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Socio-demographic factors, housing characteristics, and clinical symptoms associated with falciparum malaria in two rapidly urbanizing areas in the Ashanti region of Ghana

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Abstract

Background Malaria has been described as a disease of poverty, affecting the poorest populations typically living in rural areas. As hitherto rural areas transition into semi-urban environments, this study investigated the prevalence of falciparum malaria and associated risk factors in two rapidly urbanizing districts in the Ashanti Region of Ghana.

Methods A cross-sectional, hospital-based study was conducted at Agona and Mankranso Government Hospitals located within the Sekyere South and Ahafo Ano Southwest districts respectively, in the Ashanti Region of Ghana. Five µL of venous blood was obtained from suspected malaria patients and tested for malaria using rapid diagnostic test (RDT). Data on socio-demographic factors, clinical symptoms, and housing characteristics were collected using a structured questionnaire. Univariate and multivariate logistic regression analysis were performed to identify risk factors associated with malaria.

Results A total of 1739 participants were enrolled in the study between January and June 2021 with median age of 22 years (IQR = 6–36). Overall malaria prevalence was 24.8%. Compared to > 30-year-olds, children between 0 and 5 years (aOR = 3.36) and those aged between 6 and 14 (aOR = 6.71) were three and six times more likely to test positive for malaria, respectively. Similarly, farming (aOR = 1.74), compared to other occupations, living close to stagnant water (aOR = 1.34), experiencing chills (aOR = 1.5), and vomiting (aOR = 1.93) were associated with increased odds of malaria infection. Having roofing ceiling (aOR = 0.66) and screened doors (aOR = 0.75) were associated with decreased risk of malaria. However, sleeping under insecticide-treated nets (ITNs), using mosquito coils/repellents, and indoor residual spraying (IRS) were not statistically significantly associated with infection.

Conclusion Children between 0 and 5 years and those aged between 6 and 14 years continue to shoulder the highest burden of malaria. Efforts to improve housing characteristics such as installation of roofing ceiling, screening doors, and clearing potential mosquito breeding sites should be encouraged in these rapidly urbanizing areas.

Keywords Malaria, Risk factors, Housing characteristics, Socio-demographic factors

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Background

Malaria remains a major public health concern, particularly in sub-Saharan Africa, where more than 94% of global cases and deaths occur annually [1]. In Ghana and across West Africa, the disease consistently ranks among the leading causes of hospital admissions with the entire population at risk [2, 3]. Malaria transmission in Ghana is however heterogenous–with pockets of high transmission affecting the poorest populations typically living in rural areas [4, 5].

Over the past two decades, Ghana's urban population has more than doubled, rising from 8 to 17 million owing to increased population growth and migration [6, 7]. Within the same period, malaria incidence has declined from 431 to 164 cases per 1000 population at risk with decreasing case fatality rates [8]. These gains have been largely attributed to increased coverage of malaria preventive measures, such as insecticide-treated nets (ITNs), indoor residual spraying (IRS), seasonal malaria chemoprevention (SMC), and intermittent preventive treatment in pregnant women (IPTp) adopted by the National Malaria Elimination Programme in Ghana [5].

Aside from these measures, the declining malaria burden over the past two decades may be explained by the country's changing urbanization landscape, as more rural areas transition into semi-urban environments. According to the 2021 Population and Housing Census, 7 out of the 16 regions have more than half of its inhabitants living in urban areas [7]. Until recently, urbanization was thought to reduce malaria transmission due to improved housing and living conditions, and increased access to quality healthcare. However, when unplanned, rapid urbanization may lead to high malaria transmission due to overcrowding and resultant increase in pollution and unhygienic living conditions [9, 10].

This study sought to investigate the prevalence of falciparum malaria among febrile patients living in urban and peri-urban areas of two rapidly urbanizing districts (*i.e.,* Sekyere South and Ahafo Ano South West) in the Ashanti Region of Ghana, highlighting multiple sociodemographic factors, housing characteristics, and clinical symptoms associated with perennial disease transmission in these areas.

Methods

Study area

The current study was conducted at Agona Government Hospital (AGH) and Mankranso Government Hospital (MGH), both located in the Ashanti Region of Ghana (Fig. 1). AGH is situated in Agona, the capital of the Sekyere South District, and located about 45 km away from the regional capital, Kumasi. AGH serves as the referral health facility for the district and surrounding towns and villages. In the past decade (2010–2021), the urban population of the district has risen from 53 to 73% [7, 11]. Notwithstanding, agriculture is the predominant economic activity in the district and employs about 45% of the active population. The district experiences an average temperature of 27 °C and mean annual precipitation falls within 855–1500 mm [11]. Malaria is the most prevalent disease in the district and transmission is year-round [12].

MGH is situated in Mankranso, the capital of the Ahafo Ano South-West District in north-western part of the Ashanti Region where it serves as the main referral facility for surrounding towns and villages. The majority of the inhabitants reside in rural areas, though the urban population has risen from 10% to 23.2% in the last decade [7, 13]. The district's economy is largely agrarian and employs about 75% of the active population. The mean annual rainfall in the district ranges between 1500 and 1700 mm with average monthly temperature of 26 °C [13]. Malaria transmission is year-round and routinely tested at all health facilities within the district.

Study design

This was a cross-sectional hospital-based study, carried out between January and June 2021 to enroll suspected malaria patients seeking healthcare at AGH and MGH. Specifically, individuals of all ages and sex who were referred to the laboratory to test for malaria by clinicians were enrolled in the study after obtaining informed consent. Enrolled participants were interviewed to collect demographic, housing, and clinical information followed by malaria diagnosis using rapid diagnostic test.

Sample size

The minimum sample size for the study was computed using Cochran's formula for categorical data as previously described [14]. The final sample size was calculated using a previous malaria prevalence of 24.5% [15] assuming a 95% confidence interval and 5% acceptable margin of error. After substituting in the variables, a minimum sample size of 285 was required for the present study.

Data collection

A well-structured, paper-based questionnaire was administered to collect data of the study participants by trained research assistants at the hospital premises. The questionnaire was stratified into 4 main themes: sociodemographic factors, housing characteristics, clinical symptoms, and malaria preventive measures (Fig. 2). The questionnaire was administered in vernacular (Asante Twi) and occasionally in English or other dialect as preferred by the study participants.

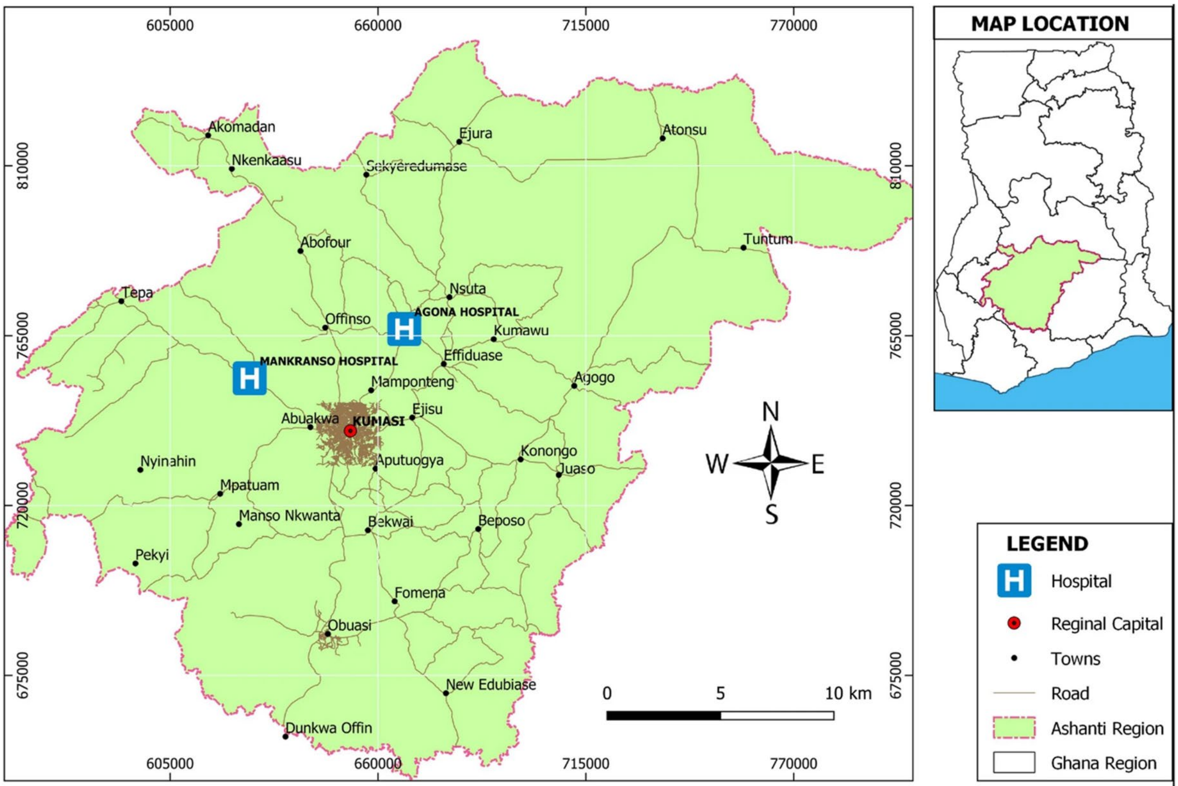

Fig. 1 A map showing the study areas

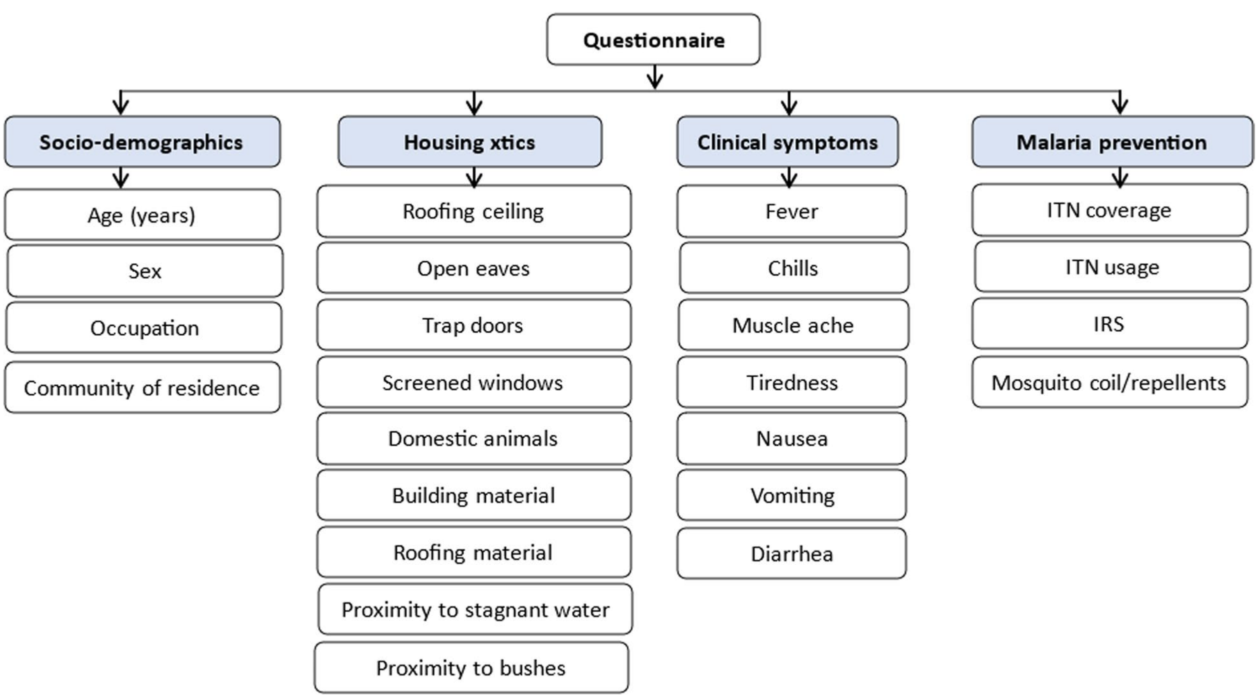

Fig. 2 Summary of data obtained from questionnaire

Malaria diagnosis

Participants were tested for falciparum malaria using the CareStart™ Malaria Pf (HRP2) Ag RDT (AccessBio, USA) kit. This rapid diagnostic test (RDT) was preferred over microscopy due to previous studies which reported superior sensitivity of RDT at the study area [15]. RDT diagnosis was performed on-site using 5 µL of venous blood collected by trained phlebotomists into EDTA tubes. Rapid diagnostic testing was carried out and interpreted according to manufacturer's instructions. Test results were recorded after 20 min. RDTs that showed faint pink/red lines were repeated.

Data analysis

Data entry and cleaning were performed using Microsoft Excel 2016 (Microsoft Corp., Redmond, WA, USA), and then exported into STATA 14 (StataCorp, College Station, TX, USA) for statistical analysis. Data were coded and presented as frequencies and percentages. Age was summarized as median (interquartile range) and then converted into categorical data as age groups (0–5, 6–14, 15–30 and > 30 years). Association between falciparum malaria and sociodemographic factors, housing characteristics, clinical symptoms, and malaria preventive measures were computed using univariate logistic regression analysis. Significant variables from the univariate analysis were included for multivariate analysis to obtain adjusted odds ratio (aOR). Statistical significance was set at $p < 0.05$ and a 95% confidence interval in all the models.

Ethics

The study was approved by the Committee on Human Research, Publications and Ethics (Approval number: CHRPE/AP/030/20) of the School of Medicine and Dentistry, KNUST and University of Notre Dame Institutional Review Board (approvals no. 19-08-5511, 19-04-5321). The protocol and purpose of the study was communicated in layman terms to all participants. Written informed consent was obtained from patients who were 18 years or older. Parental/guardian consent and child assent were obtained for those under 18 years. Participants who did not meet the inclusion criteria and those who could not provide informed consent were excluded from the study. Participants were de-identified using unique codes. No adverse events were encountered during the study.

Results

Population characteristics

A total of 1739 participants–992 (57.0%) from AGH and 747 (43.0%) from MGH–were enrolled in the study. Malaria prevalence was not significantly different ($p = 0.61$) across the sites; neither was site a significant determinant of malaria infection in the regression models. Therefore, data from both sites were combined for all subsequent analysis. Participants' age ranged from 1 to 96 years with a median age of 22 (IQR = 6–36). More than twice as many females (n = 1217, 70.0%) than males (n = 522, 30.0%) were enrolled. The majority of participants fell within the 15–30 age group (n = 596, 34.3%) closely followed by the > 30 (n = 560, 32.2%), 0–5 (n = 409, 23.5%) and the 6–14 (n = 174, 10.0%) age groups. Almost a third of the study populace were students/apprentices (n = 533, 30.6%), 253 (14.5%) were traders, 231 (13.3%) were engaged in farming, 198 (11.4%) were unemployed while 98 (5.6%) represented civil servants. Most of the participants owned ITNs (n = 1244, 71.5%) but less than half (n = 816, 46.9%) reported sleeping under the nets the night before enrolment. A third of the participants (n = 580, 33.4%) used mosquito coil/repellents while 458 (26.3%) reported recent participation in IRS campaigns (Table 1).

Association between sociodemographic factors and malaria

Of the 1739 patients examined, 432 (24.8%) tested positive for malaria. In the univariate logistic regression model, the odds of malaria infection were significantly high among males [OR = 1.51, 95% CI 1.20–1.90, $p < 0.001$] and students/apprentices [OR = 1.63, 95% CI 1.22–2.17, $p = 0.001$] compared to "other" occupation. Similarly, respondents between 0 and 5 years [OR = 3.25, 95% CI 2.36–4.48, $p < 0.001$], 6–14 years [OR = 7.84, 95% CI 5.33–11.54, $p < 0.001$] and 15–30 years [OR = 1.88, 95% CI 1.37–2.57, $p < 0.001$] were at high risk of malaria infection compared to the > 30 age group. Conversely, civil servants [OR = 0.48, 95% CI 0.26–0.90, $p = 0.023$] and traders [OR = 0.56, 95% CI 0.37–0.84, $p < 0.001$] had lower odds of malaria infection. After adjusting for possible confounders in a multivariate logistic regression model, children between 0 and 5 years [aOR = 3.36, 95% CI 2.09–5.42, $p < 0.001$], school age children (*i.e.*, 6–14 year olds) [aOR = 6.71, 95% CI 3.95–11.4, $p < 0.001$], 15–30 year olds [aOR = 1.85, 95% CI 1.26–2.72, $p = 0.002$], and farmers [aOR = 1.74, 95% CI 1.06–2.87, $p = 0.029$] were more likely to test positive for malaria. None of the malaria preventive measures assessed in the study (*i.e.*, ITN ownership/usage, recent IRS participation and using mosquito coils/repellents) was statistically significantly associated with malaria infection (Table 2).

Table 1 Socio-demographic characteristics and malaria preventive practices of the study population

Variable	Total (%)	RDT-positive (%)
Site		
AGH	992 (57.0)	251 (25.3)
MGH	747 (43.0)	181 (24.2)
Sex		
Male	522 (30.0)	160 (30.7)
Female	1217 (70.0)	272 (22.4)
Age group (years)		
0–5	409 (23.5)	134 (32.8)
6–14	174 (10.0)	94 (54.0)
15–30	596 (34.3)	131 (22.0)
> 30	560 (32.2)	73 (13.0)
Occupation		
Farming	231 (13.3)	52 (22.5)
Trading	253 (14.5)	38 (15.0)
Civil servant	98 (5.6)	13 (13.3)
Student/Apprentice	533 (30.6)	181 (34.0)
Unemployed	198 (11.4)	42 (21.2)
Other	426 (24.5)	106 (24.9)
ITN ownership		
Yes	1244 (71.5)	299 (24.0)
No	495 (28.5)	133 (26.9)
ITN usage		
Yes	816 (46.9)	204 (25.0)
No	923 (53.1)	228 (24.7)
IRS		
Yes	458 (26.3)	99 (21.6)
No	1281 (73.7)	333 (26.0)
Used mosquito coil/repellent		
Yes	580 (33.4)	157 (27.1)
No	1159 (66.6)	275 (23.7)

Table 2 Socio-demographic factors and malaria preventive practices associated with malaria infection among the study population

Variable	Unadjusted OR (95% CI)		Adjusted OR (95% CI)	
	Odds Ratio	*p*-value	Odds Ratio	*p*-value
Site				
AGH	1.06 (0.85–1.32)	0.609		
MGH	Ref.	–		
Sex				
Male	1.51 (1.20–1.90)	**0.000**	1.14 (0.86–1.50)	0.357
Female	Ref.	–	–	–
Age group (years)				
0–5	3.25 (2.36–4.48)	**0.000**	3.36 (2.09–5.42)	**0.000**
6–14	7.84 (5.33–11.54)	**0.000**	6.71 (3.95–11.4)	**0.000**
15–30	1.88 (1.37–2.57)	**0.000**	1.85 (1.26–2.72)	**0.002**
> 30	Ref.	–	–	–
Occupation				
Farming	0.92 (0.63–1.35)	0.663	1.74 (1.06–2.87)	**0.029**
Trading	0.56 (0.37–0.84)	**0.006**	1.29 (0.78–2.12)	0.326
Civil servant	0.48 (0.26–0.90)	**0.023**	1.08 (0.54–2.16)	0.826
Student/ Apprentice	1.63 (1.22–2.17)	**0.001**	1.41 (0.97–2.05)	0.075
Unemployed	0.85 (0.57–1.28)	0.44	1.42 (0.88–2.29)	0.157
Other	Ref.	–	–	–
ITN ownership				
Yes	0.86 (0.68–1.09)	0.217		
No	Ref.	–		
ITN usage				
Yes	1.02 (0.82–1.26)	0.886		
No	Ref.	–		
IRS				
Yes	0.79 (0.61–1.01)	0.063		
No	Ref.	–		
Used mosquito coil/repellent				
Yes	1.19 (0.95–1.50)	0.129		
No	Ref.	–		

Bold indicates a statistically significant variable

*Ref-Reference

Housing characteristics

The majority of the participants resided in houses built with cement or blocks (n = 1155, 66.4%) while a minority stayed in houses made of bricks (n = 313, 18.0%) and mud (n = 271, 15.6%). Almost all the respondents lived in houses roofed with galvanized sheet (n = 1699, n = 99.0%) except 17 (1.0%) who slept under thatched roof. Most of the study populace slept in rooms with roofing ceiling (n = 1444, 83.0%), screened windows (n = 1336, 76.8%) and doors (n = 1097, 63.1%). A quarter of the participants reported living near stagnant water (n = 431, 24.8%), having open eaves (n = 429, 24.7%), and reared livestock (n = 421, 24.2%) in their households. Half of the respondents reported living near bushes (n = 871, n = 50.1%) (Table 3).

Association between housing characteristics and malaria

An explorative univariate analysis revealed that apart from roofing material, all the housing characteristics assessed in the study were significantly associated ($p < 0.05$) with malaria (Table 4). In the univariate logistic regression model, households with open eaves [OR = 1.48, 95% CI 1.16–1.89, $p = 0.002$], those who reared livestock [OR = 1.43, 95% CI 1.12–1.83, $p = 0.004$], houses built with mud [OR = 1.46, 95% CI 1.09–1.96, $p = 0.011$] and those situated near stagnant water [OR = 1.46, 95% CI 1.14–1.86, $p = 0.002$] or bushes

Table 3 Housing characteristics of the study population

Housing characteristics	Total (%)	RDT-positive (%)
Roofing Ceiling		
Yes	1444 (83.0)	332 (23.0)
No	295 (17.0)	100 (33.9)
Open eaves		
Yes	429 (24.7)	130 (30.3)
No	1310 (75.3)	302 (23.1)
Screened doors		
Yes	1097 (63.1)	242 (22.1)
No	642 (36.9)	190 (29.6)
Screened windows		
Yes	1336 (76.8)	304 (22.8)
No	403 (23.2)	128 (31.8)
Domestic animals in household		
Yes	421 (24.2)	127 (30.2)
No	1318 (75.8)	305 (23.1)
Building material		
Mud	271 (15.6)	82 (30.3)
Bricks	313 (18.0)	86 (27.5)
Cement blocks	1155 (66.4)	264 (22.9)
Roofing Material		
Galvanized roofing sheet	1699 (99.0)	420 (24.7)
Thatch roof	17 (1.0)	6 (35.3)
Staying close to stagnant waters		
Yes	431 (24.8)	131 (30.4)
No	1308 (75.2)	301 (23.0)
Staying close to bushes		
Yes	871 (50.1)	237 (27.2)
No	868 (49.9)	195 (22.5)

[OR = 1.29, 95% CI 1.04–1.60, $p = 0.022$] were associated with increased risk of malaria infection. Alternatively, households with roofing ceiling [OR = 0.58, 95% CI 0.44–0.76, $p = 0.000$], screened doors [OR = 0.67, 95% CI 0.54–0.84, $p < 0.001$] and windows [OR = 0.63, 95% CI 0.50–0.81, $p < 0.001$] were less susceptible to malaria infection. After controlling for other variables in a multivariate logistic regression model, households with roofing ceiling [aOR = 0.66, 95% CI 0.44–0.99, $p = 0.042$] and screened doors [aOR = 0.75, 95% CI 0.57–0.97, $p = 0.032$] were less likely to be infected with malaria while those situated close to stagnant water [aOR = 1.34, 95% CI 1.02–1.77, $p = 0.038$] were more susceptible to malaria infection.

Clinical symptoms associated with malaria

Of the malaria symptoms assessed in the study, diarrhea (n = 196, 11.3%) was the least reported. The majority of the participants experienced a history of fever (n = 1140, 65.6%), followed by chills (n = 699, 40.2%), tiredness (n = 663, 38.1%) and muscle aches (n = 637, 36.6%). Other clinical manifestations such as nausea (n = 604, 34.7%) and vomiting (n = 415, 23.9%) were reported by a third and quarter of the respondents respectively (Table 5).

In the univariate analysis, all the symptoms assessed in the study were significantly associated with malaria except for diarrhea. According to the model, patients who presented with a history of fever [OR = 2.19, 95% CI 1.70–2.82, $p < 0.001$], chills [OR = 1.73, 95% CI 1.39–2.15, $p < 0.001$], nausea [OR = 1.34, 95% CI 1.07–1.67, $p = p = 0.011$] and vomiting [OR = 2.57, 95% CI 2.03–3.27), $p < 0.001$] were more likely to have been infected with malaria. Conversely, clinical symptoms such as muscle aches [OR = 0.78, 95% CI 0.62–0.98, $p = 0.036$] and tiredness [OR = 0.72, 95% CI 0.57–0.90, $p = 0.005$] were significantly associated with decreased odds of malaria infection. In the multivariate logistic regression model, symptoms such as fever, nausea, muscle ache and tiredness were no longer significant ($p > 0.005$) while chills [aOR = 1.50, 95% CI 1.15–1.96, $p = 0.003$] and vomiting [aOR = 1.93, 95% CI 1.43–2.60, $p = 0.000$] remained independently associated with malaria infection (Table 6).

Discussion

The intensity of malaria transmission in a given area is influenced by multiple factors that may increase or decrease chances of infection. The overall prevalence of falciparum malaria among febrile patients in the study was 24.8%, which is higher than previously reported using microscopy [15] but lower when compared to studies where PCR was used as the tool for diagnosis [15, 16]. In this study, sociodemographic factors such as age and occupation were significantly associated with increased risk of infection. Children between 0 and 5 years were three times more likely to be infected with malaria while school-age children (6–15 years) were six times more susceptible to malaria infection. This finding corroborates multiple studies in sub-Saharan Africa [17–20] which have reported a shift in malaria infection burden from children under 5 years to school-age children. Participation in routine social activities (e.g. playing outside in the evening) [21] and sleeping less frequently under bed nets as compared to children under 5 and pregnant women have been cited as reasons for this shift [22, 23]. This has important implications for targeting interventions not only to cater for pregnant women and children under 5 but to include the older school-age children as they serve as important reservoirs for sustained malaria transmission [24–27]. From the study, traders and civil servants were less likely to be infected with malaria but farming was significantly associated with increased malaria prevalence. This finding was consistent with a systematic review in sub-Saharan Africa where farming

Table 4 Association between housing characteristics and malaria infection

Housing characteristics	Unadjusted OR (95% CI)		Adjusted OR (95% CI)	
	Odds Ratio	***p*-value**	**Odds Ratio**	***p*-value**
Roofing Ceiling				
Yes	0.58 (0.44–0.76)	**0.000**	0.66 (0.44–0.99)	**0.042**
No	Ref.	–	–	–
Open eaves				
Yes	1.48 (1.16–1.89)	**0.002**	0.87 (0.61–1.23)	0.430
No	Ref.	–	–	–
Screened doors				
Yes	0.67 (0.54–0.84)	**0.000**	0.75 (0.57–0.97)	**0.032**
No	Ref.	–	–	–
Screened windows				
Yes	0.63 (0.50–0.81)	**0.000**	0.75 (0.56–1.03)	0.075
No	Ref.	–	–	–
Domestic animals in household				
Yes	1.43 (1.12–1.83)	**0.004**	1.09 (0.83–1.44)	0.520
No	Ref.	–	–	–
Building material				
Mud	1.46 (1.09–1.96)	**0.011**	1.08 (0.76–1.54)	0.658
Bricks	1.28 (0.96–1.70)	0.089	1.30 (0.95–1.79)	0.101
Cement blocks	Ref.	–	–	–
Roofing Material				
Galvanized roofing sheet	Ref.	–		
Thatch roof	1.66 (0.61–4.52)	0.32		
Staying close to stagnant waters				
Yes	1.46 (1.14–1.86)	**0.002**	1.34 (1.02–1.77)	**0.038**
No	Ref.	–	–	–
Staying close to bushes				
Yes	1.29 (1.04–1.60)	**0.022**	1.04 (0.81–1.33)	0.784
No	Ref.	–	–	–

Bold indicates a statistically significant variable

*Ref-Reference

was associated with increased risk of malaria infection [28]. Farmers tend to be more exposed to infectious bites due to frequent outdoor activities, exposure to swampy stagnant waters, and contact with bushes or vegetation around houses where mosquitoes may be breeding and/or resting [29, 30].

There was no significant association between any of the malaria preventive measures assessed in the study (*i.e.,* ITN usage, IRS, mosquito coil/repellent) and likelihood of malaria infection. Lack of association between bed net usage and malaria prevalence has been reported in Ghana [31] and elsewhere in literature [32–34]. In a recent cross-sectional study using the Ghana Demographic Health and Malaria Indicator Surveys in 2014, 2016 and 2019, the lack of association between ITN usage and malaria infection was attributed to multiple factors including staying outside late at night for socialization, night schooling, small-scale economic activities or performing household chores before sleeping under nets [31, 35]. Moreover, inconsistent sleeping under bed nets was also attributed to skin irritation, overcrowding, poor ventilation and the lack of airflow in sleeping spaces, especially in slums and rural areas [36, 37]. The lack of association between these preventive measures and malaria infection could also be explained by non-compliance or improper use of ITNs, as well as increased mosquito resistance to chemicals used for IRS and mosquito repellents which have been reported in multiple sites across Ghana [38–43]. However, insecticide resistance status in the study area has not been studied and warrants further investigation. Previous studies in Ethiopia revealed a significant reduction in malaria prevalence among children whose parents were trained on proper usage of ITNs when compared to children whose parents

Table 5 Clinical characteristics of the study population

Clinical symptoms	Total (%)	RDT-positive (%)
History of fever		
Yes	1140 (65.6)	336 (29.5)
No	599 (34.4)	96 (16.0)
Chills		
Yes	699 (40.2)	217 (31.0)
No	1040 (59.8)	215 (20.7)
Muscle aches		
Yes	637 (36.6)	140 (22.0)
No	1102 (63.4)	292 (26.5)
Tiredness		
Yes	663 (38.1)	140 (21.1)
No	1076 (61.9)	292 (27.1)
Nausea		
Yes	604 (34.7)	172 (28.5)
No	1135 (65.3)	260 (22.9)
Vomiting		
Yes	415 (23.9)	164 (39.5)
No	1324 (76.1)	268 (20.2)
Diarrhea		
Yes	196 (11.3)	55 (28.1)
No	1543 (88.7)	377 (24.4)

Table 6 Association between clinical characteristics and malaria infection

Clinical symptoms	Unadjusted OR (95% CI)		Adjusted OR (95% CI)	
	Odds Ratio	*p*-value	Odds Ratio	*p*-value
History of fever				
Yes	2.19 (1.70–2.82)	**0.000**	1.29 (0.95–1.74)	0.102
No	Ref.	–	–	–
Chills				
Yes	1.73 (1.39–2.15)	**0.000**	1.50 (1.15–1.96)	**0.003**
No	Ref.	–	–	–
Muscle aches				
Yes	0.78 (0.62–0.98)	**0.036**	1.07 (0.80–1.44)	0.650
No	Ref.	–	–	–
Tiredness				
Yes	0.72 (0.57–0.90)	**0.005**	0.81 (0.61–1.08)	0.154
No	Ref.	–	–	–
Nausea				
Yes	1.34 (1.07–1.67)	**0.011**	0.90 (0.67–1.21)	0.493
No	Ref.	–	–	–
Vomiting				
Yes	2.57 (2.03–3.27)	**0.000**	1.93 (1.43–2.60)	**0.000**
No	Ref.	–	–	–
Diarrhea				
Yes	1.21 (0.87–1.68)	0.269		
No	Ref.	–		

Bold indicates a statistically significant variable

*Ref-Reference

received no training [44]. Contrary to the findings from this study, other studies in Ghana and Tanzania where proper use of malaria preventive measures such as ITNs, IRS and mosquito repellents were found to be significantly associated with decreased odds of malaria infection [45–47].

The current study showed a strong association between multiple housing characteristics and malaria infection. Housing characteristics such as roofing ceiling, screened doors and windows were significantly associated with decreased risk of malaria infection. This finding corroborates former studies in Ethiopia which reported more than half decrease in malaria infection in screened houses [48]. Screened doors and windows provide mechanical obstruction to prevent mosquitoes from entering houses thus reducing infectious bites. The present study also revealed increased chance of malaria infection among individuals residing in mud houses when compared to those living in houses made of blocks or bricks. This observation was concordant with earlier studies in Uganda where modern housing was significantly associated with decreased odds of malaria infection [49]. Modern housing in the study was described as the use of bricks or blocks as the building material, roofing ceiling, tiled or metal roof and closed eaves. These features provide mechanical barriers that affect entry and resting of infectious mosquitoes hence reduce malaria infection. The present study also revealed increased malaria infection among households living close to stagnant water and bushes which favor breeding of infectious mosquitoes. Clearing bushes and proper wastewater management has been reported to be significantly associated with decreased malaria infection [50].

From the study, patients who presented with symptoms such as fever, chills, nausea and vomiting were more likely to be infected with malaria with the exception of tiredness (general weakness) and muscle ache. Fever is a classical symptom of malaria however, it remains a significant challenge to clearly differentiate malarial fevers form other causes of fever [51]. Chills and vomiting are symptoms of mild forms of malaria especially among *Plasmodium falciparum* malaria patients and can progress to severe forms especially among children if not treated [52]. Muscle ache and tiredness are non-specific symptoms and may be caused by other bacterial, viral or fungal pathogens. Differential diagnosis of malaria before treatment is therefore encouraged to interrupt disease transmission in the study area.

Conclusion

This study reports active ongoing malaria transmission in the two rapidly urbanizing areas, highlighting multiple sociodemographic factors (age, occupation), housing characteristics (roofing ceiling, open eaves, screened doors/windows) and clinical symptoms (fever, chills, vomiting) that are significantly associated with infection. Children between 0 and 5 years and those aged from 6 to 15 years were three and six times more likely to be infected with malaria, respectively compared to the > 30 age group. Targeting malaria interventions towards these younger age groups is, therefore, recommended. Moreover, efforts to improve housing characteristics such as installation of roofing ceiling, screening doors, clearing mosquito breeding sites, and intensive education on mosquito preventive measures should be strengthened to reduce malaria transmission in the study area.

Abbreviations

RDT	Rapid Diagnostic Test
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
IQR	Interquartile Range
OR	Odds Ratio
aOR	Adjusted Odds Ratio
AGH	Agona Government Hospital
MGH	Mankranso Government Hospital

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Author contributions
Conceptualization: SOA, KB, CK; Methodology: SOA, KBA, KB; Validation: KB, EO; Formal analysis: SOA; Investigation: SOA, KBA, A-HM, DAA, AT, TKA, KAA; Data Curation: SOA, KBA, A-HM, DAA, AT, TKA, KAA; Writing—original draft: SOA, KBA; Writing—Review and Editing: SOA, KBA, A-HM, DAA, AT, TKA, KAA, CK, KB, EO; Visualization: SOA; Supervision: KB, CK. All authors reviewed and approved submission of the manuscript.

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Availability of data and materials
The datasets generated and/or analysed during the current study are available in the Harvard Dataverse repository, https://doi.org/https://doi.org/10.7910/DVN/YH2CX4.

Declarations

Ethics approval and consent to participate
The study was approved by the Committee on Human Research, Publications and Ethics (Approval number: CHRPE/AP/030/20) of the School of Medicine and Dentistry, KNUST and University of Notre Dame Institutional Review Board (approvals no. 19-08-5511, 19-04-5321). Written informed consent was obtained from patients who were 18 years or older. Parental/guardian consent and child assent were obtained for those under 18 years.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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