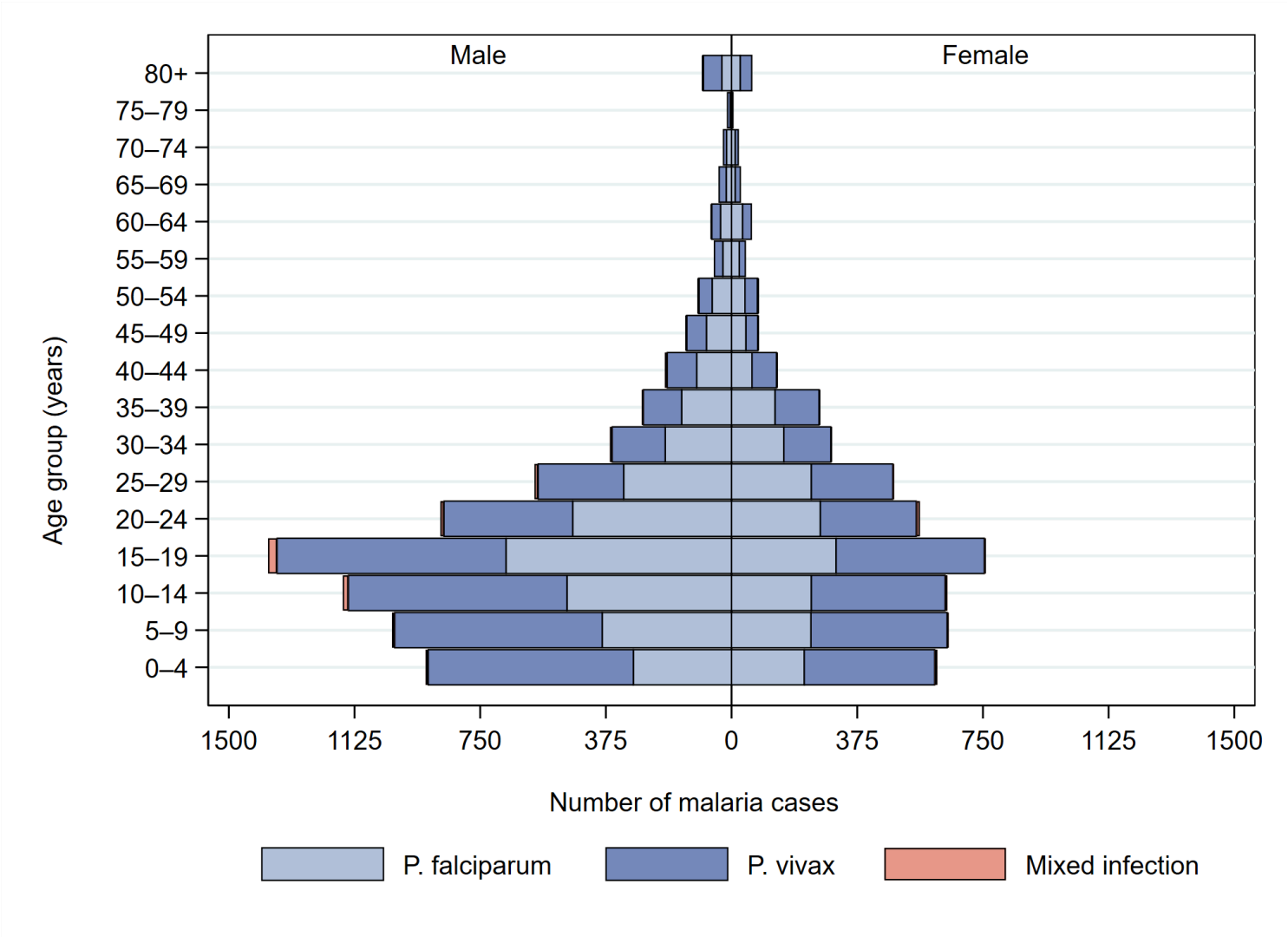


Figure 1

Age and sex distribution of malaria patients, 2023–2026

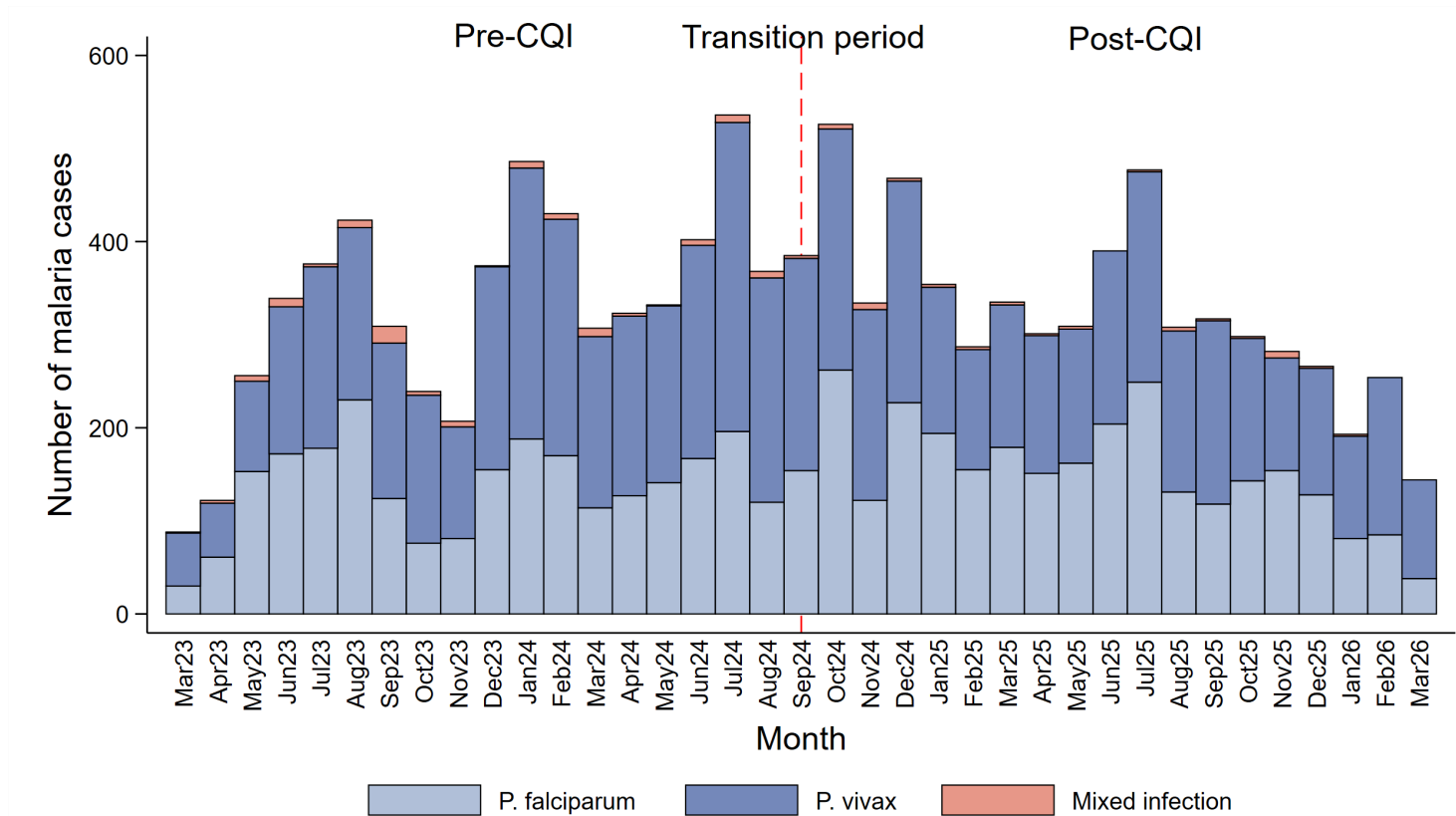


Figure 2

Malaria cases per month by *Plasmodium* species and study period. Vertical reference line represents the transition point between the retrospective and prospective phases

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [SHEPESupplementaryV1.1.docx](#)
- [FigureS1SHEPE.tif](#)