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ORIGINAL RESEARCH

Prevalence, Parasite Density and Determinants of Falciparum Malaria Among Febrile Children in Some Peri-Urban Communities in Southwestern Nigeria: A Cross-Sectional Study

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Background: Malaria remains a serious public health problem worldwide, particularly in tropical and subtropical regions, including Nigeria. This study investigates the prevalence, parasite density and determinants of malaria among symptomatic children in some peri-urban communities in southwestern Nigeria.

Methods: This was a randomized cross-sectional and hospital-based study. The standard method of microscopy was employed. Thick and thin films were prepared and viewed under a light microscope to identify and quantify malaria parasites. A well-structured and pre-tested questionnaire was used to obtain the subject's information on the demographic, socio-economic and environmental variables.

Results: A total of 380 (71.7%) participants were infected with *Plasmodium falciparum* with a mean parasite density of 1857.11 parasite/µL of blood. Malaria prevalence and mean parasite density were significantly higher among male compared to their female counterparts [80.3% vs 61.4% and 2026.46 vs 1619.63 parasite/µL of blood]. Similarly, age group ≤5 years had the highest malaria prevalence (92.2%) and mean parasite density (2031.66 parasite/µL of blood) than other age groups (AOR 2.281, 95% CI: 1.187–4.384, P < 0.05). The multivariate logistic analysis showed that malaria disease is significantly associated with having mother with no formal education (AOR 12.235, 95% CI: 3.253–46.021, P < 0.05), having well and river as a major source of household water supply (AOR 13.810, 95% CI: 3.012–63.314, P < 0.05 vs AOR 5.639, 95% CI: 1.455–21.853, P < 0.05) and presence of stagnant water around home (AOR 5.22, 95% CI: 2.921–9.332, P < 0.05). Furthermore, protective factors observed include ownership of mosquito bed net (AOR 0.474, 95% CI: 0.223–1.008, P < 0.05) and distance of home to hospital (AOR 0.279, 95% CI: 0.158–0.493, P < 0.05).

Conclusion: Malaria remains a serious public health problem in the study area. Adopting integrated malaria control measures including educating parents on malaria prevention and control strategies, distributing mosquito bed nets, and establishing larvae source management program is highly imperative.

Keywords: Akure, malaria, parasite density, *Plasmodium falciparum*, prevalence, risk factors

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Introduction

Malaria continues to constitute a major public health concern worldwide, particularly among children and pregnant women in tropical and sub-tropical regions of the world.[1,2] It is caused by the Apicomplexan parasite of the genus *Plasmodium*.[3]

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It is transmitted to humans and animals through the bite of *Plasmodium*-infected female anopheles mosquito during blood feeding.[4] The major species of *Plasmodium* worldwide include *Plasmodium falciparum, Plasmodium vivax, Plasmodium ovale, Plasmodium malariae* and the zoonotic *Plasmodium knowlesi*, which is common in the south-east Asian countries.[5,6] The major malaria vector in Nigeria include *Anopheles gambiae, Anopheles arabiensis, Anopheles moucheti* and *Anopheles funestus*.[7,8] Generally, *P. falciparum* is the most prevalent, virulent, and pathogenic in African regions.[9,10] It is estimated that about half of the world population are at risk of malaria disease worldwide in 2019.[2,11] Globally, an estimated 229 million malaria cases and 409,000 deaths were recorded in 87 countries in 2019, and Africa alone accounted for approximately 94% of all malaria cases.[2] In Nigeria, malaria is highly endemic and transmitted throughout the year, with 97% of the total population (194 million) at risk of contracting malaria disease.[2,12] Thus, Nigeria alone accounted for 27% and 23% of all malaria cases and deaths worldwide, respectively.[2] Therefore, malaria is a major public health problem that requires more attention in Nigeria.

Malaria disease is deadly, and the burden of infection is particularly enormous among children and pregnant women. Children alone accounted for an alarming rate of 67% of all malaria deaths globally.[2] Thus, a child dies of malaria every two minutes in 2019.[2,3] Prevalence of malaria parasitaemia has been reported to be between 18% and 83% among children in different settings in endemic regions of sub-Saharan African countries.[13] The major detrimental effect of malaria fever episodes and illness among children include lack of appetite and malnutrition, anaemia, reduced play, reduced social activities and interaction, and long-term neurological effect resulting from severe malaria.[14] Additionally, malaria accounted for approximately 13–50% of all school absenteeism among children.[15] This, in turn, adversely affect the cognitive capacity of children.[16,17] All these effects contribute immensely to the poor growth and development of children. Meanwhile, children continue to remain vulnerable due to delay of protective immunity, particularly in highly endemic settings such as Nigeria.[14]

To alleviate the malaria burden in Nigeria, particularly among children and pregnant women, the Federal Ministry of Health developed a National Malaria Elimination Programme (NMEP) that collaborated with partners to increase key interventions such as insecticide-treated nets, intermittent preventive treatment in pregnancy, effective case management, and indoor residual spraying.[18] Though these interventions resulted in reduced malaria disease, malaria continues to be a major health problem in Nigeria. Study on malaria among children have increased, particularly regarding clinical effect, morbidity and mortality, risk factors for malaria disease, and impacts on children educational performance and accomplishments in some parts of Nigeria.[19–21] Currently, however, there is a dearth of epidemiological information on risk factors driving malaria disease among children in peri-urban communities of Akure, Nigeria. Identifying these drivers of malaria disease is highly essential because malaria control and management strategy are based on such information. Thus, this study investigates the prevalence and risk factors associated with malaria among febrile children in some peri-urban communities in Akure, Southwestern Nigeria.

Materials and Methods

Study Area

The study was conducted in some peri-urban communities of Ifedore Local Government Area (LGA) of Ondo State, southwestern Nigeria. The study locations were Ikota (7° 21′ 0” N, 5° 9′ 0” E), Irese (7° 20′ 0” N, 5° 11′ 0” E), Ipogun (7° 19′ 0” N, 5° 5′ 0” E), Ibule-soro (7° 18′ 0” N, 5° 7′ 0” E), and Ilara-mokin (7° 21′ 0” N, 5° 7′ 0” E) (Figure 1). They are all typical peri-urban communities which are transition zones located near Akure city, the capital of Ondo State, Nigeria. The distance of these communities ranges between 12.6 km and 24 km from Akure. Meanwhile, Akure is situated between latitude 7° 15 ’0”N and longitude 5°11 ’42”E with an estimated population projection of 570,500 people in 2011.[22] Generally, the weather is tropical. The local climate is typical of the dry season and rainy season, extending from November to March and April to October, respectively. The average annual rainfall is 2378 mm, with temperatures ranging from 25.2°C to 28.1°C and relative humidity of about 80%.[23] These communities have their respective rivers and streams upon which they depend for household water supply and other activities. Basic infrastructures are either lacking or in miserable condition. Major occupations include farming, artisan, and trading, while some are civil servants. The residents are primarily of Yoruba ethnic group.

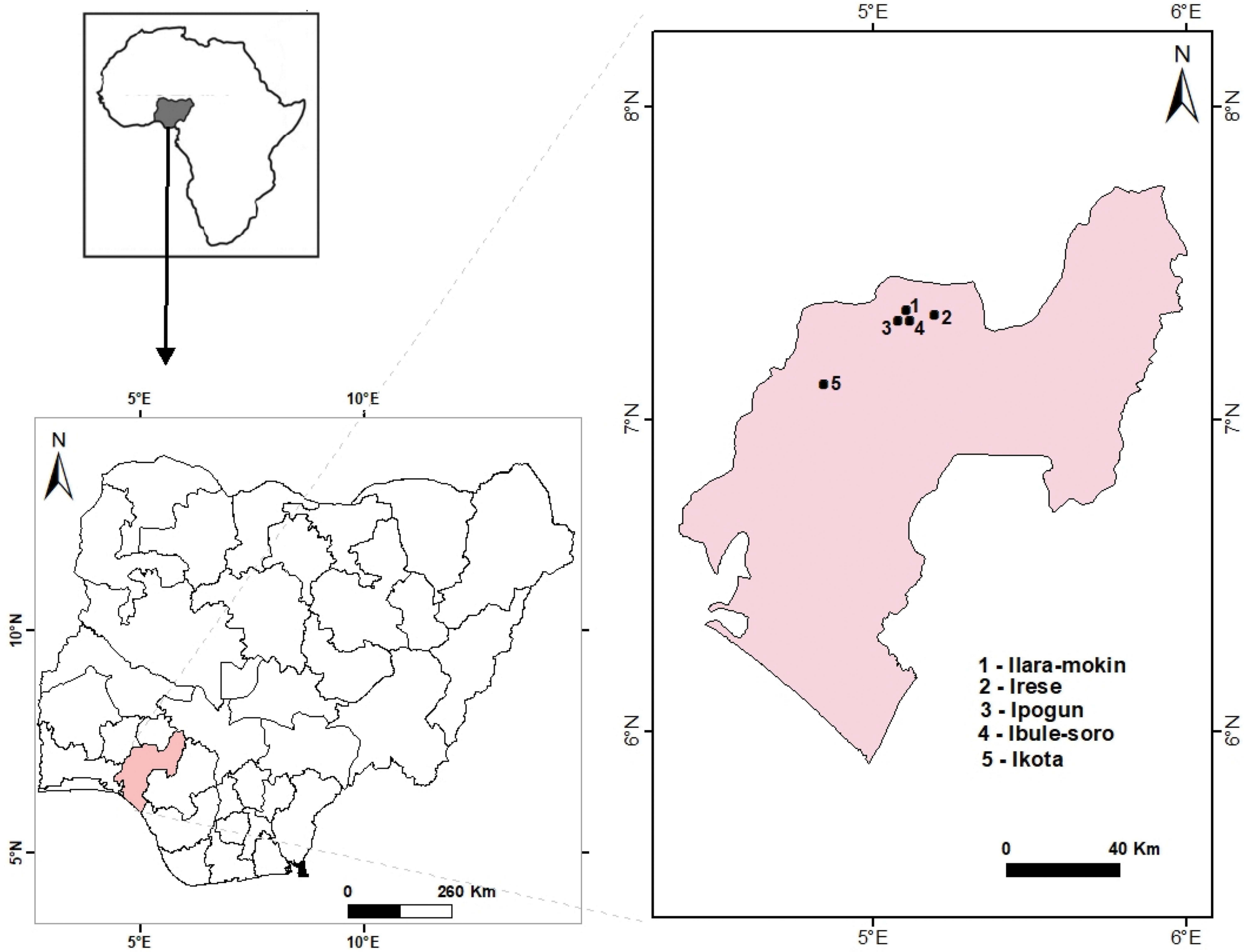

Figure 1 Map of the study area showing the peri-urban communities.

Study Design

This was a randomized cross-sectional and hospital-based study. The study was carried out between February and October 2018 in peri-urban communities of Akure, south-western Nigeria. The study was conducted in five randomly selected health facilities consisting of one Basic Health Centre from each community. These included the Basic Health Centers in Ikota, Irese, Ipogun, Ibule-soro and Ilara-mokin (Figure 2). The method of data collection utilized was the descriptive quantitative method through well-designed and pre-tested questionnaires. A face-to-face interview was conducted to collect relevant information from each of the patients visiting the health facilities. Some of the data obtained were age, sex, community of residence, father's occupation, mother's occupation, father's education, mother's education, household income, ownership of mosquito net, presence or absence of stagnant water, presence or absence of rivers or streams, household water sources and distance of the home to hospital. Recruitment of the febrile children was through a random selection, and was conducted in the outpatient department of the health facilities with the assistance of a health officer. Febrile children are the children who showed signs and symptoms. The inclusion criteria were age between 6 months and 15 years, fever with temperature ≥38°C, resident within the community for a minimum of 6 months, completing the questionnaire, submission of the blood sample, and readiness to provide informed consent. Children who have taken antimalaria drug within the last three months were excluded.

Sample and Sampling

The study sample size was calculated using single population proportion estimate formula. A previous malaria prevalence of 84.20% in Akure[24] and a confidence interval (C.I) of 95% coupled with a precision level of 5% were employed to compute the sample size. A total of 204 participants were required

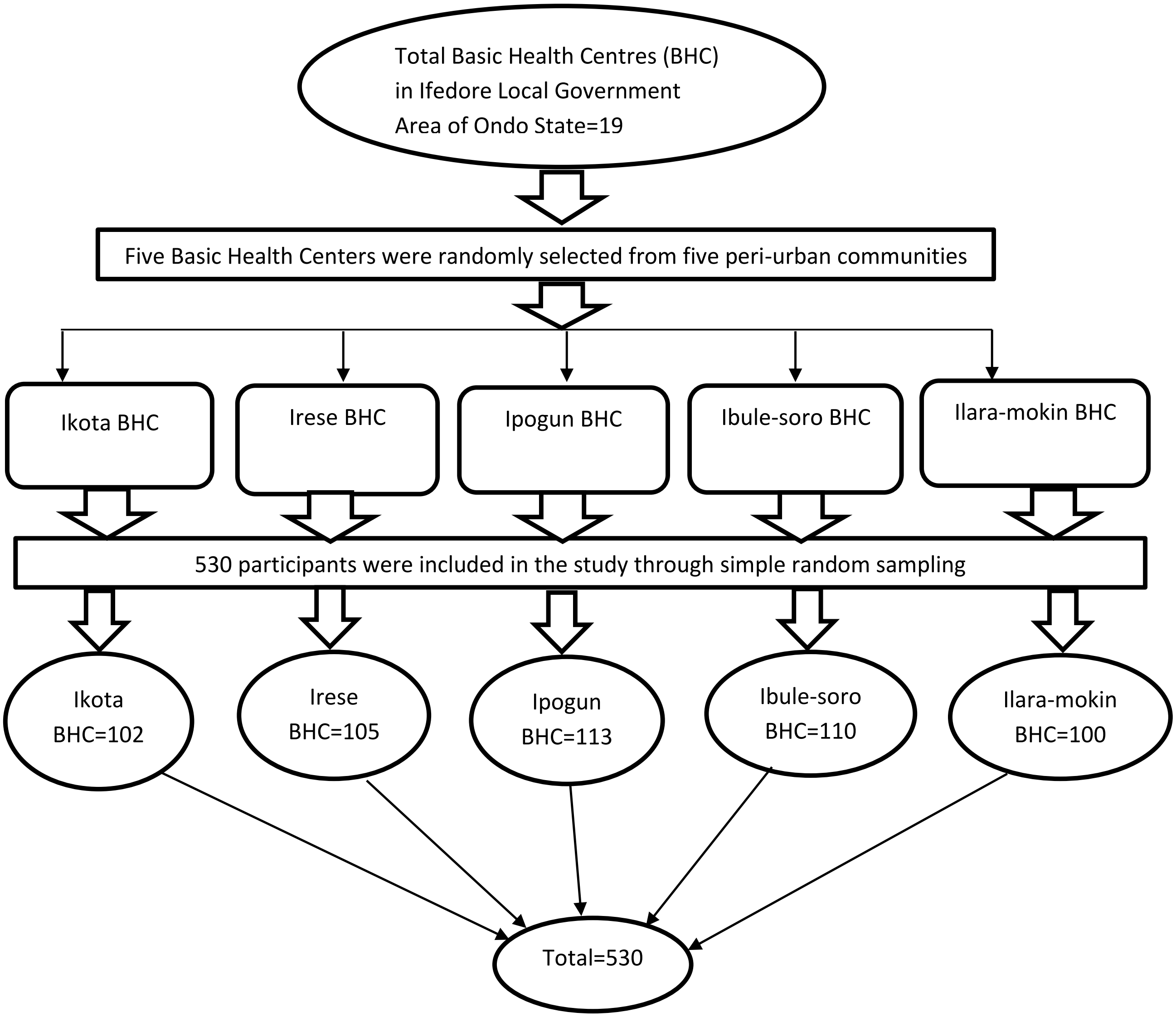

Figure 2 Schematic diagram of the study sampling technique.

according to the formula of Araoye.[25] Nevertheless, 530 participants were randomly selected in the study to cater for any statistical error. The response rate was 96% since only 530 eventually consented from a total of 550 potential subjects targeted for the study.

Blood Sample Collection, Laboratory Processing and Examination

Blood samples were collected intravenously with the aid of an expert phlebotomist. Approximately 2–3mL venous blood was obtained from each subject. The blood samples were collected into ethylenediaminetetraacetic acid (EDTA) tube to prevent the blood from clotting. After that, thick and thin smears were done to detect parasite species.[26] The thin smear was fixed in absolute ethanol. Subsequently, a 5% Giemsa stain was added to both the thick and thin smears on the slide for 30 minutes. The slides were then examined under x100 objective lens of the light microscope to determine the prevalence of *Plasmodium* parasites and their specific species. Each slide was considered negative when approximately 200 microscopic fields have been observed. Moreover, quality assurance was performed on 10% of all the positive slides by an expert senior laboratory microscopist for species identification and confirmation.[27] There was no discrepancy in the results when 10% of all the positive slides were examined by expert senior microscopist due to adequate training. The level of parasitaemia or parasite density was classified as low when parasitaemia was less than

1000 parasites/μL of blood; moderate when parasitaemia was between 1000 and 9999 parasites/μL of blood and severe when parasitaemia was greater than or equal to 10,000 parasites/μL of blood.[28] Parasite density was recorded as the number of parasite/μL of blood, assuming an average leucocyte count of 8000/μL of blood for an average individual.[3]

Statistical Analysis

Data were analyzed using Statistical Package for Social Science (SPSS) version 22.0. The presence or absence of malaria was computed, and the difference of prevalence between age groups and sex was calculated using chi-square at a 95% level of confidence. The geometric mean malaria parasite density was explored using one-way analysis of variance for the variable with more than two categories, while Student's *t*-test was used to determine dichotomous variable. The geometric mean malaria parasite density was log transformed and used to design the box plot. Multivariate Logistic Regression Analysis was used to determine the associated risk and protective factors for malaria disease. P-values less than 0.05 was considered statistically significant.

Ethical Consideration

Ethical protocol for the study was approved by the Ondo State Ministry of Health (protocol number OSHREC/21/08/2017/012) and the Ethical Review Committee of the Federal University of Technology, Akure, Nigeria. Permission was sought from the hospital management board of the Basic Health Centres in the study areas. Both written and verbal informed consent and accent was sought from all the subjects and their parents, caregiver or guardians after brief explanation about the study. All participant's information were kept confidential. According to national standard and guidelines, participants whose blood tested positive for malaria were treated in the health facilities. This study was conducted in accordance with the Declaration of Helsinki.

Results

Demographic Characteristics of the Study Participants

A total of 530 febrile children were examined in this study. The children were aged between 6 months to 15 years. There were 286 males (54.53%) and 241 (45.47%) females. The highest number of age group examined was ≤5 years (50.57%) while the least was 6–10 years (23.39%). The participants were from five peri-urban communities in Akure: 102 (19.81) from Ikota, 105 (19.81%) from Irese, 113 (21.32%) from Ipogun, 110 (20.75%) from Ibule-soro, and 100 (18.87%) from Ilara-mokin.

Malaria Prevalence and Parasite Density in Relation to Demographic Variables

Overall, the number of children positive for malaria was 380 (71.7%) with a mean parasite density of 1857.11 parasite/μL of blood. The prevalence and parasite density of malaria with respect to demographic variables are presented in Table 1. The highest malaria prevalence of 79.1% was recorded among age group ≤5 years, while the least prevalence of 58.1% was recorded among age group 11–15 years. It was observed that malaria prevalence significantly reduces with increasing age. According to sex, a higher malaria prevalence of 80.3% was recorded among males compared to their female counterparts with malaria prevalence of 61.4% (P < 0.05). Furthermore, Ipogun had the highest malaria prevalence of 74.3% while Ikota had the least malaria prevalence of 65.7% (P > 0.05).

Table 1 Prevalence and Density of *Plasmodium falciparum* Infection Stratified by Demographic Variables Among Residents of Peri-Urban Communities of Akure, Southwestern Nigeria

Variables	Number Examined	Number Positive (%)	Geometric Mean (Range of Mean) Parasite Density (Parasite/μL of Blood)
Age group (year)			
≤5	268	212 (79.1)	2031.06 (9870)
6–10	138	96 (69.6)	1696.47 (9870)
11–15	124	72 (58.1)	1609.63 (6848)
P value		<0.0001	<0.0001
Sex			
Male	289	232 (80.3)	2026.49 (9870)
Female	241	148 (61.4)	1619.63 (9870)
P-value		<0.0001	0.069
Community			
Ikota	102	67 (65.7)	1673.65 (9870)
Irese	105	76 (72.4)	1484.21 (9870)
Ipogun	113	84 (74.3)	2624.51 (8521)
Ibule-soro	110	80 (72.7)	1843.64 (7603)
Ilara-mokin	100	73 (73.0)	1746.86 (4032)
P-value		>0.05	<0.0001
Total	530	380 (71.7)	1857.11 (9870)

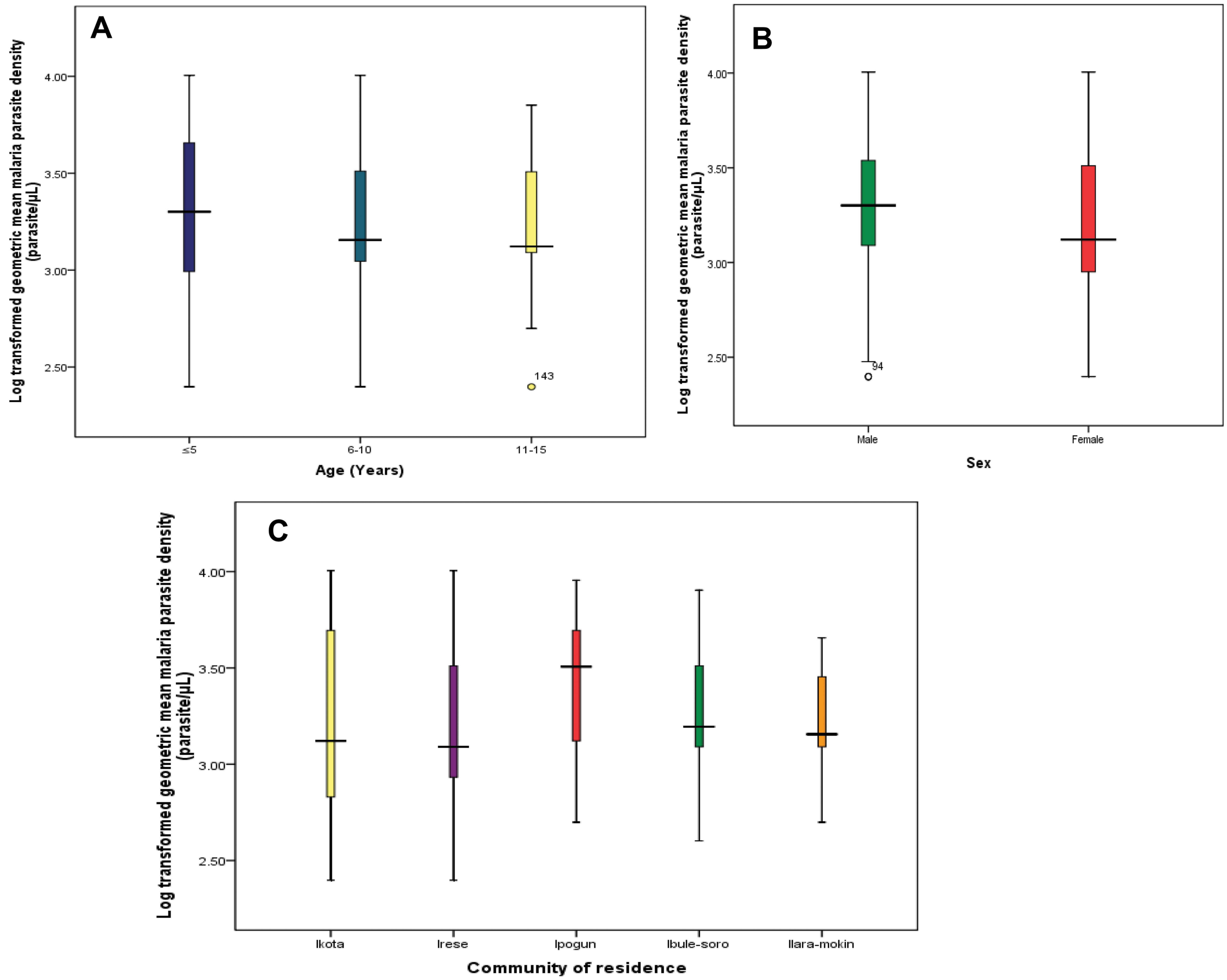

Figure 3 Box plot of the log transformed mean malaria parasite density (parasite/µL of blood) in relation to (**A**) age (**B**) sex and (**C**) community.

The box plot in Figure 3 shows the log transformed geometric mean malaria parasite density distribution with respect to age, sex, and community of residence (Figure 3A–C respectively). The highest mean parasite density was noted among age group ≤5 years while the least mean parasite density was observed among age group 11–15 years old ($P < 0.05$). Similarly, the geometric mean parasite density was higher among male compared to female children. It was however not statistically significant ($P > 0.05$). As for community of residence, the highest geometric mean parasite density was observed in Ipogun while the least was recorded in Irese ($P < 0.05$).

Malaria Prevalence and Parasite Density in Relation to Socio-Economic Variables

Table 2 shows the prevalence and parasite density of *P. falciparum* infection with respect to socio-economic variables. The highest malaria prevalence of 79.1% and mean parasite density of 2168.18 parasite/µL of blood was recorded among children whose fathers are farmers ($P < 0.05$). Also, children whose mothers are farmers recorded the highest prevalence of 81.4% and mean parasite density of 2616.92 parasite/µL of blood ($p < 0.05$). Additionally, children whose mother and father significantly have no formal education have higher malaria prevalence (83.6% vs 78.5) and mean parasite density (1812.86 vs 1937.19) than those whose father and mother have primary, secondary, and tertiary education levels ($P < 0.05$). Additionally, with regard to household income, children belonging to a household that earns <30,000 naira significantly have a higher malaria prevalence of 74.6% and mean parasite density of 2011.79 parasite/µL of blood. Similarly, children whose parent does not own a house have a higher malaria prevalence

Table 2 Prevalence and Density of *Plasmodium falciparum* Infection Stratified by Socioeconomic Variables Among Residents of Peri-Urban Communities of Akure, Southwestern Nigeria

Variables	Number Examined	Number Positive (%)	Geometric Mean (Range of Mean) Parasite Density (Parasite/μL of Blood)
Father's Occupation			
Civil servant	54	10 (18.5)	2023.52 (6848)
Farmers	215	170 (79.1)	2168.18 (9870)
Artisans	172	131 (76.2)	1635.99 (9870)
Traders	89	69 (77.5)	1593.14 (5737)
P-value		<0.05	<0.05
Mother's Occupation			
Civil servant	48	24 (50.0)	1281.46 (4208)
Farmers	102	83 (81.4)	2616.92 (8750)
Artisans	51	38 (74.5)	1858.82 (6640)
Traders	199	142 (71.4)	1638.65 (8471)
Housewife	130	93 (71.5)	1821.00 (9870)
P-value		<0.05	<0.05
Father's Education			
No formal education	177	148 (83.6)	1812.86 (9870)
Primary	146	104 (71.2)	1892.60 (9870)
Secondary	125	82 (65.6)	1884.17 (9820)
Tertiary	82	46 (56.1)	1873.91 (7467)
P-value		<0.05	0.928
Mother's Education			
No formal education	200	157 (78.5)	1937.19 (9870)
Primary	239	173 (72.4)	1832.25 (8800)
Secondary	68	44 (64.7)	1651.11 (9820)
Tertiary	23	6 (26.1)	2149.21 (6318)
P-value		<0.05	0.880
Household income (NGN)			
<30,000	343	356 (74.6)	2011.79 (9870)
30,000–50,000	159	110 (69.2)	1579.36 (9870)
>50,000	28	14 (50.0)	1535.63 (6479)
P-value		<0.05	0.098
Does the family head own house?			
Yes	108	65 (60.2)	1699.51 (9820)
No	422	315 (74.6)	1891.41 (9870)
P-value		<0.05	0.586
Total	530	380 (71.7)	1857.11 (9870)

Note: $USD 1 is equivalent to NGN305 at the time of the study.

of 74.6% and mean parasite density of 1891.41 than those whose parents own a house (P < 0.05).

Malaria Prevalence and Parasite Density in Relation to Environmental Variables

The prevalence and parasite density of *P. falciparum* infection in relation to environmental variable are presented in Table 3. Children whose household depend majorly on river/stream for household water supply have a higher malaria prevalence of 76.8% and mean parasite density of 1925.89 parasite/μL of blood. Similarly, having distance of river/stream within <1km from home, presence of stagnant water, lack of mosquito net, not sleeping under mosquito net and distance of ≥1km of the hospital from home significantly have higher malaria prevalence (P < 0.05).

Risk and Protective Factors of Malaria Among the Study Participants

The multivariate logistic regression analysis of factors associated with malaria among children is presented in Table 4. The results showed that age group of ≤5 years were approximately two fold as likely to have malaria disease compared to children of other age groups (AOR 2.281, 95% C.I.: 1.187–4.384, P value: 0.013). Similarly, male children were approximately four fold as likely to have malaria disease compared to their female counterparts (AOR 3.801, 95% C.I.: 2.131–6.780, P value: 0.001). Additionally, the results showed that malaria disease increases in children as their mother's level of education decrease. Thus, children who have mothers without formal education (AOR 12.235, 95% C.I.: 3.253–46.021, P value: 0.001) and/or having primary education (AOR 5.677, 95% C.I.: 1.588–20.300, P value: 0.008) and secondary education (AOR 4.032, 95% C.I.: 0.965–16.851, P value: 0.060) were at higher risk of malaria disease. Furthermore, children of household that solely depend on well water and river/stream water were more likely to have malaria disease (AOR 13.810, 95% C.I.: 3.012–63.314, P value: 0.001, and AOR 5.639, 95% C.I.: 1.455–21.853, P value: 0.012). Stagnant water around home was observed as a significant risk factor and was found to increase the odds of malaria disease among children by approximately five times compared with those without stagnant water around their homes (AOR 5.221, 95% C.I.: 2.921–9.332,

Table 3 Prevalence and Density of *Plasmodium falciparum* Infection Stratified by Environmental Variables Among Residents of Peri-Urban Communities of Akure, Southwestern Nigeria

Variables	Number Examined	Number Positive (%)	Geometric Mean (Range of Mean) Parasite Density (Parasite/μL of Blood)
Major source of household water supply			
Tap water	23	9 (39.1)	1855.11 (2441)
Well water	203	144 (70.9)	1749.50 (9870)
River/Stream	285	219 (76.8)	1925.89 (9870)
Others	19	8 (42.1)	2011.83 (3698)
P-value		<0.05	0.349
Distance of river/ stream from home			
<1km	333	266 (79.9)	1813.97 (9870)
≥1km	197	114 (57.9)	1961.79 (9820)
P-value		<0.05	0.797
Do you have stagnant water around home?			
Yes	355	303 (85.4)	1910.83 (9870)
No	175	77 (44.0)	1660 (9620)
P-value		<0.05	<0.05
Ownership of mosquito bed bed net			
Yes	217	103 (47.5)	1910.46 (8521)
No	313	277 (88.5)	1837.65 (9870)
P-value		<0.05	0.205
Child slept under the mosquito bed net last night			
Yes	157	64 (40.8)	1866.15 (7753)
No	373	316 (84.7)	1855.28 (9870)
P-value		<0.05	0.262
Experience malaria infection in the last 6 months			
Yes	337	261 (77.4)	1977.84 (9870)
No	193	119 (61.7)	1617.49 (8650)
P-value		<0.05	<0.05
Distance of home to hospital			
<1km	183	89 (48.6)	2042.42 (9720)
≥1km	347	291 (83.9)	1803.86 (9870)
P-value		<0.05	0.826
Total	530	380 (71.7)	1857.11 (9870)

Table 4 Multivariate Logistic Regression Analysis of Factors Associated with Malaria Infection Among Residents of Peri-Urban Communities of Akure, Southwestern Nigeria

Variables	Adjusted Odd Ratio, AOR (95% CI)	*P*-value
Age group (year)		
≤5	2.281 (1.187–4.384)	0.013
6–10	2.065 (0.995–4.285)	0.051
11–15	1	
Sex		
Male	3.801 (2.131–6.780)	0.001
Female	1	
Mother's Education		
No formal education	12.235 (3.253–46.021)	0.001
Primary	5.677 (1.588–20.300)	0.008
Secondary	4.032 (0.965–16.851)	0.060
Tertiary	1	
Major source of household water supply		
Well water	13.810 (3.012–63.314)	0.001
River/Stream	5.639 (1.455–21.853)	0.012
Others	1	
Do you have stagnant water around home?		
Yes	5.221 (2.921–9.332)	0.001
No	1	
Ownership of mosquito bed net		
Yes	0.474 (0.223–1.008)	0.049
No	1	
Child slept under the mosquito bed net last night		
Yes	0.409 (0.191–0.877)	0.022
No	1	
Distance of home to hospital		
<1km	0.279 (0.158–0.493)	0.001
≥1km	1	

P value: 0.001). Some significant factors protecting against malaria disease among participants include ownership of mosquito bed net (AOR 0.474, 95% C.I.: 0.223–1.008, P value: 0.049), sleeping under the mosquito bed net (AOR 0.409, 95% C.I.: 0.191–0.877, P value: 0.012), and having a distance of <1km from home to hospital (AOR 0.279, 95% C.I.: 0.158–0.493, P value: 0.001).

Discussion

The study provided one of the first baseline epidemiological information on malaria and risk factors among febrile children in peri-urban communities in Akure, Nigeria. Our findings highlight a high malaria prevalence of 71.7% in these communities. Thus, this supports the report of the World Health Organization (WHO) and Nigeria Malaria Indicator Survey, which stated that malaria remains a major public health problem worldwide, particularly among children and pregnant women, and this requires integrated control measures coupled with broader efforts to accomplish a universal health coverage.[2,29] Our finding is similar to the report of Umma et al[30] who reported malaria prevalence of 72.2% among febrile children attending Aminu Kano Teaching Hospital in Kano, Northwestern Nigeria. However, the malaria prevalence in this study is higher than previous reports from other parts of Nigeria like Ibadan,[31] Borno,[32] Lagos,[33] Anambra,[34,35] Enugun,[36] Ogun,[37] Jos,[38,39] Sokoto[40] and other malaria-endemic countries such as Cameroon,[41,42] Ethiopia,[43,44] Ghana,[45] Malawi[46] and Rwanda.[47] On the other hand, a higher malaria prevalence of 80.5% and 78% were reported among children in Ogun, southwestern Nigeria and Al Sabah, South Sudan,[48,49] respectively. Generally, the prevalence of malaria in this study falls within the Nigerian malaria risk map estimate of <20% in certain regions to >70% in others.[50] The high malaria prevalence among children in this study area could be due to geographical differences, poor socio-economic condition and variation in malaria prevention and control interventions in these regions. In the same vein, the geometric mean parasite density recorded in this study was 1857.11 parasite/μL of blood. This is higher than the 750 parasite/μL of blood reported in Ogun state, Nigeria[48] but lower than the geometric mean parasite density reported in studies conducted in Ghana,[51] Sudan,[52] and Cameroon.[42] The high geometric mean parasite density of malaria disease among children in this study could be as a result of constant exposure to mosquito bite without any major prevention and care intervention program which is a common characteristic of resource-poor settings.

Furthermore, our findings revealed that *P. falciparum* was the only *Plasmodium* species encountered in this study. This is similar to the report of studies conducted in Ekiti and Ibadan, southwestern Nigeria[53,54] and other malaria endemic settings.[32,55,56] This is due to the fact that *P. falciparum* is a dominant *Plasmodium* species in Nigeria and Africa.[2] It is responsible for causing serious morbidity and mortality among children, particularly in African countries.

Our findings show strong evidence of an association between age group ≤5 years, and malaria prevalence, such that malaria prevalence significantly decreases with increase in age of the children. This has been widely reported from previous studies conducted among children in resource-poor settings in Nigeria[40,48] and other sub-Saharan African countries[21,57] In the same vein, the World Health Organization, has reported that the odds of malaria infection increased among children, particularly in Africa in 2017.[11] This could be attributed to delayed protective immunity experienced among age group ≤5 years compared to adults who have a well-defined immunity acquired over time due to exposure. Additionally, the report of Dobbs and Dent[58] showed that mosquitoes show more preference for biting older children. To tackle the menace of malaria among children, there is a need for health officers to educate parents, particularly mothers, on malaria preventive measures such as ownership and appropriate use of mosquito net to cover their children all night. Similarly, more mosquito net should be distributed to ensure that sufficient mosquito net is available in each household. Additionally, a significantly higher geometric mean parasite density was recorded among age group ≤5 years. This is in accordance with results from other studies which revealed that majority of children usually experience and harbour heavy malaria parasite load in their first and second year of life, particularly in stable malaria endemic regions.[48,59,60] This could be because of delayed acquired immunity in children ≤5 years of age. Apparently, it takes several years of constant exposure to infection to build up and develop such immunity. Another reason could be due to the fact that only febrile children attending health facilities were included in the study.

The association of malaria infection with sex was observed to be significant. Male children significantly have higher malaria infection compared to their female counterparts (80.3% vs 61.4%). This is consistent with the findings from other malaria-endemic regions.[61,62] This could be because male children tend to be more venturesome and engage in outdoor activities and play than female children. All these activities can expose male children to mosquito bites and subsequent malaria infection than female children. Also, a higher geometric mean parasite density was recorded among male children than their female counterparts though the result was not statistically significant. Many studies found no significant relationship between sex and geometric mean parasite density.[38,63,64] Notwithstanding, this higher geometric mean parasite density among males could be as a result of indiscriminate exposure of male children to incessant mosquito bite due to unavailability or insufficiency of mosquito bed net.

Furthermore, our findings also highlight that education has a great impact on malaria prevalence in this study area. Obviously, lower level of maternal education significantly resulted in higher risk of malaria disease in their children. Thus, children whose mothers do not have formal education are at a greater risk of malaria disease than others whose mothers have primary, secondary and tertiary education. This finding is in conjunction with reports of studies conducted in many malaria-endemic settings.[57,65–67] This association between childhood malaria and maternal education could be attributed to the fact that mothers with higher education are more likely to have a better standard of living and access to better health care; afford malaria treatment, mosquito bed net and indoor residual spray; and have better knowledge of malaria signs and symptoms, which can help them take appropriate proactive prevention and control measures. In the same vein, educated mothers have higher probability to engage in activities that boost health such as use of mosquito net, regular antenatal care visit and vaccination. Thus, there is a need for malaria education for the general population through workshops, radio and television advertisement on malaria prevention and care, and spreading appropriate malaria prevention and care information on social media platforms in local languages.

Our findings further revealed unequivocally that household income plays a pivotal role to determine malaria infection in this study. Children from a household earning <NGN 30,000 significantly have higher malaria prevalence and parasite density. Consistent with the present study, previous findings reported from studies conducted in other malaria-endemic region showed that low income is intricately linked to malaria infection.[68,69] This could result from the inability to afford basic malaria preventive and treatment measures such as indoor residual spray, mosquito net and good and well-protected accommodation. In this case, the government should distribute free mosquito net for the community members.

Additionally, children whose household depends on well water and river or stream water have a higher odd of contracting malaria disease. This could be as a result of their exposure to mosquito bites while fetching water and on their way to and from the river or stream since the river or stream and environs serves as mosquito breeding sites. This validates the observation that the spread and location of water bodies and ponds can affect mosquito vector population distribution and abundance.[70] Moreover, studies elsewhere have noted that open artesian well, spring and surface water such as rivers or streams, lakes, ponds and dams can be a good mosquito breeding site.[71] In accordance with this, studies from Ethiopia,[72] Kenya,[73] Tanzania,[74] and India[75] have revealed higher number of mosquito larvae in ponds and dams and higher malaria parasite prevalence among people living around such ponds and dams. Similarly, this finding conforms with the report of Yang et al[76] who reported a higher malaria infection among those who depend on unprotected water as a source of household water supply. Furthermore, children of household having stagnant water around their homes are four-fold likely to have malaria infection compared to their counterparts who do not have stagnant water around their homes. Previous studies have demonstrated that stagnant water is a favourable breeding site for mosquito development and proliferation, leading to increased malaria transmission.[72] Under this situation, there is a need for larvae source management program in which all mosquito breeding sites such as stagnant water are actively searched for and destroyed to prevent the growth and development of mosquito vectors. Additionally, there is a need for environmental sanitation in which all bushes that could serve as mosquito breeding site are being cleared.

The use of treated bed nets has been recognized as an effective, productive, and low-cost intervention that has greatly reduced malaria infection in endemic countries. In this study, our results show that ownership of mosquito bed net and sleeping under the bed net the previous night before the study survey significantly reduced malaria infection among children. This finding corroborates the report of Gahutu et al[77] in Rwanda, Okebe et al[78] in Gambia, Winskill et al[79] in Tanzania, and Ntonifor and Veyufambom[80] in Cameroon. The significant reduction in malaria infection among those children who slept under the mosquito net could be due to the protective capacity of the mosquito bed net. The mosquito bed net has been demonstrated to be highly effective if it is properly utilized.[81] In contrast, the report of Wotodjo et al[82] in Senegal showed no association between mosquito bed net and malaria infection. The lack of association observed might be due to improper use of mosquito net. It could also be attributed to exposure to mosquito bite during the day when mosquito net was not in use. Alternative preventive measures such as repellents should be encouraged when children engage in any outdoor activities. At the same time, the indoor residual spray should be applied when playing indoors or watching television before finally going to sleep.

Finally, the present study demonstrates that shorter distance from home to hospital significantly reduced malaria disease among children. Similar findings have been documented in previous studies.[83,84] They found that shorter distance from home to health facility is significantly associated with early diagnosis and treatment of malaria disease. This could be because residents feel more comfortable going to nearby health facilities for diagnosis and treatment, unlike longer distance, which could be exhausting and discouraging, thereby delaying visit and access to health facilities. Therefore, health facilities should be cited and be accessible within a reasonable distance from residents. It should as well have a good road network for better access to health facilities and as such better malaria diagnosis and treatment.

Limitations

This study was hospital-based and may not represent the general population. Additionally, the study did not include mosquito vector surveillance on identification, diversity and abundance. Thus, no confirmation regarding the presence of *Plasmodium* infection in mosquito vector. Notwithstanding, the findings in this study provided reliable and relevant epidemiological information upon which malaria control and management strategy can be based in endemic countries.

Conclusion

In conclusion, the findings of this study have shown that malaria continues to be a major public health problem, particularly among children of five years and below. Major contributing risk factors that intricately increase the odds of malaria infection among the population include being age ≤5 years, being male, no maternal formal education, low income, source of household water supply, having stagnant water around home. Some protective factors include ownership and sleeping under mosquito bed net, and having a distance of ≤1km from home to the nearest health facility. Appropriate malaria control measures and intervention should be put in place to mitigate the menace. These could include educating parents on malaria prevention and control strategies, additional distribution of insecticide mosquito bed net coupled with indoor residual spray and mosquito repellents, establishing a larvae source management program and encouraging all household in the communities to participate, and citing health facilities within the community where it can easily be accessed. Moreover, chemopreventive treatment for children and vaccination is highly essential. These measures, if properly applied, can engender a malaria-free community and world at large.

Abbreviations

NGN, Nigerian Naira; WHO, World Health Organization.

Data Sharing Statement

The datasets used and/or analyzed in this study are available from the corresponding author on reasonable request.

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References

1. Steketee RW, Nahlen BL, Parise ME, Menendez C. The burden of malaria in pregnancy in malaria-endemic areas. *Am J Trop Med Hyg*. 2001;64(1):28–35. doi:10.4269/ajtmh.2001.64.28
2. World Health Organization. *World Malaria Report 2020: 20 Years of Global Progress and Challenges*. Geneva: World Health Organization; 2020.
3. World Health Organization. *Microscopy for the Detection, Identification and Quantification of Malaria Parasites on Stained Thick and Thin Blood Films in Research Settings (Version 1.0): Procedure: Methods Manual*. World Health Organization; 2015:32.
4. Besansky NJ, Hill CA, Costantini C. No accounting for taste: host preference in malaria vectors. *Trends Parasitol*. 2004;20(6):249–251. doi:10.1016/j.pt.2004.03.007
5. Gilles HM. The malaria parasites. In: Gilles HM, Warrell DA, editors. *Bruce-Chwatt's Essential Malariology*. 3rd ed. London: Edward Arnold; 1993:12–34.
6. Abeysinghe R. Outcomes from the evidence review group on Plasmodium knowlesi. In Malaria Policy Advisory Committee Meeting; March 22–24 2017; Geneva.
7. Sinka ME, Bangs MJ, Manguin S, et al. A global map of dominant malaria vectors. *Parasit Vectors*. 2012;5(1):1–26. doi:10.1186/1756-3305-5-69
8. Akpan GE, Adepoju KA, Oladosu OR, Adelabu SA. Dominant malaria vector species in Nigeria: modelling potential distribution of Anopheles gambiae sensu lato and its siblings with MaxEnt. *PLoS One*. 2018;13(10):e0204233. doi:10.1371/journal.pone.0204233

9. Caraballo H, King K. Emergency department management of mosquito-borne illness: malaria, dengue, and West Nile virus. *Emerg Med Pract*. 2014;16(5):1–23.
10. World Health Organization. *World Malaria Report 2017*. Geneva: World Health Organization; 2017.
11. World Health Organization. World malaria report 2018. Geneva: World Health Organization; 2018. Available from: https://www.who.int/malaria/publications/world-malaria-report-2018/en/. Accessed March 05, 2021.
12. World Health Organization. *World Malaria Report 2014*. Geneva: World Health Organization; 2014.
13. Nankabirwa JI, Wandera B, Amuge P, et al. Impact of intermittent preventive treatment with dihydroartemisinin-piperaquine on malaria in Ugandan schoolchildren: a randomized, placebo-controlled trial. *Clin Infect Dis*. 2014;58(10):1404–1412.
14. Holding PA, Kitsao-Wekulo PK. Describing the burden of malaria on child development: what should we be measuring and how should we be measuring it? *Am J Trop Med Hyg*. 2004;71(2_suppl):71–79. doi:10.4269/ajtmh.2004.71.2_suppl.0700071
15. Bundy DA, Lwin S, Osika JS, McLaughlin J, Pannenborg CO. What should schools do about malaria? *Parasitol Today.* 2000;16(5):181–182. doi:10.1016/S0169-4758(00)01658-6
16. Halliday KE, Karanja P, Turner EL, et al. Plasmodium falciparum, anaemia and cognitive and educational performance among school children in an area of moderate malaria transmission: baseline results of a cluster randomized trial on the coast of Kenya. *Trop Med Int Health*. 2012;17(5):532–549. doi:10.1111/j.1365-3156.2012.02971.x
17. Clarke SE, Jukes MC, Njagi JK, et al. Effect of intermittent preventive treatment of malaria on health and education in schoolchildren: a cluster-randomised, double-blind, placebo-controlled trial. *Lancet*. 2008;372(9633):127–138. doi:10.1016/S0140-6736(08)61034-X
18. Nigeria Federal Ministry of Health, National Malaria Control Programme. *Strategic Plan 2009–2013: "A Road Map for Malaria Control in Nigeria", Abridged Version*. Abuja: Yaliam Press Ltd, Federal Ministry of Health; 2009.
19. Ajayi IO, Afonne C, Dada-Adegbola H, Falade CO. Prevalence of asymptomatic malaria and intestinal helminthiasis co-infection among children living in selected rural communities in Ibadan Nigeria. *Am J Epidemiol Infect Dis*. 2015;3(1):15–20.
20. Morakinyo OM, Fagbamigbe AF. Neonatal, infant and under-five mortalities in Nigeria: an examination of trends and drivers (2003–2013). *PLoS One*. 2017;12(8):e0182990. doi:10.1371/journal.pone.0182990
21. Morakinyo OM, Balogun FM, Fagbamigbe AF. Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey. *Malar J*. 2018;17(1):1. doi:10.1186/s12936-018-2463-6
22. Ayeni AO. Malaria morbidity in Akure, Southwest, Nigeria: a temporal observation in a climate change scenario. *Trends Appl Sci Res*. 2011;6(5):488. doi:10.3923/tasr.2011.488.494
23. Geonames Geographical Database. Population of Akure, Nigeria; 2021. Available from: http://population.mongabay.com/population/nigeria/2350841/Akure. Accessed March 15, 2021.
24. Awosolu O, Adesina F, Afolabi O, Ogunsanya D. Malaria parasite distribution and knowledge among students of Federal University of Technology, Akure, Nigeria. *Anim Res Int*. 2020;17(3):3903–3910.
25. Araoye MO. *Sample Size Determination. Research Methodology with Statistics for Health and Social Sciences*. Ilorin: Nathadex Publishers; 2004:115–121.
26. Cheesbrough M. *District Laboratory Practice in Tropical Countries Part 2*. New York: Cambridge University Press; 2006:300–301.
27. Berzosa P, de Lucio A, Romay-Barja M, et al. Comparison of three diagnostic methods (microscopy, RDT, and PCR) for the detection of malaria parasites in representative samples from Equatorial Guinea. *Malar J*. 2018;17(1):333. doi:10.1186/s12936-018-2481-4
28. Atroosh WM, Al-Mekhlafi HM, Al-Jasari A, et al. Genetic variation of pfhrp2 in Plasmodium falciparum isolates from Yemen and the performance of HRP2-based malaria rapid diagnostic test. *Parasit Vectors*. 2015;8(1):388. doi:10.1186/s13071-015-1008-x
29. National Malaria Elimination Programme (NMEP), National Population Commission (NPopC), National Bureau of Statistics (NBS) and ICF International. *Nigeria Malaria Indicator Survey 2015*. Abuja, Nigeria, and Rockville, Maryland, USA: Federal Ministry of Health. Federal Republic of Nigeria; 2016.
30. Umma IA, Robinson WD, Jamilu FA, Gwarzo GD. Prevalence of malaria parasitaemia among febrile Nigerian children with severe malnutrition in Northwestern Nigeria. *Niger J Basic Clin Sci*. 2017;14(2):113. doi:10.4103/njbcs.njbcs_29_16
31. Adebisi NA, Dada-Adegbola HO, Dairo MD, Ajayi IO, Ajumobi OO. Performance of malaria rapid diagnostic test in febrile under-five children at Oni Memorial Children's Hospital in Ibadan, Nigeria, 2016. *Pan African Med J*. 2018;30(1).
32. Elechi HA, Rabasa AI, Muhammad FB, Garba MA, Abubakar GF, Umoru MA. Prevalence and pattern of malaria parasitaemia among under-five febrile children attending peadiatric outpatient clinic at University of Maiduguri teaching hospital, Maiduguri. *Niger J Paediatr*. 2015;42(4):319–324. doi:10.4314/njp.v42i4.7
33. Oladosu OO, Oyibo WA. Overdiagnosis and overtreatment of malaria in children that presented with fever in Lagos, Nigeria. *Int Scholar Res Notices*. 2013;2013:914675. doi:10.5402/2013/914675
34. Ezedudu CE, Ebenebe JC, Chukwuka JO, Ugochukwu EF, Amilo GI, Okorie OI. Malaria parasitaemia among febrile under-five children at Nnamdi Azikiwe University Teaching Hospital, Nnewi, South-East, Nigeria. *Niger J Med*. 2016;25(2):113–118.
35. Nwaneli EI, Eguonu I, Ebenebe JC, Osuorah CDI, Ofiaeli OC, Nri-Ezedi CA. Malaria prevalence and its sociodemographic determinants in febrile children - a hospital-based study in a developing community in South-East Nigeria. *J Prev Med Hyg*. 2020;61(2):173–180.
36. Odikamnoro OO, Oko NF, Uhuo CA, Okereke CN, Azi SO, Ogiji ED. Epidemiology of malaria among children aged 1 to 15 years in Southeast Nigeria. *J Public Health Epidemiol*. 2014;6(11):390–397. doi:10.5897/JPHE2014.0631
37. Olasehinde GI, Ojurongbe DO, Akinjogunla OJ, Egwari LO, Adeyeba AO. Prevalence of malaria and predisposing factors to antimalarial drug resistance in Southwestern Nigeria. *Res J Parasitol*. 2015;10(3):92–101. doi:10.3923/jp.2015.92.101
38. Ikeh EI, Teclaire NN. Prevalence of malaria parasitaemia and associated factors in febrile under-5 children seen in primary health care centers in Jos, North Central Nigeria. *Niger Postgrad Med J*. 2008;15(2):65–69.
39. Okoli C, Solomon M. Prevalence of hospital-based malaria among children in Jos, North Central Nigeria. *Br J Med Med Res*. 2014;4(17):3231–3237. doi:10.9734/BJMMR/2014/8068
40. Ahmad AE, Sheyin Z, Kabir M, Nuhu A, Garba MK, Nata'ala U. Prevalence of malaria infection in children attending emergency paediatrics unit of Usmanu Danfodiyo University Teaching hospital, Sokoto-Nigeria. *African J Infect Dis*. 2015;9(2):29–31. doi:10.4314/ajid.v9i2.2
41. Kwenti TE, Kwenti TD, Latz A, Njunda LA, Nkuo-Akenji T. Epidemiological and clinical profile of paediatric malaria: a cross sectional study performed on febrile children in five epidemiological strata of malaria in Cameroon. *BMC Infect Dis*. 2017;17(1):1–3. doi:10.1186/s12879-017-2587-2
42. Nyasa RB, Fotabe EL, Ndip RN. Trends in malaria prevalence and risk factors associated with the disease in Nkongho-mbeng; a typical rural setting in the equatorial rainforest of the South West Region of Cameroon. *PLoS One*. 2021;16(5):e0251380. doi:10.1371/journal.pone.0251380
43. Abossie A, Yohanes T, Nedu A, Tafesse W, Damitie M. Prevalence of malaria and associated risk factors among febrile children under five years: a cross-sectional study in Arba Minch Zuria District, South Ethiopia. *Infect Drug Resist*. 2020;13:363–372. doi:10.2147/IDR.S223873

44. Ahmed A, Mulatu K, Elfu B. Prevalence of malaria and associated factors among under-five children in Sherkole refugee camp, Benishangul-Gumuz region, Ethiopia. A cross-sectional study. *PLoS One*. 2021;16(2):e0246895. doi:10.1371/journal.pone.0246895
45. Orish VN, Sanyaolu AO, Francois M, et al. Malaria related deaths among children with manifestations of fever symptoms on admission in a secondary health care institution in Western Region of Ghana - a retrospective study. *Int J Trop Dis Health*. 2018;31(3):1–5. doi:10.9734/IJTDH/2018/42278
46. Chilanga E, Collin-Vézina D, MacIntosh H, Mitchell C, Cherney K. Prevalence and determinants of malaria infection among children of local farmers in Central Malawi. *Malar J*. 2020;19(1):308. doi:10.1186/s12936-020-03382-7
47. Habyarimana F, Ramroop S. Prevalence and risk factors associated with malaria among children aged six months to 14 years old in Rwanda: evidence from 2017 Rwanda Malaria Indicator Survey. *Int J Environ Res Public Health*. 2020;17(21):7975. doi:10.3390/ijerph17217975
48. Olasehinde GI, Ajay AA, Taiwo SO, Adekeye BT, Adeyeba OA. Prevalence and management of falciparium malaria among infants and children in Ota, Ogun State, Southwestern Nigeria. *African J Clin Experimen Microbiol*. 2010;11(3). doi:10.4314/ajcem.v11i3.57773
49. Tongun JB, Madison AB, Lado EG, et al. Prevalence and outcome of malaria among hospitalized children in Al Sabah Children Hospital, South Sudan. *South Sudan Med J*. 2020;13(5):178–181.
50. Onyiri N. Estimating malaria burden in Nigeria: a geostatistical modelling approach. *Geospat Health*. 2015;10:306. doi:10.4081/gh.2015.306
51. Adu-Gyasi D, Adams M, Amoako S, et al. Estimating malaria parasite density: assumed white blood cell count of 10,000/μL of blood is appropriate measure in Central Ghana. *Malar J*. 2012;11(1):1–6. doi:10.1186/1475-2875-11-238
52. Bilal J, Gasim G, Karsani A, Elbashir L, Adam I. Malaria parasite density estimation using actual and assumed white blood cells count in children in Eastern Sudan. *J Trop Pediatr*. 2016;62:171–175. doi:10.1093/tropej/fmv087
53. Awosolu OB, Yahaya ZS, Farah Haziqah MT, Simon-Oke IA, Fakunle C. A cross-sectional study of the prevalence, density, and risk factors associated with malaria transmission in urban communities of Ibadan, Southwestern Nigeria. *Heliyon*. 2021;7(1):e05975. doi:10.1016/j.heliyon.2021.e05975
54. Awosolu OB, Yahaya ZS, Farah Haziqah MT, Simon-Oke IA, Olanipekun IT, Oniya MO. Epidemiology of falciparum malaria among residents of some rural and periurban communities in Ekiti State, Southwestern Nigeria. *Trop Biomed*. 2021;38(1):14–21. doi:10.47665/tb.38.1.003
55. Ezeudu CE, Ebenebe JC, Ugochukwu EF, Chukwuka JO, Amilo GI, Okorie OI. Performance of a Histidine rich protein-2 rapid diagnostic test (RDT) against the standard microscopy in the diagnosis of malaria parasitemia among febrile under-five children at Nnewi. *Nig J Paediatr*. 2015;42:59–63. doi:10.4314/njp.v42i1.13
56. Umaru ML, Uyaiabasi GN. Prevalence of malaria in patients attending the General Hospital Makarfi, Markarfi Kaduna State, North-Western Nigeria. *Ame J Infect Dis Microbiol*. 2015;3:1–5. doi:10.12691/ajidm-3-1-1
57. Zgambo M, Mbakaya BC, Kalembo FW, Paul R. Prevalence and factors associated with malaria parasitaemia in children under the age of five years in Malawi: a comparison study of the 2012 and 2014 Malaria Indicator Surveys (MISs). *PLoS One*. 2017;12(4):e0175537. doi:10.1371/journal.pone.0175537
58. Dobbs KR, Dent AE. Plasmodium malaria and antimalarial antibodies in the first year of life. *Parasitology*. 2016;143(2):129–138. doi:10.1017/S0031182015001626
59. WHO/UNICEF. *Africa Malaria Report 2003*. Geneva: WHO; 2003:17.
60. Ben-Edet AE, Lesi FE, Mage AG, Grange AO. Diagnosis of fal¬ciparum malaria in children using the immunochromatographic technique. *Nig J Paediatr*. 2004;31:71–78. doi:10.4314/njp.v31i3.12105
61. Gebretsadik D, Feleke DG, Fiseha M. Eight-year trend analysis of malaria prevalence in Kombolcha, South Wollo, north-central Ethiopia: a retrospective study. *Parasit Vectors*. 2018;11(1):55. doi:10.1186/s13071-018-2654-6
62. Escobar DF, Lucchi NW, Abdallah R. Molecular and epidemiological characterization of imported malaria cases in Chile. *Malar J*. 2020;19:289. doi:10.1186/s12936-020-03353-y
63. Nwaorgu OC, Orajaka BN. Prevalence of malaria among children 1–10 years old in communities in awka north local government area, Anambra State South East Nigeria. *African Res Rev*. 2011;5 (5):264–281. doi:10.4314/afrrev.v5i5.21
64. Kimbi HK, Keka FC, Nyabeyeu HN, Ajeagah HU, Tonga CF. An update of asymptomatic falciparum malaria in school children in Muea, Southwest Cameroon. *J Bacteriol Parasitol*. 2012;3:154. doi:10.4172/2155-9597.1000154
65. Snyman K, Mwangwa F, Bigira V, et al. Poor housing construction associated with increased malaria incidence in a cohort of young Ugandan children. *Am J Trop Med Hyg*. 2015;92(6):1207–1213. doi:10.4269/ajtmh.14-0828
66. Njau JD, Stephenson R, Menon MP, et al. Investigating the important correlates of maternal education and childhood malaria infections. *Am J Trop Med Hyg*. 2014;91(3):509–519. doi:10.4269/ajtmh.13-0713
67. Ma C, Claude KM, Kibendelwa ZT, Brooks H, Zheng X, Hawkes M. Is maternal education a social vaccine for childhood malaria infection? A cross-sectional study from war-torn Democratic Republic of Congo. *Pathog Glob Health*. 2017;111(2):98–106. doi:10.1080/20477724.2017.1288971
68. Loha E, Lunde TM, Lindtjørn B, Bejon P. Effect of bednets and indoor residual spraying on spatio-temporal clustering of malaria in a village in south Ethiopia: a longitudinal study. *PLoS One*. 2012;7 (10):e47354. doi:10.1371/journal.pone.0047354
69. Kepha S, Nikolay B, Nuwaha F, et al. Plasmodium falciparum parasitaemia and clinical malaria among school children living in a high transmission setting in western Kenya. *Malar J*. 2016;15:157. doi:10.1186/s12936-016-1176-y
70. Dida GO, Anyona DN, Abuom PO, et al. Spatial distribution and habitat characterization of mosquito species during the dry season along the Mara River and its tributaries, in Kenya and Tanzania. *Infect Dis Poverty*. 2018;7(1):2. doi:10.1186/s40249-017-0385-0
71. Getachew D, Balkew M, Tekie H. Anopheles larval species composition and characterization of breeding habitats in two localities in the Ghibe River Basin, southwestern Ethiopia. *Malar J*. 2020;19(1):65. doi:10.1186/s12936-020-3145-8
72. Hawaria D, Demissew A, Kibret S, Lee MC, Yewhalaw D, Yan G. Effects of environmental modification on the diversity and positivity of anopheline mosquito aquatic habitats at Arjo-Dedessa irrigation development site, Southwest Ethiopia. *Infect Dis Poverty*. 2020;9 (1):9. doi:10.1186/s40249-019-0620-y
73. Muriuki JM, Kitala P, Muchemi G, Njeru I, Karanja J, Bett B. A comparison of malaria prevalence, control and management strategies in irrigated and non-irrigated areas in eastern Kenya. *Malar J*. 2016;15(1):402. doi:10.1186/s12936-016-1458-4
74. Rumisha SF, Shayo EH, Mboera LEG. Spatio-temporal prevalence of malaria and anaemia in relation to agro-ecosystems in Mvomero district, Tanzania. *Malar J*. 2019;18(1):228. doi:10.1186/s12936-019-2859-y
75. Panigrahi BK, Mahapatra N. Anopheline ecology and malaria transmission during the construction of an irrigation canal in an endemic district of Odisha, India. *J Vector Borne Dis*. 2013;50 (4):248–257.
76. Yang GJ, Liu Y, Shang LY, et al. From Plasmodium vivax outbreak to elimination: lessons learnt from a retrospective analysis of data from Guantang. *Malar J*. 2020;19(1):427. doi:10.1186/s12936-020-03501-4

77. Gahutu JB, Steininger C, Shyirambere C, et al. Prevalence and risk factors of malaria among children in southern highland Rwanda. *Malar J*. 2011;10:134. doi:10.1186/1475-2875-10-134
78. Okebe J, Mwesigwa J, Kama EL, et al. A comparative case control study of the determinants of clinical malaria in The Gambia. *Malar J*. 2014;13:306. doi:10.1186/1475-2875-13-306
79. Winskill P, Rowland M, Mtove G, Malima RC, Kirby MJ. Malaria risk factors in north-east Tanzania. *Malar J*. 2011;10:98. doi:10.1186/1475-2875-10-98
80. Ntonifor NH, Veyufambom S. Assessing the effective use of mosquito nets in the prevention of malaria in some parts of Mezam division, Northwest Region Cameroon. *Malar J*. 2016;15(1):390. doi:10.1186/s12936-016-1419-y
81. West PA, Protopopoff N, Rowland M, et al. Malaria risk factors in North West Tanzania: the effect of spraying, nets and wealth. *PLoS One*. 2013;8(6):e65787. doi:10.1371/journal.pone.0065787
82. Wotodjo AN, Doucoure S, Diagne N, et al. Another challenge in malaria elimination efforts: the increase of malaria among adults after the implementation of long-lasting insecticide-treated nets (LLINs) in Dielmo, Senegal. *Malar J*. 2018;17(1):384. doi:10.1186/s12936-018-2536-6
83. Mpimbaza A, Ndeezi G, Katahoire A, Rosenthal PJ, Karamagi C. Demographic, socioeconomic, and geographic factors leading to severe malaria and delayed care seeking in Ugandan children: a case-control study. *Am J Trop Med Hyg*. 2017;97(5):1513–1523. doi:10.4269/ajtmh.17-0056
84. Ouédraogo M, Samadoulougou S, Rouamba T, et al. Spatial distribution and determinants of asymptomatic malaria risk among children under 5 years in 24 districts in Burkina Faso. *Malar J*. 2018;17(1):460. doi:10.1186/s12936-018-2606-9