

Trends and Socioeconomic Determinants of Malaria Prevalence Among Children Under Five Years in Ghana: Evidence from the 2014–2022 Demographic and Health and Malaria Indicator Surveys

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Abstract

Background

Malaria remains one of the leading causes of illness among children under five years in Ghana, despite major progress in prevention and control. While national malaria prevalence has declined over time, it is unclear whether these gains have been shared equally across different socioeconomic groups. This study assessed trends in malaria prevalence and examined the socioeconomic factors associated with malaria infection among children aged 6–59 months in Ghana using nationally representative survey data collected between 2014 and 2022.

Methods

A repeated cross-sectional study was conducted using data from the 2014 Ghana Demographic and Health Survey (GDHS), the 2016 and 2019 Ghana Malaria Indicator Surveys (GMIS), and the 2022 GDHS. The analysis included 13,513 children aged 6–59 months with valid malaria microscopy results. Survey-weighted descriptive analyses were performed to estimate malaria prevalence across the four survey years. Associations between malaria infection and socioeconomic characteristics were assessed using design-adjusted chi-square tests. Multilevel logistic regression models were fitted separately for each survey year to identify factors associated with malaria infection while accounting for clustering within survey sampling units. Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported.

Results

Malaria prevalence declined markedly over the study period. Microscopy-confirmed malaria fell from 25.0% in 2014 to 21.0% in 2016, 14.0% in 2019, and 8.0% in 2022, while rapid diagnostic test positivity declined from 36.0% to 16.0%. Children aged 48–59 months consistently had about three times higher odds of malaria than those aged 6–11 months across all survey years (2014: AOR = 2.86, 95% CI: 1.90–4.30; 2016: AOR = 2.59, 95% CI: 1.72–3.89; 2019: AOR = 2.99, 95% CI: 1.75–5.10; 2022: AOR = 3.03, 95% CI: 1.91–4.81). A strong socioeconomic gradient was observed. Compared with children from the poorest households, those from the richest households had significantly lower odds of malaria in every survey year (2014: AOR = 0.17, 95% CI: 0.09–0.35; 2016: AOR = 0.12, 95% CI: 0.05–0.24; 2019: AOR = 0.06, 95% CI: 0.02–0.18; 2022: AOR = 0.13, 95% CI: 0.05–0.35). Rural residence remained a significant predictor of malaria, with children living in rural areas having 57–83% higher odds of infection than those in urban areas. Higher maternal education was also associated with lower malaria risk, although the strength of this relationship varied across survey years.

Conclusions

Ghana has made substantial progress in reducing malaria among children under five over the past decade. However, the burden of malaria remains concentrated among children living in poorer households, rural communities, and other socially disadvantaged groups. Achieving malaria elimination will require strategies that go beyond universal interventions by targeting populations at greatest risk and addressing the socioeconomic conditions that continue to drive malaria transmission.

Introduction

Malaria remains one of the most important vector-borne infectious diseases worldwide and continues to pose a major public health challenge, particularly in low- and middle-income countries. According to the World Health Organization (WHO), an estimated 249 million malaria cases and 608,000 malaria-related deaths occurred globally in 2022, with the WHO African Region accounting for approximately 94% of all cases and 95% of malaria-related deaths [1]. Despite considerable progress in malaria control over the past two decades through expanded vector control, improved diagnosis, effective treatment, and strengthened surveillance systems, progress towards malaria elimination has slowed in many endemic settings [1, 2]. Children aged under five years and pregnant women remain disproportionately affected because of their relatively lower immunity and increased susceptibility to severe disease and mortality [1].

Ghana remains highly endemic for malaria, with stable transmission occurring throughout the country and the entire population at risk of infection. Malaria continues to be one of the leading causes of outpatient attendance, hospital admissions, and childhood morbidity despite sustained investments in malaria control [3]. National malaria control interventions, including the large-scale distribution of long-lasting insecticide-treated nets (ITNs), indoor residual spraying (IRS), prompt diagnosis using rapid diagnostic tests (RDTs), artemisinin-based combination therapy (ACT), seasonal malaria chemoprevention in eligible districts, and intermittent preventive treatment during pregnancy, have contributed to substantial reductions in malaria burden over the past decade [1, 3]. Malaria parasite prevalence among children aged 6–59 months declined from 28% in 2011 to 14% in 2019 and further to 8% in 2022, reflecting important gains towards national malaria control targets [3]. Building on these achievements, Ghana has adopted the National Malaria Elimination Strategic Plan (2024–2028), which aligns with the WHO Global Technical Strategy for Malaria 2016–2030 and marks a transition from malaria control towards malaria elimination [4, 5].

Although considerable progress has been achieved, malaria transmission remains unequally distributed across populations and geographic areas. Increasing evidence suggests that socioeconomic conditions play a critical role in determining both malaria risk and the uptake of preventive interventions [6, 7]. Household wealth, maternal educational attainment, housing quality, place of residence, access to electricity and healthcare, sanitation, and environmental conditions influence exposure to malaria vectors, healthcare-seeking behaviour, and access to effective preventive measures such as ITNs and IRS [6, 8]. Previous studies conducted in Ghana and other malaria-endemic countries have consistently demonstrated significant associations between socioeconomic disadvantage and increased malaria

risk, while improvements in living conditions and educational attainment have been associated with reduced malaria transmission and greater utilization of preventive interventions [7, 9, 10]. However, these relationships remain complex because socioeconomic development may interact with ecological, environmental, and behavioural factors that vary across settings, resulting in substantial heterogeneity in malaria risk within and between countries [8].

Despite extensive malaria research in Ghana, important knowledge gaps remain. Most previous studies have focused either on malaria prevalence or on specific preventive interventions using data from a single survey round or limited geographic settings [9, 10]. Few studies have comprehensively examined temporal trends in malaria burden alongside the socioeconomic determinants of malaria infection using multiple nationally representative surveys spanning almost a decade. Such evidence is essential to identify population groups that continue to experience disproportionately high malaria burden and to guide equitable, evidence-based malaria elimination strategies. Addressing socioeconomic disparities is particularly important as Ghana transitions from malaria control to malaria elimination, where interventions must become increasingly targeted and efficient [4, 5]. Therefore, this study analysed nationally representative data from the 2014 Ghana Demographic and Health Survey (GDHS), the 2016 and 2019 Ghana Malaria Indicator Surveys (GMIS), and the 2022 GDHS to assess trends in malaria prevalence among children aged 6–59 months and to examine the socioeconomic determinants of malaria infection in Ghana. The findings provide nationally representative evidence to inform policy, strengthen equity-focused malaria interventions, and support implementation of Ghana's National Malaria Elimination Strategic Plan and the achievement of Sustainable Development Goal 3.3, which seeks to end the epidemics of malaria and other communicable diseases by 2030 [11].

Methods

Study design and setting

This was a repeated cross-sectional analysis of secondary data from four rounds of the Ghana Demographic and Health Survey (DHS) programme: the 2014 DHS, the 2016 Malaria Indicator Survey (MIS), the 2019 MIS, and the 2022 DHS. Ghana is a West African country of approximately 238,533 km² comprising sixteen administrative regions; at the time of the most recent census (2021) the national population was 30.8 million, roughly evenly split between urban and rural residence. Malaria transmission occurs year-round across all ecological zones, with more intense transmission in the forested southern and mid-belt regions than in the coastal savannah around Greater Accra.

Data source

All four surveys were implemented by the Ghana Statistical Service and the Ghana Health Service with technical support from ICF Macro through the Measure DHS programme, and were funded by the United States Agency for International Development, the Government of Ghana, and several co-financing

partners (UNICEF, the Global Fund, the International Labour Organization, the Danish International Development Agency, the United Nations Development Programme, and the United Nations Population Fund). Each survey used a standardised DHS household and biomarker questionnaire, collecting information on household composition, socioeconomic circumstances, and, for children aged 6–59 months, malaria testing by RDT and/or microscopy. De-identified datasets in STATA format were obtained from Measure DHS following submission of a study concept note and approval of data access.

Study population and sample size

The analytic population comprised children aged 6–59 months with a valid malaria test result in each survey round. The four surveys enumerated 12,831 (2014), 5,841 (2016), 5,799 (2019), and 18,450 (2022) households; from the pooled 42,921 age-eligible children under five, 13,513 with complete malaria testing data were retained for analysis (2,869 in 2014; 3,127 in 2016; 2,965 in 2019; 4,552 in 2022). Children older than five years at the time of interview, and those who aged out of the 6–59-month window between the sampling frame and interview date, were excluded.

Sampling strategy

Each survey used a stratified two-stage cluster design. Enumeration areas (clusters) were selected in the first stage with probability proportional to size, stratified by region and urban/rural residence; households were selected within each cluster in the second stage. No additional sampling was undertaken for this analysis, which relied entirely on the existing DHS/MIS sampling frames.

Variables

Outcome Variable

The outcome variable was malaria infection among children aged 6–59 months. Malaria status was determined using microscopy test results obtained during the DHS and MIS surveys. Children with a positive microscopy result were classified as having malaria and coded as 1, while those with a negative microscopy result were classified as not having malaria and coded as 0.

Exposure Variables

The exposure variables comprised selected socioeconomic and demographic characteristics that were consistently available across the 2014 Ghana Demographic and Health Survey (DHS), the 2016 and 2019 Ghana Malaria Indicator Surveys (MIS), and the 2022 Ghana DHS. These variables were selected based on their documented association with malaria risk in previous studies and their relevance to the objectives of the present study. The child-level variables included age, categorized into 6–11, 12–23, 24–

35, 36–47, and 48–59 months, and sex (male or female). Maternal education was categorized as no education, primary, middle/JHS, secondary, and higher education.

Household socioeconomic characteristics included insecticide-treated net (ITN) utilization, household wealth index, place of residence, sex of the household head, age of the household head, access to electricity, and region of residence. ITN utilization was classified as no child slept under an ITN, all children slept under an ITN, some children slept under an ITN, and no ITN in the household. Household wealth index was categorized into poorest, poorer, middle, richer, and richest quintiles based on the DHS wealth index, which is constructed using principal component analysis of household assets and housing characteristics. Place of residence was classified as urban or rural, while the sex of the household head was categorized as male or female. The age of the household head was grouped into less than 25 years, 25–34 years, 35–44 years, and 45 years or older. Household access to electricity was recorded as either yes or no. Region of residence included Western, Central, Greater Accra, Volta, Eastern, Ashanti, Brong Ahafo, Northern, Upper East, and Upper West. All exposure variables were treated as categorical variables and included in the multilevel logistic regression models to examine their association with malaria prevalence among children under five years in Ghana.

Operational definitions

Wealth index quintiles follow the standard DHS asset-based construction and are not directly comparable to income; they reflect relative household position within each survey round rather than an absolute standard of living. ITN utilization refers to self-reported net use the night preceding the survey, a standard DHS proxy for regular use rather than a direct behavioural observation.

Statistical analysis

All statistical analyses were performed using Stata version 17.0 (StataCorp, College Station, TX, USA). The complex survey design of the Ghana Demographic and Health Surveys (DHS) and Malaria Indicator Surveys (MIS) was accounted for using the `svyset` command, specifying the primary sampling unit (PSU), sampling weights, and stratification variables. This ensured that all estimates were representative of the national population and accounted for unequal probabilities of selection, clustering, and stratification.

Weighted frequencies and percentages were used to describe the socioeconomic characteristics of study participants and the prevalence of malaria across the four survey years (2014 DHS, 2016 MIS, 2019 MIS, and 2022 DHS). The prevalence of malaria was compared across survey years and socioeconomic characteristics using design-adjusted Pearson chi-square tests. Statistical significance was assessed at a 5% level ($p < 0.05$).

To identify socioeconomic factors associated with malaria prevalence, multilevel logistic regression models were fitted separately for each survey year. A multilevel approach was adopted because children

were nested within primary sampling units (clusters), violating the assumption of independence required for conventional logistic regression. Four models were estimated for each survey. Model I was an empty model containing only the random intercept to assess the extent of clustering in malaria prevalence across clusters. Model II included child-level characteristics, Model III incorporated household-level socioeconomic variables, and Model IV represented the fully adjusted model, including child-, household-, and community-level characteristics.

Adjusted odds ratios (AORs) with 95% confidence intervals (CIs) were reported to quantify the associations between the explanatory variables and malaria prevalence. Random-effects parameters, including the cluster-level variance and intraclass correlation coefficient (ICC), were estimated to assess the degree of between-cluster variation in malaria prevalence. The Bayesian Information Criterion (BIC) was used to compare model fit, with lower BIC values indicating a better-fitting model. Sampling weights were applied throughout both the descriptive and multivariable analyses to account for the complex survey design. Records with missing data on variables included in the analyses were excluded using complete-case analysis. Statistical significance was defined as $p < 0.05$.

Ethical considerations

The Ghana Health Service Ethics Review Board reviewed and approved the protocol for each DHS/MIS round, and written informed consent was obtained from all participating households prior to interview and biomarker testing. Permission to access and analyse the de-identified datasets for this secondary analysis was granted by Measure DHS following review of a study concept note. Institutional ethical clearance for the present analysis was obtained from the Research Ethics Committee of the University of Health and Allied Sciences.

Results

Socio-demographic characteristics

Socio-economic characteristics of GDHS survey respondents in Ghana Table 4.1 provides a detailed analysis of the socioeconomic characteristics of malaria prevalence across DHS 2014, MIS 2016, MIS 2019, and DHS 2022. The mean age of participants remained relatively consistent over the years, ranging between 32.00($\pm$ 16.00) in 2022 and 33.00($\pm$ 16.00) in 2019. Regarding the age distribution of children, the 12–23-month group recorded the highest proportion in DHS 2014 with 652 (22.7%) participants, a trend that persisted in DHS 2022 with 1,070 (22.7%). However, MIS 2016 and MIS 2019 showed a peak in the 24–35-month age group, recording 728 (23.3%) and 700 (24.0%), respectively. Across all years, males consistently outnumbered females, with 1,512 (52.7%) in DHS 2014, 1,601 (51.2%) in MIS 2016, 1,506 (51.0%) in MIS 2019, and 2,303 (51.0%) in DHS 2022. Similarly, ITN (insecticide-treated net) utilization showed improvements across the years. For instance, the proportion of households where all children used nets increased from 1,230 (44.0%) in DHS 2014 to 2,100 (47.0%) in DHS 2022. Although the percentage of households without nets initially dropped from 576 (21.0%) in DHS 2014 to 427 (15.0%) in MIS 2019, it rose slightly to 911 (20.2%) in DHS 2022. Also, rural residence consistently

accounted for a majority of participants, rising steadily from 1,532 (53.4%) in DHS 2014 to 2,656 (58.4%) in DHS 2022. However, while male-headed households were dominant in DHS 2014, representing 2,105 (73.4%), their proportion declined markedly to 2,323 (51.0%) in DHS 2022.

Table 1
Socio-demographic characteristics

Variable	Category	2014 DHSN = 2,869n (%)	2016 MISN = 3,127n (%)	2019 MISN = 2,965n (%)	2022 DHSN = 4,552n (%)
Mean age (months), Mean ± SD		32.32 ± 15.42	32.32 ± 15.47	33.00 ± 16.00	32.00 ± 16.00
Age of child (months)	6–11	316 (11.0)	340 (10.9)	320 (10.8)	506 (11.0)
	12–23	652 (22.7)	702 (22.5)	640 (21.6)	1,070 (22.7)
	24–35	638 (22.2)	728 (23.3)	700 (24.0)	971 (22.2)
	36–47	627 (21.8)	639 (20.4)	656 (22.1)	1,022 (21.8)
	48–59	637 (22.2)	718 (23.0)	650 (21.9)	983 (22.2)
Sex of child	Male	1,512 (52.7)	1,601 (51.2)	1,506 (51.0)	2,303 (51.0)
	Female	1,357 (47.3)	1,526 (49.0)	1,459 (49.2)	2,250 (49.4)
Mother's educational level	No education	944 (36.3)	728 (27.0)	707 (28.4)	1,019 (25.0)
	Primary	522 (20.1)	548 (20.3)	540 (22.0)	606 (15.0)
	Middle/JHS	966 (35.8)	1,050 (40.4)	836 (34.0)	2,111 (51.3)
	Secondary/SHS	84 (3.2)	282 (10.5)	118 (5.0)	379 (9.2)
	Higher	84 (3.2)	173 (6.4)	118 (5.0)	379 (9.2)
ITN utilization	No	835 (30.0)	862 (28.0)	772 (26.4)	1,155 (26.0)
	All children	1,230 (44.0)	1,475 (48.0)	1,380 (47.1)	2,100 (47.0)
	Some children	152 (5.4)	264 (9.0)	350 (12.0)	351 (8.0)
	No net	576 (21.0)	493 (16.0)	427 (15.0)	911 (20.2)
Wealth index	Poorest	642 (22.4)	695 (22.2)	697 (24.0)	1,055 (23.2)
	Poorer	584 (20.4)	639 (20.4)	645 (22.0)	925 (20.3)
	Middle	586 (20.4)	630 (20.2)	615 (21.0)	870 (19.1)
	Richer	551 (19.2)	642 (21.0)	531 (18.0)	866 (19.0)
	Richest	507 (17.7)	521 (17.0)	478 (16.1)	837 (18.4)
Residence	Urban	1,337 (46.6)	1,409 (41.7)	1,122 (37.8)	1,896 (41.7)
	Rural	1,532 (53.4)	1,718 (58.3)	1,843 (62.2)	2,656 (58.4)

Variable	Category	2014 DHSN = 2,869n (%)	2016 MISN = 3,127n (%)	2019 MISN = 2,965n (%)	2022 DHSN = 4,552n (%)
Sex of household head	Male	2,105 (73.4)	2,391 (77.0)	2,119 (72.0)	2,323 (51.0)
	Female	764 (27.0)	736 (24.0)	846 (29.0)	2,229 (49.0)
Age of household head (years)	< 25	175 (6.1)	175 (6.0)	168 (6.0)	290 (6.4)
	25–34	858 (30.0)	798 (26.0)	750 (25.3)	1,162 (26.0)
	35–44	985 (34.3)	1,000 (32.0)	871 (29.4)	1,572 (35.0)
	≥ 45	851 (30.0)	1,155 (37.0)	1,176 (40.0)	1,527 (34.0)
Household has electricity	No	807 (28.1)	771 (25.0)	819 (28.0)	909 (20.0)
	Yes	2,062 (72.0)	2,356 (75.4)	2,146 (72.3)	3,643 (80.0)
Region	Western	311 (11.0)	228 (7.3)	308 (10.4)	400 (9.0)
	Central	339 (12.0)	317 (10.2)	219 (7.4)	464 (10.2)
	Greater Accra	444 (16.0)	457 (15.0)	359 (12.1)	555 (12.2)
	Volta	206 (7.2)	235 (8.0)	332 (11.2)	319 (7.0)
	Eastern	260 (9.1)	248 (10.0)	315 (11.0)	340 (8.0)
	Ashanti	494 (17.2)	704 (23.0)	475 (16.0)	850 (19.0)
	Brong Ahafo	284 (10.0)	250 (8.0)	254 (9.0)	465 (10.2)
	Northern	347 (12.1)	493 (16.0)	470 (16.0)	797 (18.0)
	Upper East	113 (4.0)	116 (4.0)	141 (5.0)	219 (5.0)
	Upper West	72 (3.0)	79 (3.0)	91 (3.1)	143 (3.1)

Figure 1 shows that malaria positive among children under five in Ghana using RDT reduced from 36% in 2014 to 16% in 2022 whiles microscopy positives decreased from 25% in 2014 to 8% in 2022.

Figure 2 shows that malaria prevalence among the poorest wealth index using RDT reduced from 58% in 2014 to 33% in 2022. Also, those in poorer wealth index decreased from 56% in 2014 to 21% in 2022. Besides, those in middle wealth index decreased from 37% in 2014 to

14% in 2022. Moreover, those in richer wealth index decreased from 14% in 2014 to 9% in

Figure 4 shows that malaria prevalence among the rural folks using microscopy reduced from 36% in 2014 to 13% in 2022. Meanwhile, the prevalence in the urban areas decreased from 14% in 2014 to 5% in

2022.

Association between Socioeconomic Factors and Malaria Prevalence among Children Under Five in Ghana

In the 2014 Demographic and Health Survey (DHS), the child's age ($\chi^2 = 31.47, p = 0.002$), maternal educational level ($\chi^2 = 129.67, p < 0.001$), insecticide-treated net (ITN) utilization ($\chi^2 = 20.64, p = 0.010$), household wealth index ($\chi^2 = 261.06, p < 0.001$), place of residence ($\chi^2 = 209.00, p < 0.001$), access to electricity ($\chi^2 = 142.72, p < 0.001$), and region of residence ($\chi^2 = 166.41, p < 0.001$) were significantly associated with malaria prevalence. Similarly, findings from the 2016 Malaria Indicator Survey (MIS) showed that the child's age ($\chi^2 = 17.29, p = 0.031$), maternal educational level ($\chi^2 = 114.12, p < 0.001$), ITN utilization ($\chi^2 = 20.64, p = 0.010$), household wealth index ($\chi^2 = 280.35, p < 0.001$), place of residence ($\chi^2 = 135.16, p = 0.001$), access to electricity ($\chi^2 = 162.11, p < 0.001$), and region of residence ($\chi^2 = 124.28, p = 0.008$) were also significantly associated with malaria prevalence.

The 2019 MIS showed a similar pattern. The child's age ($\chi^2 = 31.38, p = 0.004$), household wealth index ($\chi^2 = 126.16, p < 0.001$), place of residence ($\chi^2 = 107.32, p < 0.001$), access to electricity ($\chi^2 = 100.60, p < 0.001$), and region of residence ($\chi^2 = 117.51, p = 0.028$) were significantly associated with malaria prevalence. Maternal educational level and ITN utilization were not significantly associated with malaria prevalence in the 2019 survey. In the 2022 DHS, the child's age ($\chi^2 = 38.06, p = 0.001$), maternal educational level ($\chi^2 = 100.88, p < 0.001$), ITN utilization ($\chi^2 = 26.36, p = 0.003$), household wealth index ($\chi^2 = 157.97, p < 0.001$), place of residence ($\chi^2 = 103.67, p < 0.001$), access to electricity ($\chi^2 = 51.11, p < 0.001$), and region of residence ($\chi^2 = 51.39, p < 0.001$) were all significantly associated with malaria prevalence among children under five years.

Table 2
Association between Socioeconomic Factors and Malaria Prevalence

Variable	DHS 2014% (95% CI)	MIS 2016% (95% CI)	MIS 2019% (95% CI)	DHS 2022% (95% CI)	Chi-square (p-value)
Age of child (months)					
6–11	16.7 (12.6–21.7)	17.0 (11.9–23.8)	13.9 (10.3–18.5)	5.9 (3.7–9.2)	31.47 (0.002), 17.29 (0.031), 31.38 (0.004), 38.06 (0.001)
12–23	21.8 (18.0–26.2)	17.6 (14.1–21.7)	19.3 (15.3–24.0)	5.6 (4.0–7.7)	
24–35	23.9 (19.8–28.5)	6.7 (4.2–10.5)	—	7.0 (5.2–9.3)	
36–47	27.8 (23.3–32.8)	13.3 (10.1–17.3)	—	10.2 (8.2–12.7)	
48–59	31.3 (26.4–36.6)	19.6 (15.1–25.0)	—	11.9 (9.5–14.7)	
Sex of child	Male: 24.7 (21.3–28.5)	Male: 13.8 (10.7–17.8)	Male: 21.9 (18.1–26.2)	Male: 14.0 (11.4–17.1)	—
	Female: 25.5 (22.3–29.0)	Female: 19.3 (16.0–23.1)	Female: 13.9 (10.3–18.5)	Female: 8.5 (7.1–10.2)	—
Mother's education	No edu: 35.9 (30.7–41.4)	30.0 (21.1–40.7)	22.2 (18.4–26.5)	10.2 (7.5–13.6)	Highly significant (< 0.001)
	Primary: 32.4 (27.5–37.7)	25.3 (20.2–31.1)	29.3 (25.7–33.2)	16.9 (14.0–20.3)	
	Middle/JHS: 17.0 (14.0–20.5)	19.8 (16.1–24.0)	17.1 (12.5–22.8)	8.1 (6.7–9.7)	
	Secondary: 2.2 (0.5–9.1)	5.3 (3.0–9.4)	21.3 (17.4–25.8)	0.29 (0.667)	
	Higher: —	3.1 (1.3–7.3)	14.3 (11.9–17.1)	0.9 (0.2–3.4)	

Variable	DHS 2014% (95% CI)	MIS 2016% (95% CI)	MIS 2019% (95% CI)	DHS 2022% (95% CI)	Chi-square (p-value)
ITN utilization	No ITN: 30.2 (21.2–41.0)	26.8 (21.1–33.4)	14.0 (9.6–19.9)	12.1 (7.9–17.9)	Significant in DHS 2014 & 2022
	Household ITN: 21.6 (17.0–27.0)	21.3 (16.1–27.6)	12.1 (8.0–17.9)	6.3 (4.4–9.0)	
Wealth index	Poorest: 40.2 (34.3–46.3)	37.3 (29.9–45.3)	22.4 (17.7–28.0)	15.6 (13.1–18.5)	Highly significant (< 0.001)
	Poorer: 37.7 (32.6–43.1)	28.9 (21.5–37.5)	18.3 (14.5–22.9)	10.8 (8.4–13.8)	
	Middle: 23.3 (18.4–29.1)	17.1 (12.5–23.0)	15.2 (11.2–20.2)	7.5 (5.3–10.5)	
	Richer: 12.9 (8.8–18.5)	12.4 (9.2–16.5)	7.0 (4.3–11.1)	4.8 (3.2–7.3)	
	Richest: 6.9 (4.2–11.0)	2.0 (1.0–4.1)	2.1 (0.7–6.2)	0.8 (0.2–2.5)	
Residence	Urban: 12.6 (10.0–15.7)	11.2 (8.4–14.7)	6.1 (4.2–8.8)	4.1 (3.0–5.6)	Highly significant (< 0.001)
	Rural: 36.1 (32.0–40.3)	28.2 (22.4–34.9)	19.7 (16.4–23.4)	12.4 (10.7–14.3)	
Electricity	No: 40.6 (35.3–46.1)	36.8 (30.0–44.2)	26.6 (21.3–32.8)	14.2 (11.4–17.5)	Highly significant (< 0.001)
	Yes: 19.1 (16.3–22.2)	15.3 (12.8–18.2)	10.8 (8.9–12.9)	6.8 (5.8–8.1)	
Region	Western: 36.2 (28.9–44.1)	23.5 (15.6–33.9)	27.1 (20.3–35.2)	7.8 (4.8–12.3)	Significant regional variation
	Central: 35.9 (26.1–47.0)	30.2 (23.7–37.7)	17.6 (12.7–23.9)	9.4 (6.4–13.6)	
	Greater Accra: 10.1 (6.3–15.9)	4.8 (2.8–8.0)	2.4 (0.8–6.7)	1.9 (0.6–6.0)	

Variable	DHS 2014% (95% CI)	MIS 2016% (95% CI)	MIS 2019% (95% CI)	DHS 2022% (95% CI)	Chi-square (p- value)
	Volta: 24.1 (14.0–38.2)	27.7 (20.5– 36.2)	20.4 (13.9– 28.9)	9.9 (6.3– 15.2)	
	Eastern: 28.1 (21.0–36.6)	30.8 (21.7– 41.8)	12.1 (6.0– 22.8)	6.6 (3.9– 11.0)	
	Ashanti: 15.5 (11.2–21.2)	16.4 (11.2– 23.4)	10.4 (5.9– 17.7)	7.1 (4.3– 11.5)	
	Brong Ahafo: 25.3 (17.9– 34.5)	22.8 (12.5– 38.0)	17.5 (12.2– 24.4)	11.0 (8.5– 14.	

Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence in 2014: Fixed and Random Effects Models

The analysis of socioeconomic factors influencing malaria prevalence in 2014 revealed several significant associations. Age of the child demonstrated a strong positive correlation with malaria prevalence. Compared to children aged 6–11 months (reference group), those aged 48–59 months had the highest odds of malaria prevalence in both Model III (AOR: 2.85, 95% CI: 1.88–4.31, $p < 0.001$) and Model IV (AOR: 2.86, 95% CI: 1.90–4.30, $p < 0.001$). Maternal education was inversely associated with malaria prevalence. In Model III, children of mothers with secondary education had significantly lower odds of malaria (AOR: 0.40, 95% CI: 0.30–0.54, $p < 0.001$), and this effect persisted in Model IV (AOR: 0.54, 95% CI: 0.40–0.73, $p < 0.001$). The effect was even stronger for mothers with higher education (Model IV: AOR: 0.14, 95% CI: 0.03–0.65, $p = 0.012$). Addition, wealth index exhibited a clear gradient, with higher wealth associated with reduced malaria prevalence. Compared to the poorest households, the richest had the lowest odds in Model III (AOR: 0.10, 95% CI: 0.05–0.19, $p < 0.001$) and Model IV (AOR: 0.17, 95% CI: 0.09–0.35, $p < 0.001$). Also, Rural residence was linked to higher malaria prevalence, with rural children having increased odds in Model IV (AOR: 1.57, 95% CI: 1.07–2.30, $p = 0.021$) compared to urban residents. Furthermore, regionally, malaria prevalence was highest in the Western Region (Model IV: AOR: 2.76, 95% CI: 1.32–5.87, $p = 0.007$) and the Central Region (AOR: 2.64, 95% CI: 1.25–5.56, $p = 0.011$) compared to Greater Accra. However, the Upper East Region exhibited the lowest odds of malaria prevalence (Model IV: AOR: 0.18, 95% CI: 0.08–0.45, $p < 0.001$). Random effects showed a decline in PSU variance and intra-cluster correlation (ICC) from Model I (ICC = 0.34) to Model IV (ICC = 0.19), indicating improved explanatory power of the adjusted models. The Bayesian Information Criterion (BIC) decreased from 3085.03 in Model I to 2685.44 in Model IV, further confirming model fit improvement.

Table 3
Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence in 2014: Fixed and Random Effects Models

Variable	Model I	Model II	Model III	Model IV
Fixed Effects				
Age of child (months)				
6–11		Ref		Ref.
12–23		1.42 (0.94–2.15), 0.094		1.44 (0.96–2.16), 0.082
24–35		1.72 (1.14–2.60), 0.010		1.71 (1.13–2.56), 0.011
36–47		2.62 (1.73–3.97), < 0.001		2.46 (1.63–3.70), < 0.001
48–59		2.85 (1.88–4.31), < 0.001		2.86 (1.90–4.30), < 0.001
Mother's Educational Level				
No education		Ref.		Ref.
Primary		0.95 (0.70–1.29), 0.756		1.05 (0.77–1.42), 0.767
Middle/JHS				
Secondary		0.40 (0.30–0.54), < 0.001		0.54 (0.40–0.73), < 0.001
Higher		0.05 (0.01–0.25), < 0.001		0.14 (0.03–0.65), 0.012
ITN Utilization				
No		Ref.		
All children		1.19 (0.91–1.57), 0.210		
Some children		1.06 (0.66–1.71), 0.801		
No net in household		1.11 (0.78–1.56), 0.567		
Wealth Index				
Poorest		Ref.		Ref.

Variable	Model I	Model II	Model III	Model IV
Fixed Effects				
Age of child (months)				
Poorer		0.71 (0.52–0.96), 0.026		0.74 (0.53–1.04), 0.081
Middle		0.32 (0.22–0.48), < 0.001		0.40 (0.26–0.61), < 0.001
Richer		0.15 (0.09–0.26), < 0.001		0.19 (0.11–0.32), < 0.001
Richest		0.10 (0.055–0.19), < 0.001		0.17 (0.086–0.35), < 0.001
Residence				
Urban		Ref.		Ref.
Rural		1.41 (0.98–2.01), 0.063		1.57 (1.07–2.30), 0.021
Region				
Western		2.72 (1.34–5.50), 0.005		2.76 (1.32–5.87), 0.007
Central		2.18 (1.07–4.41), 0.031		2.64 (1.25–5.56), 0.011
Greater Accra		Ref.		Ref.
Volta		0.83 (0.38–1.80), 0.639		0.86 (0.38–1.95), 0.721
Eastern		1.47 (0.71–3.03), 0.299		1.80 (0.83–3.91), 0.135
Ashanti		0.88 (0.42–1.85), 0.736		1.04 (0.48–2.26), 0.928
Brong Ahafo		0.99 (0.45–2.03), 0.987		1.04 (0.49–2.22), 0.912
Northern		0.86 (0.41–1.81), 0.695		0.80 (0.36–1.76), 0.574
Upper East		0.19 (0.08–0.45), < 0.001		0.18 (0.08–0.45), < 0.001
Upper West		1.05 (0.48–2.28), 0.905		0.95 (0.42–2.18), 0.908

Variable	Model I	Model II	Model III	Model IV
Fixed Effects				
Age of child (months)				
Random Effects Model				
PSU variance	1.67 (1.25–2.24)	1.53 (1.11–2.11)	0.79 (0.55–1.15)	0.76 (0.52–1.16)
ICC	0.34 (0.27–0.40)	0.32 (0.25–0.39)	0.19 (0.14–0.26)	0.19 (0.14–0.26)
N	2,869	2,531	2,869	2,600
Number of clusters	423	419	423	419
BIC	3085.03	2698.48	2995.98	2685.44

Note: Values are adjusted odds ratios (AOR) with 95% confidence intervals in parentheses, followed by the p-value (e.g., 1.42 (0.94–2.15), 0.094). "Ref." denotes the reference category. Bold values indicate statistically significant associations ($p < 0.05$). Blank cells indicate that data for that variable/model combination were not reported.

Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence: MIS 2016

The table below shows analysis of malaria prevalence determinants in MIS 2016 reveals critical associations. The age of the child remained a significant predictor of malaria prevalence. Compared to children aged 6–11 months (reference group), those aged 48–59 months had the highest odds of malaria prevalence, with adjusted odds ratios (AOR) of 2.56 (95% CI: 1.70–3.85, $p < 0.001$) in Model III and 2.59 (95% CI: 1.72–3.89, $p < 0.001$) in Model IV. Also, maternal education exhibited a strong inverse relationship with malaria prevalence. In Model III, children of mothers with secondary education had significantly reduced odds of malaria (AOR: 0.23, 95% CI: 0.13–0.41, $p < 0.001$), with the effect persisting in Model IV (AOR: 0.35, 95% CI: 0.19–0.63, $p < 0.001$). Mothers with higher education showed no significant effect after adjustments in Model IV (AOR: 0.67, 95% CI: 0.26–1.70, $p = 0.397$). Wealth index demonstrated a gradient effect, with higher wealth associated with reduced odds of malaria. For instance, the richest households had the lowest odds in Model III (AOR: 0.10, 95% CI: 0.05–0.21, $p < 0.001$) and Model IV (AOR: 0.12, 95% CI: 0.05–0.24, $p < 0.001$). Furthermore, rural residence significantly increased the likelihood of malaria, with an AOR of 1.91 (95% CI: 1.29–2.82, $p = 0.001$) in Model III and 1.83 (95% CI: 1.20–2.79, $p = 0.005$) in Model IV, compared to urban residence. In addition, regionally, malaria prevalence varied significantly. Children in the Central Region had the highest odds compared to Greater Accra, with AORs of 4.07 (95% CI: 1.60–10.41, $p = 0.003$) in Model III and 4.13 (95% CI: 1.56–

10.95, $p = 0.004$) in Model IV. 41 Similar high odds were observed in the Western, Volta, and Eastern regions. The Random effects model demonstrated a reduction in PSU variance from Model I (1.54, 95% CI: 1.11–2.14) to Model IV (0.76, 95% CI: 0.51–1.14), while the intraclass correlation (ICC) declined from 0.32 to 0.19, indicating improved model fit with adjustments. The Bayesian Information Criterion (BIC) also decreased, from 2973.02 in Model I to 2602.89 in Model IV, confirming better explanatory power in adjusted models.

Table 4
Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence: MIS 2016

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
6–11	Ref.	Ref.		
12–23	1.26 (0.83–1.91), 0.271	1.22 (0.81–1.84), 0.342		
24–35	1.86 (1.24–2.79), 0.003	1.85 (1.23–2.78), 0.003		
36–47	1.94 (1.30–2.96), 0.001	1.99 (1.32–3.00), 0.001		
48–59	2.56 (1.70–3.85), < 0.001	2.59 (1.72–3.89), < 0.001		
Mother's educational level				
No education	Ref.	Ref.		
Primary	0.76 (0.56–1.03), 0.080	0.86 (0.63–1.17), 0.326		
Middle/JHS	0.68 (0.51–0.92), 0.012	0.88 (0.65–1.21), 0.442		
Secondary	0.23 (0.13–0.41), < 0.001	0.35 (0.19–0.63), < 0.001		
Higher	0.19 (0.08–0.45), < 0.001	0.67 (0.26–1.70), 0.397		
Wealth index				
Poorest	Ref.	Ref.	Ref.	Ref.
Poorer	0.73 (0.55–0.99), 0.042	0.82 (0.59–1.13), 0.216		
Middle	0.41 (0.28–0.59), < 0.001	0.45 (0.30–0.68), < 0.001		
Richer	0.37 (0.24–0.57), < 0.001	0.38 (0.23–0.61), < 0.001		
Richest	0.10 (0.05–0.21), < 0.001	0.12 (0.05–0.24), < 0.001		

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
Residence				
Urban	Ref.	Ref.		
Rural	1.91 (1.29–2.82), 0.001	1.83 (1.20–2.79), 0.005		
Sex of head of household				
Male	Ref.	Ref.		
Female	—	—		
Age of household head				
< 25	Ref.	Ref.		
25–34	—	—		
35–44	—	—		
45+	—	—		
Has electricity				
No	Ref.	Ref.		
Yes	3.22 (1.25–8.32), 0.016	3.09 (1.15–8.31), 0.026		
Region				
Western	4.07 (1.60–10.41), 0.003	4.13 (1.56–10.95), 0.004		
Central	Ref.	Ref.		
Greater Accra	3.63 (1.42–9.27), 0.007	3.29 (1.24–8.73), 0.017		
Volta	3.90 (1.52–10.05), 0.005	3.83 (1.43–10.23), 0.007		
Eastern	2.29 (0.91–5.79), 0.080	2.42 (0.92–6.34), 0.072		

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
Ashanti	2.36 (0.91–6.13), 0.078	2.04 (0.76–5.51), 0.158		
Brong Ahafo	2.26 (0.87–5.89), 0.095	1.97 (0.72–5.36), 0.185		
Northern	0.93 (0.34–2.54), 0.894	0.86 (0.31–2.45), 0.784		
Upper East	—	—		
Upper West	1.58 (0.58–4.27), 0.368	1.36 (0.48–3.85), 0.561		
Random effects				
PSU variance	1.54 (1.11–2.14)	1.41 (0.99–2.02)	0.69 (0.47–1.02)	0.76 (0.51–1.14)
ICC	0.32 (0.25–0.39)	0.30 (0.23–0.38)	0.17 (0.12–0.24)	0.19 (0.13–0.26)
N	3,078	2,674	3,078	2,674
Number of clusters	200	200	200	200
BIC	2973.02	2595.75	2950.46	2602.89

Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence: MIS 2019

Child age remained significantly associated with malaria prevalence, with children aged 12–23 months (AOR = 1.80, 95% CI: 1.04–3.10), 24–35 months (AOR = 2.65, 95% CI: 1.55–4.51), 36–47 months (AOR = 2.73, 95% CI: 1.60–4.65), and 48–59 months (AOR = 2.99, 95% CI: 1.75–5.10) having significantly higher odds of malaria than those aged 6–11 months. Household wealth was a significant predictor of malaria. Compared with children from the poorest households, those from poorer (AOR = 0.51, 95% CI: 0.35–0.76), middle (AOR = 0.39, 95% CI: 0.24–0.63), richer (AOR = 0.19, 95% CI: 0.10–0.36), and richest households (AOR = 0.06, 95% CI: 0.02–0.18) had significantly lower odds of malaria. Children residing in rural areas also had higher odds of malaria than those in urban areas (AOR = 1.70, 95% CI: 1.09–2.66). Maternal education and ITN utilization were not significantly associated with malaria prevalence after adjustment for other covariates. Likewise, no significant regional differences were observed in the fully adjusted model. The random-effects analysis showed substantial between-cluster variation in malaria prevalence, with the intraclass correlation coefficient (ICC) decreasing from 0.27 in the null model to

0.12 in the fully adjusted model, indicating that much of the clustering was explained by the covariates included in the models. The lowest Bayesian Information Criterion (BIC = 1901.85) was observed for Model II, suggesting the best model fit.

Table 5
Multilevel Analysis of Socioeconomic Determinants of Malaria Prevalence

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
6–11	Ref.	Ref.		
12–23	1.83 (1.07–3.15), 0.028	1.80 (1.04–3.10), 0.035		
24–35	2.67 (1.57–4.52), < 0.001	2.65 (1.55–4.51), < 0.001		
36–47	2.81 (1.65–4.78), < 0.001	2.73 (1.60–4.65), < 0.001		
48–59	3.07 (1.80–5.23), < 0.001	2.99 (1.75–5.10), < 0.001		
Mother's educational level				
No education	Ref.	Ref.		
Primary	0.76 (0.53–1.10), 0.143	0.69 (0.48–1.01), 0.053		
Middle/JHS	0.70 (0.46–1.00), 0.051	0.72 (0.49–1.01), 0.092		
Secondary	0.59 (0.35–1.00), 0.049	0.86 (0.50–1.49), 0.597		
Higher	—	—		
ITN utilization				
No	Ref.	Ref.		
All children	0.88 (0.54–1.44), 0.607	0.87 (0.53–1.43), 0.582		
Some children	1.24 (0.82–1.87), 0.317	0.94 (0.62–1.44), 0.783		
No net in household	1.07 (0.63–1.84), 0.797	0.83 (0.48–1.42), 0.494		
Wealth index				
Poorest	Ref.	Ref.	Ref.	Ref.

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
Poorer	0.58 (0.41–0.81), 0.002	0.51 (0.35–0.76), 0.001		
Middle	0.45 (0.29–0.68), < 0.001	0.39 (0.24–0.63), < 0.001		
Richer	0.21 (0.12–0.36), < 0.001	0.19 (0.10–0.36), < 0.001		
Richest	0.04 (0.01–0.13), < 0.001	0.06 (0.02–0.18), < 0.001		
Residence				
Urban	Ref.	Ref.		
Rural	1.81 (1.21–2.71), 0.004	1.70 (1.09–2.66), 0.019		
Has electricity				
No	Ref.	Ref.		
Yes	5.21 (1.62–16.76), 0.006	4.34 (1.31–14.42), 0.016		
Region				
Western	3.13 (0.96–10.25), 0.059	2.74 (0.80–9.35), 0.108		
Central	Ref.	Ref.		
Greater Accra	2.42 (0.73–8.03), 0.150	2.07 (0.60–7.19), 0.250		
Volta	2.15 (0.64–7.27), 0.217	1.94 (0.55–6.84), 0.301		
Eastern	1.76 (0.52–5.92), 0.359	1.81 (0.53–6.25), 0.346		
Ashanti	2.34 (0.71–7.75), 0.164	1.87 (0.54–6.24), 0.323		
Brong Ahafo	0.92 (0.28–3.09), 0.894	0.63 (0.18–2.23), 0.474		

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
Northern	0.75 (0.21–2.59), 0.644	0.56 (0.15–2.08), 0.389		
Upper East	0.66 (0.19–2.30), 0.510	0.44 (0.12–1.63), 0.219		
Upper West	—	—		
Random effects				
PSU variance	1.22 (0.82–1.83)	1.11 (0.72–1.72)	0.42 (0.24–0.74)	0.45 (0.24–0.84)
ICC	0.27 (0.20–0.36)	0.25 (0.18–0.34)	0.11 (0.07–0.18)	0.12 (0.07–0.20)
N	2,872	2,324	2,872	2,324
Number of clusters	200	200	200	200
BIC	2268.15	1901.85	2241.25	1910.92

Socioeconomic factors influencing malaria prevalence (DHS 2022)

The analysis of socioeconomic factors influencing malaria prevalence in 2022 revealed several significant associations. Age of the child demonstrated a strong positive correlation with malaria prevalence. Compared to children aged 6–11 months (reference group), those aged 48–59 months had the highest odds of malaria prevalence in both Model II (AOR: 2.91, 95% CI: 1.83–4.62, $p < 0.001$) and Model IV (AOR: 3.03, 95% CI: 1.91–4.81, $p < 0.001$). Maternal education was inversely associated with malaria prevalence. In Model II, children of mothers with secondary education had significantly lower odds of malaria (AOR: 0.44, 95% CI: 0.33–0.58, $p < 0.001$), and this effect persisted in Model IV (AOR: 0.59, 95% CI: 0.43–0.81, $p < 0.001$). Addition, wealth index exhibited a clear gradient, with higher wealth associated with reduced malaria prevalence. Compared to the poorest households, the richest had the lowest odds in Model II (AOR: 0.07, 95% CI: 0.03–0.18, $p < 0.001$) and Model IV (AOR: 0.13, 95% CI: 0.05–0.35, $p < 0.001$). Also, Rural residence was linked to higher malaria prevalence, with rural 51 children having increased odds in in Model III (AOR: 1.70, 95% CI: 1.21–2.37, $p = 0.002$) and Model IV (AOR: 1.73, 95% CI: 1.20–2.50, $p = 0.003$) compared to urban residents. Random effects showed a decline in PSU variance and intra-cluster correlation (ICC) from Model I (ICC = 0.55) to Model IV (ICC = 0.54), indicating improved explanatory power of the adjusted models. The Bayesian Information Criterion (BIC) decreased from 2813.16 in Model I to 2509.38 in Model IV, further confirming model fit improvement.

Table 6
Socioeconomic factors influencing malaria prevalence (DHS 2022)

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
6–11	Ref.	Ref.		
12–23	1.24 (0.77–2.00), 0.379	1.22 (0.76–1.97), 0.409		
24–35	1.76 (1.10–2.83), 0.018	1.82 (1.13–2.93), 0.013		
36–47	2.36 (1.49–3.73), < 0.001	2.45 (1.55–3.90), < 0.001		
48–59	2.91 (1.83–4.62), < 0.001	3.03 (1.91–4.81), < 0.001		
Sex of child				
Male	Ref.	Ref.		
Female	—	—		
Mother's educational level				
No education	Ref.	Ref.		
Primary	1.05 (0.77–1.43), 0.776	1.13 (0.82–1.56), 0.447		
Middle/JHS	0.44 (0.33–0.58), < 0.001	0.59 (0.43–0.81), 0.001		
Secondary	0.10 (0.04–0.28), < 0.001	0.33 (0.11–0.99), 0.048		
Higher	Ref.	Ref.		
ITN utilization				
No	Ref.	Ref.		
All children	1.26 (0.92–1.75), 0.154	1.45 (0.93–2.25), 0.100		
Some children	1.45 (0.93–2.25), 0.100	1.08 (0.72–1.62), 0.712		

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
No net in household	Ref.	Ref.		
Wealth index				
Poorest	Ref.	Ref.	Ref.	Ref.
Poorer	0.57 (0.43–0.76), < 0.001	0.64 (0.47–0.88), 0.005		
Middle	0.32 (0.21–0.49), < 0.001	0.39 (0.25–0.62), < 0.001		
Richer	0.32 (0.20–0.52), < 0.001	0.41 (0.24–0.71), 0.001		
Richest	0.07 (0.03–0.18), < 0.001	0.13 (0.05–0.35), < 0.001		
Residence				
Urban	Ref.	Ref.		
Rural	1.70 (1.21–2.37), 0.002	1.73 (1.20–2.50), 0.003		
Sex of head of household				
Male	Ref.	Ref.		
Female	—	—		
Age of household head				
< 25	Ref.	Ref.		
25–34	—	—		
35–44	—	—		
45+	—	—		
Has electricity				
No	Ref.	Ref.		

Variable	Model I OR (95% CI), p-value	Model II OR (95% CI), p-value	Model III OR (95% CI), p-value	Model IV OR (95% CI), p-value
Fixed effects				
Age of child (months)				
Yes	2.43 (0.67–8.75), 0.176	2.06 (0.56–7.62), 0.279		
Region				
Western	4.14 (1.12–15.32), 0.033	3.68 (0.97–14.00), 0.056		
Central	Ref.	Ref.		
Greater Accra	2.84 (0.80–10.07), 0.106	2.26 (0.62–8.20), 0.216		
Volta	2.47 (0.63–9.63), 0.193	1.78 (0.43–7.39), 0.428		
Eastern	3.00 (0.81–11.16), 0.101	2.58 (0.67–9.88), 0.166		
Ashanti	3.10 (0.89–10.77), 0.074	3.04 (0.86–10.73), 0.084		
Brong Ahafo	2.10 (0.61–7.26), 0.239	1.71 (0.48–6.04), 0.406		
Northern	2.17 (0.59–7.98), 0.244	1.91 (0.50–7.24), 0.343		
Upper East	2.88 (0.79–10.46), 0.109	2.42 (0.65–9.06), 0.189		
Upper West	—	—		
Random effects				
PSU variance	0.55	0.76 (0.49–1.18)	0.48 (0.28–0.80)	0.54 (0.32–0.93)
ICC	0.14	0.19 (0.13–0.26)	0.13 (0.08–0.20)	0.14 (0.09–0.22)
N	4,115	4,084	4,552	4,115
Number of clusters	615	615	615	615
BIC	2813.16	2470.97	2800.83	2509.38

Discussion

The study examined trends in malaria prevalence and the socioeconomic determinants of malaria infection among children aged 6 to 59 months in Ghana using nationally representative survey data collected between 2014 and 2022. The findings showed a substantial decline in malaria prevalence over the study period, while also demonstrating that important socioeconomic inequalities remain. Child age, maternal education, household wealth, place of residence, and geographical region were important predictors of malaria infection across most survey years. These findings suggest that although Ghana has made considerable progress in malaria control, the benefits have not been experienced equally across all population groups. They also indicate that achieving malaria elimination will require greater attention to the social and economic factors that continue to increase children's vulnerability to infection [7, 8].

One of the most important findings of this study was the marked decline in malaria prevalence between 2014 and 2022. Microscopy confirmed malaria prevalence decreased from 25% in 2014 to 8% in 2022, while RDT positivity declined from 36% to 16% during the same period. This decline likely reflects the considerable investments made by Ghana in malaria prevention and control over the past decade. The expansion of long lasting insecticide treated nets, improved access to rapid diagnostic testing, widespread use of artemisinin based combination therapy, intermittent preventive treatment during pregnancy, seasonal malaria chemoprevention in eligible districts, and strengthened surveillance systems have collectively contributed to reducing malaria transmission [1, 4]. Similar declines have been reported in Ghana's National Malaria Control Programme reports and national household surveys, indicating that malaria control interventions have achieved measurable public health gains [3]. This trend is also consistent with reports from several malaria endemic countries in Africa where sustained investment in malaria interventions has resulted in substantial reductions in childhood malaria [1]. The reduction in malaria prevalence observed in this study agrees with findings from other regions of the world. In Ethiopia, improvements in vector control, expanded diagnostic services, and increased access to effective treatment have contributed to declining malaria transmission [12]. Similar progress has been reported in Rwanda and Tanzania following the implementation of integrated malaria control programmes [13, 14]. Outside Africa, India has recorded substantial reductions in malaria following strengthened surveillance and improved case management [15], while Indonesia has experienced declining transmission through targeted elimination strategies in endemic provinces [16]. Likewise, Brazil and Peru have reduced malaria transmission through improved surveillance, early diagnosis, and prompt treatment in high risk communities [17, 18]. Although malaria epidemiology differs across these settings, the consistent decline demonstrates that sustained implementation of evidence based malaria interventions can substantially reduce disease burden.

Despite these encouraging improvements, malaria remains an important public health problem among children in Ghana. Even in 2022, microscopy confirmed malaria infection in approximately one in every twelve children aged 6 to 59 months, indicating that transmission persists despite considerable progress. This finding supports previous evidence showing that as malaria prevalence declines nationally, residual transmission increasingly becomes concentrated among socially disadvantaged

populations and geographically underserved communities [1, 8]. Consequently, future malaria elimination efforts should increasingly focus on identifying and targeting these high risk populations.

This study found that child age was consistently associated with malaria infection throughout the study period. Compared with children aged 6 to 11 months, older children had progressively higher odds of malaria, with those aged 48 to 59 months experiencing the greatest risk across all survey years. This association remained significant after adjustment for socioeconomic and household characteristics, indicating that age independently influences malaria susceptibility. Infants often receive partial protection through maternal antibodies transferred during pregnancy and usually sleep close to their mothers under insecticide treated nets. As children become older, maternal immunity gradually declines while increased mobility exposes them more frequently to mosquito bites during outdoor activities and evening play. Although repeated malaria exposure contributes to the gradual development of partial immunity, this protection remains insufficient during the preschool years in areas of stable transmission such as Ghana [1, 7]. The age related increase in malaria prevalence observed in this study agrees with findings from several African countries. Yaya et al. [19] reported a similar increase in malaria prevalence with child age across multiple sub Saharan African countries. Comparable findings have also been reported in Nigeria [20], Uganda [21], Kenya [22], and Tanzania [14]. Similar age patterns have also been observed outside Africa. Studies from India have shown that malaria infection increases during early childhood as children experience greater environmental exposure [15], while research from Papua New Guinea reported higher malaria prevalence among older preschool children because of repeated exposure to infectious mosquito bites [23]. These consistent findings across different epidemiological settings suggest that increasing child age remains an important determinant of malaria infection.

Moreover, maternal education also emerged as an important protective factor against malaria infection. Children whose mothers had secondary or higher education generally had lower odds of malaria than those whose mothers had no formal education, particularly in the 2014, 2016, and 2022 surveys. Although this association was not statistically significant in the fully adjusted 2019 model, the overall pattern indicates that maternal education remains an important social determinant of childhood malaria. Mothers with higher educational attainment are more likely to understand malaria prevention strategies, recognise symptoms promptly, seek timely healthcare, and ensure appropriate use of insecticide treated nets and antimalarial treatment. Education also improves employment opportunities and household income, enabling families to access better housing and healthcare services, thereby reducing children's exposure to malaria vectors [6, 7].

The protective effect of maternal education observed in this study is consistent with previous studies conducted in Ghana and other malaria endemic countries. Afoakwah et al. [9] reported that higher maternal education significantly reduced the likelihood of malaria infection among Ghanaian children. Similar findings have been reported in Nigeria [20], Ethiopia [12], Kenya [22], Uganda [21], India [15], Indonesia [16], and Brazil [17]. These studies collectively suggest that maternal education improves health literacy and preventive practices regardless of geographical setting.

Furthermore, household wealth was another strong predictor of malaria infection throughout the study period. Across all four surveys, children from wealthier households consistently had significantly lower odds of malaria than those from the poorest households, demonstrating a clear socioeconomic gradient. Wealthier households are more likely to have improved housing with screened windows, closed eaves, finished walls, and better drainage systems that reduce mosquito entry and breeding. They are also more likely to have access to electricity, healthcare services, and financial resources that facilitate prompt treatment and preventive practices [6, 7]. These findings agree with previous studies from Ghana and elsewhere. Afoakwah et al. [9] found that wealth significantly reduced malaria risk among Ghanaian children, while Carrasco Escobar et al. [8] demonstrated that malaria remains disproportionately concentrated among poorer households across sub Saharan Africa. Similar socioeconomic inequalities have been reported in Nigeria [20], Ethiopia [12], Kenya [22], Uganda [21], Tanzania [14], Brazil [17], Peru [18], and India [15]. The consistency of these findings across continents reinforces poverty as one of the strongest determinants of malaria transmission.

In addition, residence was also significantly associated with malaria infection. Children living in rural areas consistently had higher odds of malaria than those residing in urban communities. Rural environments generally provide more favourable breeding habitats for mosquitoes because of agricultural activities, wetlands, forests, and poor drainage systems. Rural communities also often have poorer housing conditions, limited access to healthcare services, and lower availability of preventive interventions, all of which increase malaria transmission [1, 6]. Similar rural urban differences have been reported in Ghana [9], Nigeria [20], Ethiopia [12], Kenya [22], Uganda [21], Tanzania [14], Indonesia [16], Papua New Guinea [23], and Brazil [17]. Although insecticide treated net utilisation showed significant associations in some survey years, it was not consistently associated with malaria infection after adjustment for other socioeconomic factors. This finding should not be interpreted as evidence that insecticide treated nets are ineffective. Rather, it likely reflects the high national coverage of net distribution programmes and the influence of other factors such as housing quality, environmental conditions, mosquito behaviour, insecticide resistance, and measurement limitations associated with self reported net use. Previous studies have similarly shown that the effectiveness of insecticide treated nets is influenced by consistent utilisation, physical condition of the nets, and environmental factors [6, 9].

The study also found important regional variation in malaria prevalence, particularly during the earlier survey years. Children residing in the Western and Central Regions generally experienced higher malaria prevalence than those living in Greater Accra, reflecting differences in climate, vegetation, rainfall, mosquito ecology, socioeconomic development, and implementation of malaria interventions. Similar geographical variation has been reported in Ghana's National Malaria Control Programme reports [3] and in studies from Tanzania [14], Ethiopia [12], Nigeria [20], Brazil [17], Peru [18], and Indonesia [16]. These findings support the continued implementation of geographically targeted malaria control strategies based on local transmission intensity.

Implications for public health

The findings of this study have important implications for malaria control in Ghana. Although considerable progress has been made in reducing malaria prevalence, persistent socioeconomic inequalities indicate that biomedical interventions alone will not achieve malaria elimination. Improving female education, reducing poverty, strengthening rural healthcare services, promoting housing improvement, and expanding access to quality healthcare should complement existing malaria interventions. Evidence suggests that housing improvements, including screened windows, closed eaves, and improved roofing materials, can substantially reduce malaria transmission by limiting mosquito entry into homes [6]. Similarly, investments in female education improve health literacy, preventive behaviours, and healthcare utilisation, thereby contributing to reductions in childhood malaria [24]. These findings support the multisectoral approach outlined in Ghana's National Malaria Elimination Strategic Plan 2024 to 2028, which emphasises surveillance strengthening, geographical stratification, and targeted interventions for high burden populations [4].

Strengths

This study has several strengths. It utilised four nationally representative DHS and MIS datasets collected over an eight year period, allowing robust assessment of temporal trends in malaria prevalence and socioeconomic inequalities. The use of laboratory confirmed malaria diagnosis through microscopy and rapid diagnostic tests improved the validity of the outcome measures, while multilevel logistic regression appropriately accounted for the hierarchical nature of the survey data by considering both individual and community level variation.

Limitations

The cross sectional design prevents causal inference, and the observed associations should therefore be interpreted cautiously. Rapid diagnostic tests may remain positive after successful treatment because of persistent parasite antigens, potentially overestimating active malaria infection [1]. In addition, several important environmental factors, including rainfall, temperature, mosquito density, insecticide resistance, housing characteristics, and proximity to breeding sites, were not available in the DHS and MIS datasets. Measures such as insecticide treated net utilisation were also based on caregiver reports and may have been affected by recall bias or social desirability bias.

Conclusion

Overall, this study demonstrates that Ghana has achieved substantial reductions in malaria prevalence among children aged 6 to 59 months between 2014 and 2022. Nevertheless, malaria remains disproportionately concentrated among older children, those living in poorer households, rural communities, and children whose mothers have lower educational attainment. These findings indicate that future malaria elimination efforts should move beyond universal intervention coverage and increasingly address the socioeconomic inequalities that continue to sustain malaria transmission. Combining effective malaria interventions with improvements in education, poverty reduction, housing quality, and equitable access to healthcare will be essential for accelerating progress towards malaria

elimination in Ghana and achieving the goals of the National Malaria Elimination Strategic Plan 2024 to 2028.

Abbreviations

ACT	Artemisinin-based Combination Therapy
AOR	Adjusted Odds Ratio
BIC	Bayesian Information Criterion
CI	Confidence Interval
DHS	Demographic and Health Survey
GDHS	Ghana Demographic and Health Survey
GHS	Ghana Health Service
GMIS	Ghana Malaria Indicator Survey
ICC	Intraclass Correlation Coefficient
ICF	ICF International (formerly Inner City Fund)
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
JHS	Junior High School
MIS	Malaria Indicator Survey
PCA	Principal Component Analysis
PSU	Primary Sampling Unit

Declarations

Ethics Approval and Consent to Participate

Ethical approval for the original surveys was obtained by the Ghana Health Service Ethics Review Committee, and written informed consent was obtained from all participants. Permission to use the de-identified datasets for this secondary analysis was obtained from the DHS Program. Ethical approval for the present study was granted by the Research Ethics Committee of the University of Health and Allied Sciences.

Consent for Publication

Not applicable.

Competing Interests

The authors declare that they have no competing interests.

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Author Contribution

I.A conceptualized the study, developed the research idea, and supervised the project. A.S led the project and coordinated the overall implementation of the study. A.T conducted the statistical analysis and interpreted the data. P.A contributed to drafting and critically revising the manuscript for important intellectual content. All authors reviewed, cross-checked, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work.

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Data Availability

The datasets analysed during the current study are publicly available from the Demographic and Health Surveys (DHS) Program upon reasonable request and approval through the DHS website.

References

1. World Health Organization. (2023). World Malaria Report 2023. Available from World malaria report 2023.
2. Weiss, D. J., Lucas, T. C. D., Nguyen, M., Nandi, A. K., Bisanzio, D., Battle, K.E., Cameron, E., Twohig, K. A., Pfeffer, D. A., Rozier, J. A., Gibson, H. S., Rao, P. C., Casey, D., Bertozzi-Villa, A., Collins, E. L., Dalrymple, U., Gray, N., Harris, J. R., Howes, R. E., ... Gething, P. W. (2019). Mapping the global prevalence, incidence, and mortality of *Plasmodium falciparum*, 2000–17: A spatial and temporal

- modelling study. *The Lancet*, 394(10195), 322–331. [https://doi.org/10.1016/S0140-6736\(19\)31097-9](https://doi.org/10.1016/S0140-6736(19)31097-9).
3. Ghana Health Service. (2023). National Malaria Control Programme Annual Report 2023. Available from WHO Ghana - Annual Report 2023 - Ghana | ReliefWeb.
 4. Ghana Health Service. (2024). National Malaria Elimination Strategic Plan 2024–2028. Available from National Malaria Strategic Plan (NMSP) of Ghana: 2024–2028 - MESA.
 5. World Health Organization. (2021). Global Technical Strategy for Malaria 2016–2030 (2021 update). Available from Global technical strategy for malaria 2016–2030, 2021 update.
 6. Tusting LS, Bottomley C, Gibson H, Kleinschmidt I, Tatem AJ, Lindsay SW, Gething PW. Housing improvements and malaria risk in sub-Saharan Africa: A multi-country analysis of survey data. *PLoS Med*. 2017;14(2):e1002234. <https://doi.org/10.1371/journal.pmed.1002234>.
 7. Degarege A, Degarege D, Madhivanan P. (2019). Improving socioeconomic status may reduce the burden of malaria in sub Saharan Africa: A systematic review and meta-analysis, 14(10), e0223668. <https://doi.org/10.1371/journal.pone.0211205>
 8. Carrasco-Escobar G, Fornace KM, Benmarhnia T. Mapping socioeconomic inequalities in malaria in Sub-Saharan African countries. *Sci Rep*. 2021;11:15121. <https://doi.org/10.1038/s41598-021-94601-x>.
 9. Afoakwah C, Deng X, Onur I. Malaria infection among children under five: The use of large-scale interventions in Ghana. *BMC Public Health*. 2018;18:536. <https://doi.org/10.1186/s12889-018-5428-3>.
 10. Budu E, Okyere J, Mensah F, Seidu AA, Ahinkorah BO, Yaya S. Inequalities in the use of insecticide-treated nets by pregnant women in Ghana, 2011 and 2017. *Malar J*. 2022;21:376. <https://doi.org/10.1186/s12936-022-04388-z>.
 11. United Nations. Transforming our world: The 2030 Agenda for Sustainable Development. Transforming our World: The 2030. Agenda for Sustainable Development | Department of Economic and Social Affairs; 2015.
 12. Yitageasu G, Worede EA, Alemu EA. & others. (2025). Malaria prevalence and its determinants across 19 sub-Saharan African countries: A spatial and geographically weighted regression analysis. *Malaria Journal*, 24, 305. <https://doi.org/10.1186/s12936-025-05573-6>
 13. Gnambani EJ, Bilgo E, Sanou A. & others. (2020). Infection of highly insecticide-resistant malaria vector *Anopheles coluzzii* with entomopathogenic bacteria *Chromobacterium violaceum* reduces its survival, blood feeding propensity and fecundity. *Malaria Journal*, 19, 352. <https://doi.org/10.1186/s12936-020-03420-4>
 14. Njotto LL, Senyoni W, Cronie O, Stensgaard AS. Bayesian spatio-temporal modeling and prediction of malaria cases in Tanzania mainland (2016–2023): unveiling associations with climate and intervention factors. *Int J Health Geogr*. 2025;24(1):20. <https://doi.org/10.1186/s12942-025-00408-8>.

15. Rahi M, Sharma A. (2022). Malaria control initiatives that have the potential to be gamechangers in India's quest for malaria elimination. *Malar J*, 21(9), Article 2100009.
16. Herdiana H, Prameswari HD, Puspadewi RT, Fajariyani SB, Diptyanusa A, Theodora M, Supriyanto D, Hawley WA. Shrinking the malaria map in Indonesia: Progress of subnational control, elimination, and future strategies. *BMC Med*. 2025;23:512. <https://doi.org/10.1186/s12916-025-04355-w>.
17. Rocha EM, Katak RM, Campos de Oliveira J, Araujo MDS, Carlos BC, Galizi R, Tripet F, Marinotti O, Souza-Neto JA. Vector-Focused Approaches to Curb Malaria Transmission in the Brazilian Amazon: An Overview of Current and Future Challenges and Strategies. *Trop Med Infect disease*. 2020;5(4):161. <https://doi.org/10.3390/tropicalmed5040161>.
18. Pinedo-Cancino V, Arista KM, Baldeviano GC. & others. (2024). Unravelling heterogeneous malaria transmission dynamics in the Peruvian Amazon: Insights from a cross-sectional survey. *Malaria Journal*, 23, 209. <https://doi.org/10.1186/s12936-024-05032-8>
19. Edusei MYA, Alaba O, Okova D, Obse A. Socio-economic inequalities in malaria prevalence among under-five children in Ghana between 2016 and 2019: a decomposition analysis. *Malar J*. 2025;24(1):147. <https://doi.org/10.1186/s12936-025-05349-y>.
20. Isiko I, Nyegenye S, Mwesigwa A, Asingwire JM, Olot H, Amaka S-RC, Okoro LN, Etane PAA. Determinants of malaria spread among under-five children in Nigeria: Results from a 2021 Nigerian malaria indicator cross-sectional survey. *BMC Pediatr*. 2024;24:646. <https://doi.org/10.1186/s12887-024-05135-w>.
21. Nyawanda BO, Khagayi S, Ochomo E, Bigogo G, Kariuki S, Munga S, Vounatsou P. The influence of malaria control interventions and climate variability on changes in the geographical distribution of parasite prevalence in Kenya between 2015 and 2020. *Int J Health Geogr*. 2024;23(1):22. <https://doi.org/10.1186/s12942-024-00381-8>.
22. Lakew G, Tareke AA, Yigzaw ZA, Getachew D, Getachew E, Yirsaw AN. Individual and community level factors of malaria among under-five children in Kenya: Based on the Kenya Demographic and Health Survey. *PLoS ONE*. 2025;20(10). <https://doi.org/10.1371/journal.pone.0335346>. Article e0335346.
23. Cleary E, Hetzel MW, Siba PM. & others. (2021). Spatial prediction of malaria prevalence in Papua New Guinea: A comparison of Bayesian decision network and multivariate regression modelling approaches for improved accuracy in prevalence prediction. *Malaria Journal*, 20, 269. <https://doi.org/10.1186/s12936-021-03804-0>
24. Victora CG, Christian P, Vdaletti LP, Gatica-Domínguez G, Menon P, Black RE. Revisiting maternal and child undernutrition in low-income and middle-income countries: Variable progress towards an unfinished agenda. *Lancet*. 2021;397(10282):1388–99. [https://doi.org/10.1016/S0140-6736\(21\)00394-9](https://doi.org/10.1016/S0140-6736(21)00394-9).

Figures

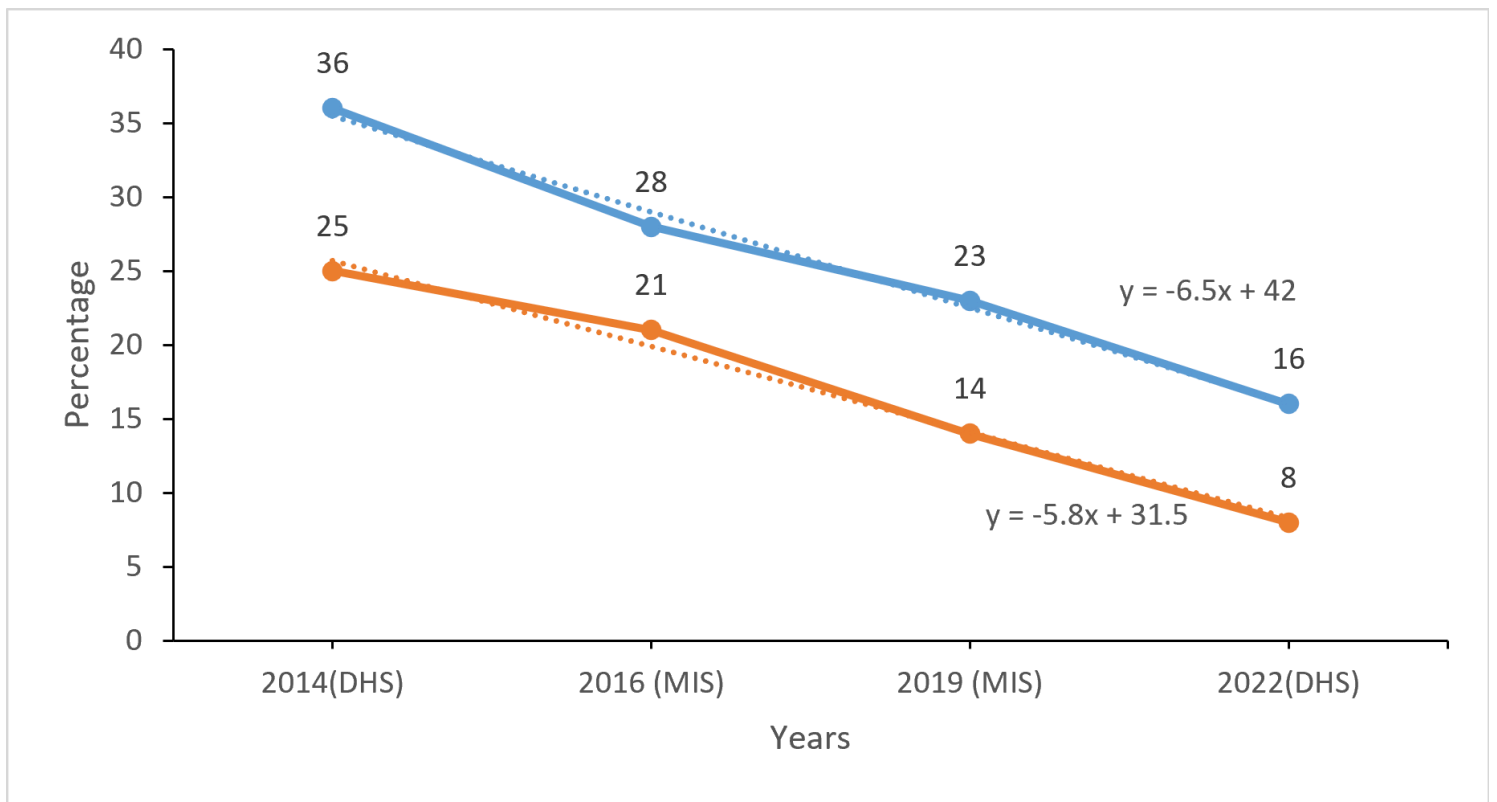


Figure 1

Malaria burden among children under five in Ghana, using data from three Demographic Health Surveys conducted in 2014, 2016, 2019 and 2022.

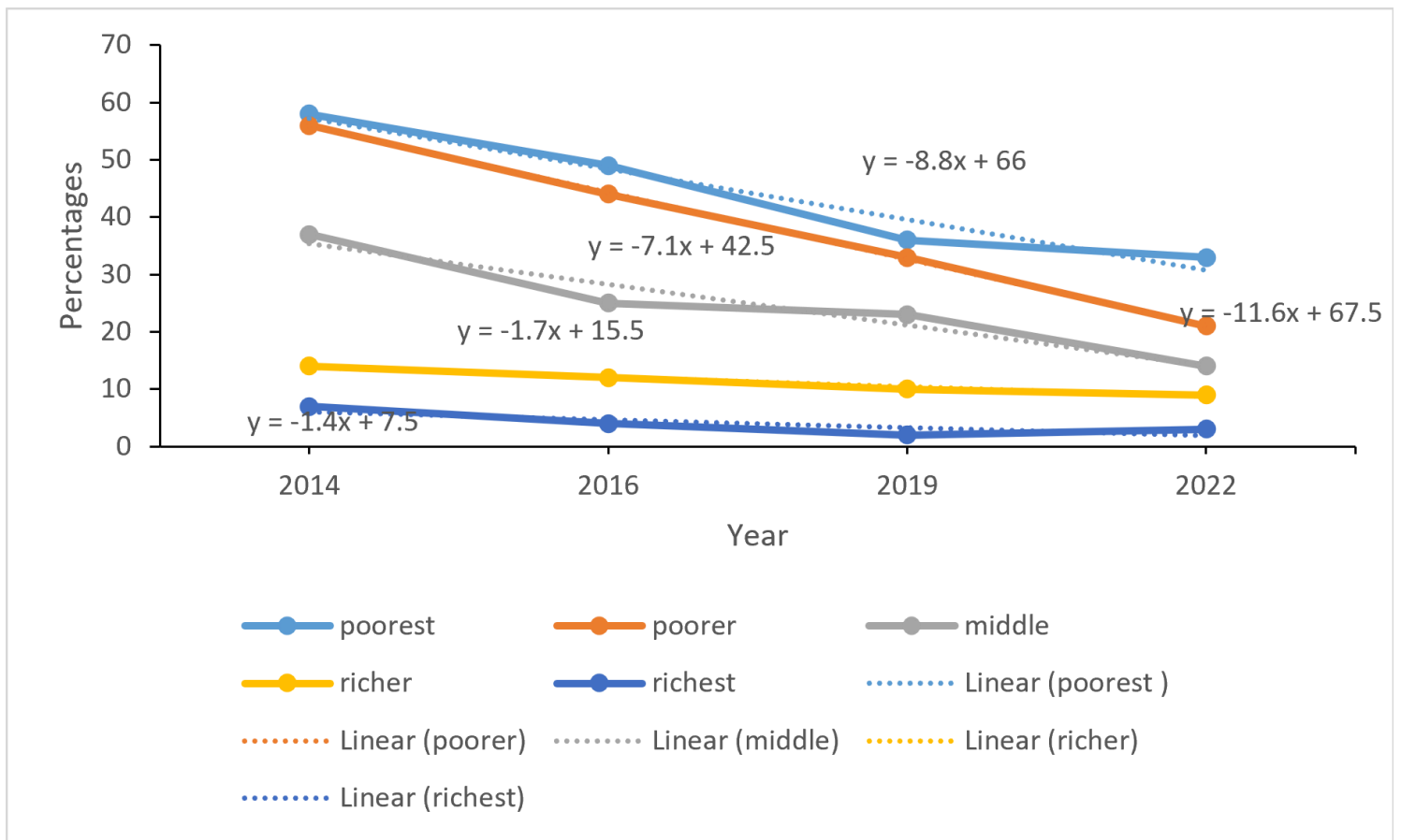


Figure 2

Results from malaria blood smear test and RDT test

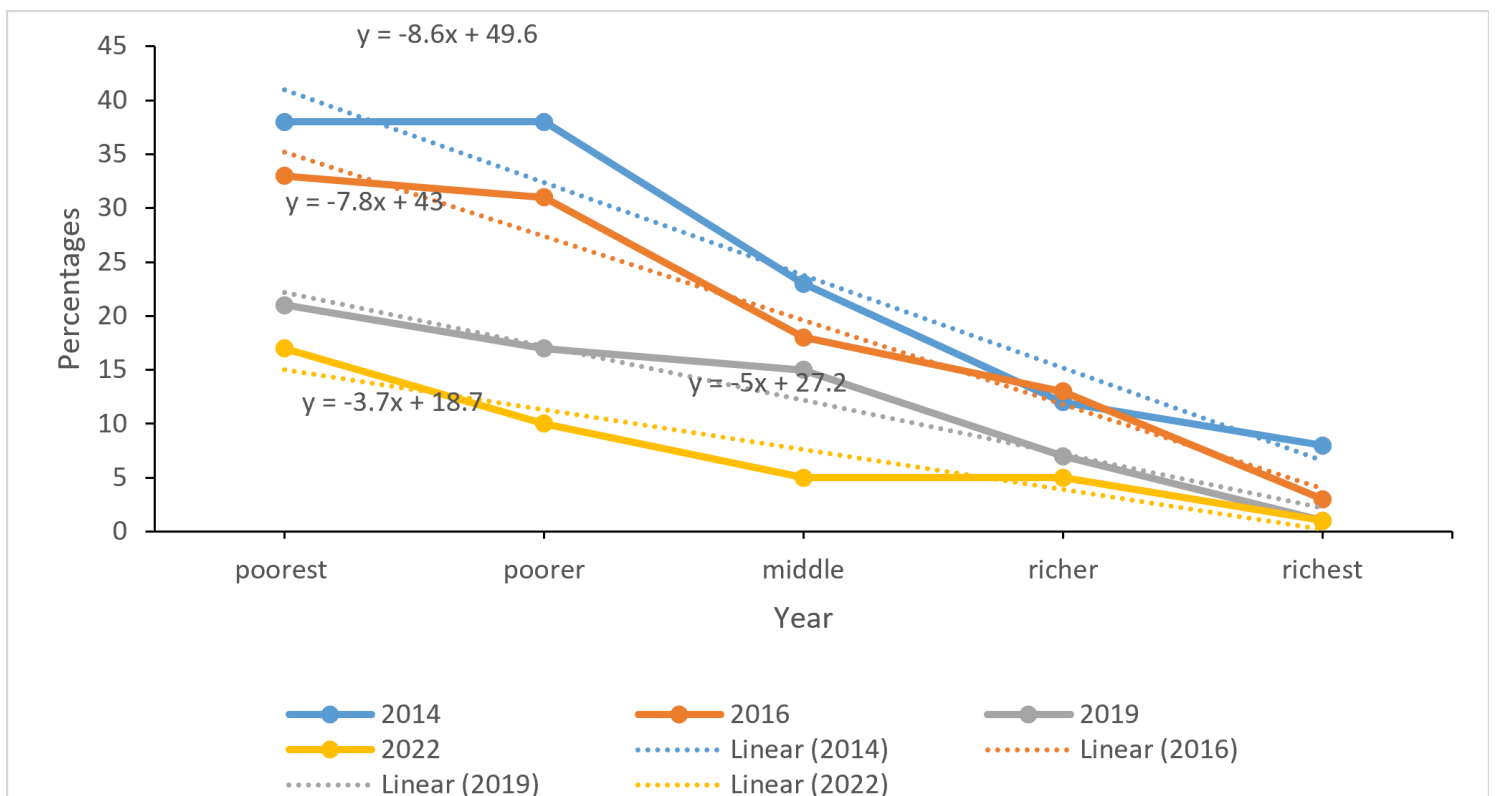


Figure 3

Malaria prevalence by RDT positives

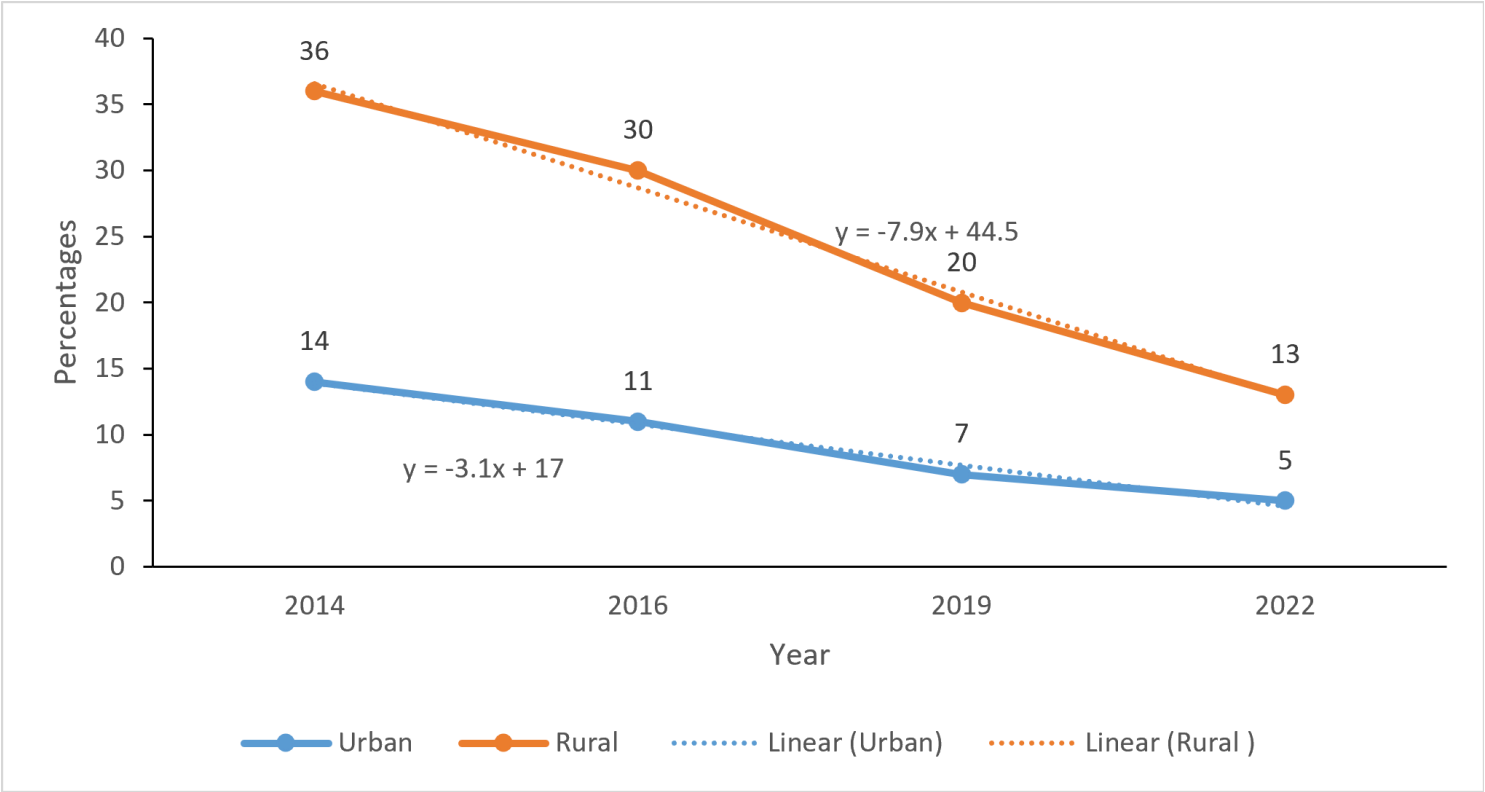


Figure 4

Malaria prevalence by microscopy positives

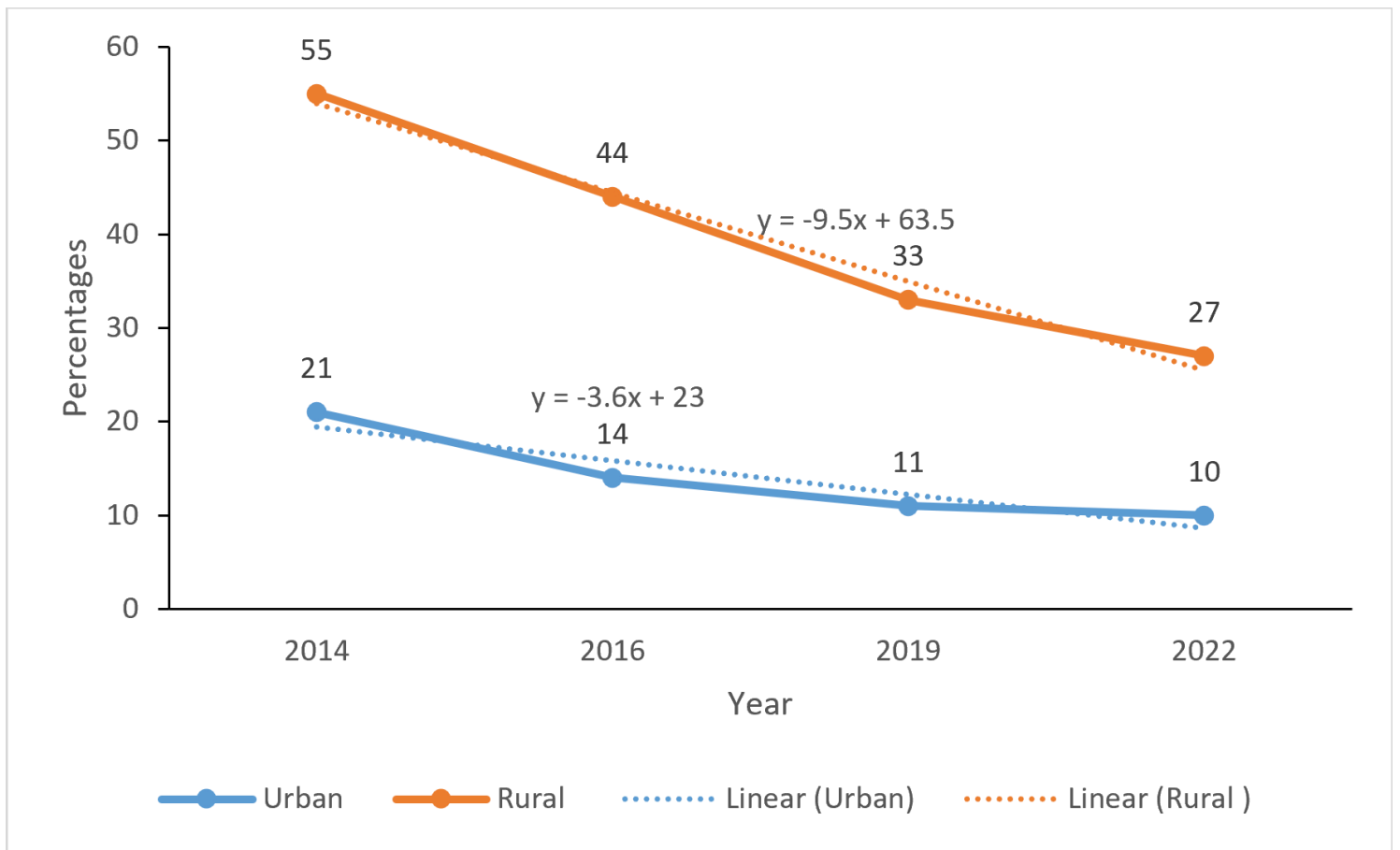


Figure 5

Malaria prevalence by place of residence (Microscopy)