The fight against malaria in Edo-North: identifying risk factors for effective control (#101253)

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The fight against malaria in Edo-North: identifying risk factors for effective control

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Background Nigeria continues to face a significant burden of malaria, despite national control efforts. This study investigated malaria epidemiology in Edo-North, Nigeria, a region within the equatorial rainforest belt that has lacked prior research on malaria prevalence.

Methodology The study employed a household survey 605 participants, and blood samples were drawn from veins and tested for malaria parasites. Researchers then investigated potential associations between malaria infection and prevalence factors such as mosquito net use, antimalarial medication, and various socio-demographic variables. The study also investigates the trends in malaria disease rates over time. Statistical analysis was performed using R software version 4.2.3. Results were considered statistically significant if the p-value was less than 0.05.

Results Findings revealed a malaria prevalence of 15.54% and identified significant risk factors including age, marital status, education level, occupation, sex, housing type, household size, and toilet facilities. The study also found a high average parasite density, with an overall geometric mean of approximately 5,146 parasites per microliter of blood. Despite 91.51% of participants owning long-lasting insecticidal nets (LLINs), consistent use remained low. Encouragingly, hospital data indicated a downward trend in malaria prevalence between 2020 and 2023. This decline potentially reflects recent improvements in malaria prevention programs, possibly aligned with the WHO's 2030 Agenda for malaria elimination, which Nigeria has adopted.

Conclusions The findings from this study can inform the development of more effective malaria control measures in Edo-North.

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Abstract

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Introduction

Malaria, caused by Plasmodium parasites is a potentially fatal disease that humans contract by the bite of an infected female Anopheles mosquito. Malaria is still a serious global public health issue. Though it is preventable and curable; nearly 95% of cases and fatalities occur in Nigeria, which is the country with the highest economic burden from the disease. Four major Plasmodium species (Plasmodium malariae, Plasmodium falciparum, Plasmodium vivax, and Plasmodium ovale) are responsible for almost 200 million cases reported each year in African countries [1]. Malaria requires substantial personal and governmental financial resources for prevention and treatment, in addition to its high rates of morbidity and mortality throughout the African continent [2, 3]. It consequently has an impact on the wealth and health of the nation and is a primary contributor to poverty in many African nations [3, 4]. The Global Technical Strategy (GTS) for Malaria 2016–2030, a global drive to end malaria by 2030 with precise targets and milestones, was created by the World Health Organization (WHO) in response to this threat [5]. The WHO recommends that nations adopt context-specific interventions that prioritize early diagnosis, timely treatment, vector control, and elimination of vectors in accordance with this strict strategy [1, 5].

Many African nations are far from reaching the GTS target, regardless of their best efforts [6–8]. The fact that adults exposed to Plasmodium species constitute a serious threat to attempts to control and eradicate malaria, they are frequently disregarded in these nations in favor of pregnant women and children under five. In order to effectively accomplish WHO's objectives, new approaches must be devised to reach all populations, including adults infected with Plasmodium spp., and existing programs must be enhanced.In highly endemic environments like Sub-Saharan Africa, adult Plasmodium species infections constitute a primarily composite challenge for the pathogenicity and epidemiology of malaria [9]. Actually, more exposure to this species of Plasmodium has resulted in the development of anti-parasitic immunity, which has also reduced blood parasite levels, prevented symptoms, and offered notable protection against acute malaria and mortality associated with it [10, 11]. Adults naturally accumulate more infections over time, and the majority of them acquire immunity to the malaria parasite, unless they have an underlying medical condition like pregnancy or HIV/AIDS [10].

Acquired immunity, however, is still only partially effective at preventing infections. Adults who are semi-immune can still have Plasmodium species infections, although exhibiting few or no symptoms and having the parasites in their blood for extended periods of time [11–13]. Community surveys conducted in sub-Saharan Africa reveal Plasmodium species prevalence estimates that are both over and below 5% amongst asymptomatic persons [14– 19]. Different current vector species, different intervention coverage, and broad ecological changes (such as altitude temperature, and seasons) are likely to be associated with regional variations. Long-term consequences, including anemia, cognitive decline, and recurring symptomatic episodes, may arise from persistent infections with Plasmodium spp., despite the fact that these infections are frequently asymptomatic [12, 15]. In the end, they would significantly raise healthcare expenses, decrease productivity, and put more financial strain on African communities already dealing with other social problems. Furthermore, typical diagnostic methods, such as conventional microscopy and rapid diagnostic tests (RDTs), are greatly hampered by the fact that infected adults in endemic areas frequently have low blood levels of parasites [8, 12, 13].

Malaria in Nigeria

Variations in socio-demographic, environmental, and climatic factors may account for the variation in the prevalence rate of malaria infection among young people, even within a single country [16, 17]. Past research has shown malaria prevalence rates in Nigeria of 66.7% [18], 64.0% [19], and 58.0% [20]. Urban and suburban centers have comprehensively recorded the effects of socio-demographic variables or factors, including gender, age, occupation, and level of education, on human exposure and treatment, as well as environmental variables like rainfall, humidity, and temperature, may facilitate the rapid growth of mosquitos' vectors [16, 20]. The spread of malaria is more common in Africa's rural settings than in its urban ones, which may be caused by the region's increased vector density, subpar housing conditions, and inadequate drainage infrastructure [17, 21]. Though, not in the transmission of malaria infection, hematopathological profile may influence the clinical manifestation of malaria [16, 22]. The person's packed cell volume (PCV), ABO blood type, and electrophoresis of blood hemoglobin pattern may all be connected to these alterations [16, 22]. In regions where malaria is widespread, anemia is typically a symptom of a parasite illness, and P. falciparum is a major cause of anemia in children [16, 23].

Innate characteristics serve as a protective factor against infections, and the development of immune system response that the host acquires is what defines resistance to malaria. ABO blood type, sickle cell feature (HbAS), with sickle cell illness (HbSS) are a few examples of these intrinsic characteristics [16, 24]. There hasn't been enough research done on how teenagers' genetic makeup and ABO blood type relate to their vulnerability to malaria [16, 33, 23]. Although numerous research on the relationship between hemoglobin genotype and blood grouping by ABO and malaria infection have been documented in Nigerian cities, the majority of these studies lay emphasis on pregnant mothers and children under five years, who are regarded as the those most at risk to malaria [16, 17, 22]. An increasing amount of research indicates that children and teenagers attending school may potentially be susceptible to malaria [22, 23]. Furthermore, the prime age of clinical bouts of malaria is moving from young infants and adolescents to children and teenagers due to a drop in spread and exposure in some locations [22, 23]. Data on P. falciparum infection prevalence and related variables among teenage age groups in rural Nigeria are desperately needed to be able to modify the prevention and control of malaria strategies. For the purpose of malaria prevention and control strategies, decision-makers must identify the major risk factors for malaria infection.

Currently, the most common approaches for managing malaria vectors and related malaria transmission are indoor residual spraying (IRS) and insecticide-treated nets (ITNs), both of which have been shown to decrease malaria [4, 5]. Nonetheless, the primary and most encouraging element of the specific vector control and management practice are long-lasting insecticide-treated nets (LLINs) on sleeping beds, which the Nigerian Ministry of Health uses to combat the disease and its vector. Therefore, the goal of this study was to ascertain the malaria risk factors and trend in these populations. The majority of the population of Edo-North is rural, with a focus on subsistence and commercial farming. The area is located in Nigeria's equatorial rain forest. Currently, Edo-North is the only Senatorial District without a University Teaching Hospital, and Akoko-Edo Local Government Area is the Largest Local Government Area in Edo State. Taking socio-demographic parameters into consideration, this study examined the associated variables in a rural community in Edo-North, Edo State, South-South, Nigeria, in order to determine the frequency of malaria infection among individuals in this geographic area. When combined with the tropical rain forests, diverse topography, which includes mountains, lowlands, and sloping streams within of settlement, which serves as a breeding site for the malaria vector, this would likely result in a high breeding ground for malaria vector.

Survey methodology

Study Location

This study was carried out in Edo-North, a Senatorial District in Edo State, South-South Region of Nigeria, Figure 1. The six local government districts that make up the Edo North senatorial district in Edo State are Akoko-Edo, Etsako-West, Etsako-Central, Etsako-East, Owan-East and Owan-West (See Figure 1 for map). There are hills all around, a few rivers that cut through towns and villages, and a generally uneven topography. Towns and villages have numerous smaller streams, each at various locations. Common rain forest vegetation can be found in Edo-North, where residents' homes are surrounded by plantains, cashews, bananas, palm trees, and cocoa. Two seasons (Rainy and the Dry) are experienced in the area. The rainy season begins in March, and then ends in October; the dry season normally lasts from November to February.

Study design

There were two parts to the study: a cross-sectional household survey conducted in the selected communities that took place in September 2023, when most people had returned from their farms, and involved meeting participants at their homes in cool evening to conduct personal interviews. Blood samples were taken for microscopy and sent for testing at the Irrua Specialists teaching hospital in Irrua, Edo State. In order to determine trends in the prevalence of malaria in Edo-North, data on hospital prevalence from 2021 to 2023 were collected retrospectively from Edo-North's Public Health Centers as part of the study's second arm.

Exclusion Criteria for the study

Individuals who declined to provide their consent, those who did not reside in Edo-North, those suffering from mental health issues, and those receiving anti-malarial treatment or those who has received anti-malarial treatment two weeks before the commencement of this study were also not included in the study.

Determination of Minimum Sample size

The Swinscow Formula was used to determine the minimum sample size (n).

$$n = \frac{Z^2 \times \text{Prevalence from asimilar study} \times (1 - \text{Prevalence from similar study})}{\text{Level of Precision}^2}$$

$$n = \frac{Z^2 P(1 - P)}{d^2} = 384.6$$

where n is the minimum sample size for this study, Z is the confidence level, d is set to be 0.05, Z is 1.96 and P is 0.5.

Using the minimum sample size formula resulted in approximately 385. A total number of 605 people in all were sampled, including men and women of all ages who gave their consent.

Ethical Approval and Participant Consent

This research received ethical approval from the Health Research Ethics Committee, ISTH (Ref: 51/23). To ensure informed consent, the study objectives were explained clearly to each participant individually. For those with literacy limitations, the questionnaires were read aloud and any questions clarified to maintain consistency in responses. Participation was entirely voluntary, and participants were informed of their right to withdraw at any time. Written informed consent, obtained through signatures or thumbprints, was collected from all participants before the study began. Confidentiality and privacy of all participants were strictly maintained throughout the research. There were no costs associated with participation in the study.

Data Collection and Instrumentation Process

This study used a semi-structured questionnaire that was developed. Before being administered to the entire study population, it was pretested in Auchi, Igarra, Ibillo, Ozala, Otuo, Sabongida-Ora, Afuze, Fuga, Jattu, Agenebode and Okpella to gather data on demographics (age, sex, occupation, marital status, and educational status) and the socio-demographic features (house type, households' size, type of surroundings, type of toilet, water sources and water storage methods), and malaria prevention (owners' and users' use of and exposure to indoor residual spray (IRS) and long-lasting insecticide nets (LLIN).

Sample collection

A digital clinical thermometer was used to take the participants' body temperatures; the thumb cleaned sterile disposable cotton wool and "lancet" is used to prick the finger in order to collect blood for microscopic analysis in the laboratory. Laboratory records of General Hospitals and Public Health Centers were used to get data on trends in hospital prevalence of malaria in Edo-North.

Laboratory analysis

After being air-dried, the thick blood films were taken to Irrua Specialist Teaching Hospital and stained for fifteen to thirty minutes with 5% Giemsa. They were cleaned, dried by air, and examined under an optical microscope with an X-100 objective. After examining over 100 fields with X-100 high power microscopy and finding no malaria parasite, a thick blood smear was considered negative. By comparing the number of parasites on positive slides to 200 white blood cells (WBC), they computed the parasites/µl of blood using the assumption that there are 8000 leucocytes per microliter.

Statistical analyses

The data collected was assessed, cleaned, and analyzed with the aid R4.3.2 software. The mean ± standard deviation was used to express the age. Malaria prevalence among participants was obtained using frequencies and percentages. The findings of the Hosmer-Lemeshow test, which was used to test the data's goodness of fit or normality, reveal a non-normal distribution. Kruskal-Wallis (H) and Mann-Whitney (W) tests were used to analyze the parasite load. The prevalence and factors influencing the parasite load were determined using the binary logistic regression model and Chi-square. Multivariate logistic regression study model variables were selected based on their significance at P-value < 0.05. Odd ratios were computed along with 95% confidence ranges. p-values less than 0.05 were regarded as statistically significant.

Results

Prevalence of malaria in Edo-North

Table 1 shows that out of the 605 blood samples tested, 94 were microscopically malaria parasites positive, giving a total prevalence of malaria in Edo-North of 15.54%. The percentage of persons who tested positive for malaria parasite but asymptomatic to malaria infection is 13.06% while that of persons with symptomatic malaria infection who also tested positive for malaria parasite is 2.48%. The percentage of persons observed to be febrile but was not as a result of malaria parasite was 6.45%. Approximately 78.02% of the study participants were apparently free of malaria parasites. Hence, from Table 1, the malaria infection prevalence in Edo-North was statistically significant.

The Relationship Between Malaria Prevalence and Demographic Factors

Table 2 shows that the malaria prevalence in Edo-North was not significantly correlated with, location and local government area, while there was significant relationship between prevalence of malaria and age, marital status, age, education, occupation, sex, type of house, household size and type of toilet at 5% level of significance. Males were found to have a higher prevalence of malaria (61.7%) than females (38.3%). In addition, malaria infection was more prevalent among infants (44.7%) than in all other age group, in rural dwellers (77.7%) than in urban dwellers, in people with no education (29.8%) than in people with an education category, in students and pupils (27.7%) than in people with an occupation category, in unmarried people (45.7%) than in the married category, in people living in mud houses (54.3%) than in cement or modern houses, in households with more than ten people (51.1%) than in other household sizes, and in those using pit latrine systems (48.9%) than in other categories of toilet type.

Logistic regression analysis was then performed on the significant variables, using the response variable (malaria prevalence) and the explanatory variables (socio-demographic factors). The results of the analysis included the following: infants (COR = 18.54), children (COR = 7.73), teenagers (COR = 7.21), urban dwellers (COR = 0.56), Etsako-Central local government area (COR = 0.440), persons with secondary education (COR = 0.121), persons with polytechnic education (COR = 0.080), persons with university education (COR = 0.154), single persons (COR = 0.116), married persons (COR = 0.120), clay house dwellers (COR = 4.756), 1- 5 household size (COR = 0.027), 6-10 household size (COR = 0.045), water system toilet users (COR = 0.055) and pit latrine toilet users (COR = 0.568) were statistically associated with highest prevalence of malaria infection among Edo North residents at 5% level of significance. None of the socio-demographic characteristics were statistically significant risk factors for malaria acquisition among people living in Edo-North after multivariate logistic regression analysis.

Environmental and Behavioral Characteristics of Residents and Malaria Prevalence

Table 3 shows that the percentage prevalence of malaria was significantly higher in bushy areas (80.9%) compared to non-bushy areas (19.1%), in houses without mosquito nets (63.8%) compared to those with nets (39.4%), and in houses not near streams and rivers (60.6%) compared to those near streams and rivers (39.4%). Similarly, the percentage prevalence of malaria was significantly higher in houses with asbestos (27.1%) than in any other ceiling type, and the percentage of malaria cases was significantly higher in people who stored their water in open containers (69.6%) than in others in that category.

Under the bivariate analysis, residents living near bushy areas (COR = 2.563), areas with streams and rivers (COR = 18.863), having window mosquito nets (COR = 0.393), PVC ceiling (COR = 0.334), POP ceiling (COR = 0.284), plywood or plastic ceiling (COR = 0.423); no ceiling (COR = 0.357), living dam or tap source of water (COR = 4.192), closed water storage containers (COR = 0.154), and open water storage containers (COR = 0.183) were all significantly associated with the malaria prevalence. The results of multivariate logistic regression analysis indicated that the only people who were significantly at risk for malaria prevalence in Edo-North were those who stored water in open containers (COR = 0.058).

Malaria Prevalence and Management Factors in Human Populations

Table 4 shows that those who had previously had malaria fever had a significantly higher prevalence of malaria than those who had never had it. The highest prevalence of malaria was seen in those who had had malaria in the five months prior to the survey. The majority of people (40.4%) usually receive treatment for malaria from health centers, followed by medical hospitals (22.3%), pharmacies or chemists (20.2%) and herbal/traditional medicines (16.7%). In Edo North, the most commonly used drugs to treat malaria are artemether (56.4%), chloroquine or quinine (7.4%), and herbs known locally as "agbo" (16.7%).

Geometric Mean Malaria Parasite Density in Relation to Demographic Factors

From Table 5, the average geometric mean parasite density (GMPD) for malaria was approximately 5,146 parasites/µL of blood. At $p = 0.002$, the GMPD of men (7,765.48 parasites/µL) was higher than that of women (4,786.16 parasites/µL). Similarly, farmers had a higher GMPD of malaria (6,654.43/µL) than people in other occupations or professions ($p < 0.001$). When marital status was taken into consideration, single persons had a higher GMPD (6542.32 parasites/µL) than other groups at the significance level of 5%.

From Figure 2, LLIN coverage in Edo North is 76.53%, with approximately 463 of the 605 respondents reporting having LLINs at home. The majority (61.98%) of people with LLINs rarely sleep under them on a daily basis, while 27.50% sleep under them frequently and 10.41% do not use them. From Figure 3, with 8876.03 parasites/µL, residents of Owan-East had the highest geometric mean malaria parasite density, followed by Owan-West (656.65 parasites/µL), Etsako-Central (6545.23 parasites/µL), Etsako-East (6087.65 parasites/µL), Etsako-West (5876.31 parasites/µL) and Akoko Edo (5345.87 parasites/µL). Compared to other age groups, infants had the highest malaria parasite density (5812.11 parasites/µL). Figure 3 shows that residents who have lived in their locations for over 15 years had lower malaria parasite density load in their blood. Records from health facilities and hospitals show that between 2020 and 2023, the prevalence of malaria among residents of Edo North is on a downward trend.

Discussion

In Edo-North, the overall prevalence of malaria fever was 15.54%. According to the malaria endemicity classification [10], Edo-North may fall under the mesoendemic stratum, which is characterized by a high prevalence of Plasmodium falciparum parasites in the infant age group (pfpr2-10) during the rainy season and a low prevalence during the dry season. Infants were found to have a higher incidence of malaria fever than other age groups (18.54%). The prevalence of malaria among the age groups seen here is consistent with [6, 11].

Men had a higher prevalence of malaria (61.7%) than women (38.2%), with a significant gender difference. This may be because men are more likely than women to be exposed to mosquito vectors as a result of their outdoor work as family breadwinners, such as farming and running open workshops. Similarly, the prevalence of malaria was found to be higher among pupils/students and farmers compared to other occupational groups. This high malaria prevalence among these groups could also be traced to their frequent daily exposure to the malaria vectors, especially in rural settings. Compared to those in the married status category, single (or unmarried) people were also found to have a significantly ($p = 0.001$) higher prevalence of malaria. Living in mud houses was more prevalent than living in cement buildings, and using a pit latrine and living in a household of more than ten people were also associated with an increased risk of malaria.

A total of 5,146 parasites/µL blood was the GMPD of malaria in the Edo North population. Observations across all age groups showed that infants were highly parasitized (Figure 2). This may be due to the fact that older people develop immunity more quickly than younger people because they have been exposed to the malaria parasite multiple times [25]. The GMPD was found to be higher for men than for women, for business people than for other occupational groups, and for single people than for married people, according to sex, occupation and marital status. The results of some research suggest that marriage may support a healthy lifestyle in a number of ways, which may explain the higher parasite burden in single people compared to married people [26].

A significant association was observed between the length of stay in Edo-North and parasite density. Individuals who had lived in their current area for less than 15 years were found to have higher parasite loads than those who had reside there for more than 15 years (Figure 3). This is supported by the results of [7, 27]. The development of immunity to the parasite may have occurred as a result of people staying longer. It was also found that the presence of grasses, streams and rivers near the houses had a significant effect on both the GMPD and the prevalence of malaria. Although the use of LLINs and insecticide-treated mosquitoes has been shown to reduce malaria infections, the study found that the use of these preventatives is still quite low. While the study found that a significant proportion of the population has LLINs, they are not always used every night and the level of provision of LLINs by government is not statistically significant (Figure 2).

From the logistic regression analysis, living in a bush or water-prone area, male sex, children, rural settler, student, farmer, single, mud-house dweller, pit-latrine user and households with more than 10 members were significantly associated with malaria prevalence among Edo North residents.

According to medical records, the prevalence of malaria among people in Edo North declined between 2020 and 2023 (Figure 3). This could be the result of recent improvements in malaria prevention services, in line with the WHO 2030 Agenda, which has been prioritized by the Nigerian government.

Conclusions

In conclusion, the low prevalence of 15.54% for malaria in Edo-North, Edo State, South-South region of Nigeria indicates a declining prevalence. Proximity to bush or watery environment, male sex, children, school children, farmers, single persons, mud houses, pit latrines and households with more than 10 members are the major risk factors for the prevalence of the disease [28]. Although many people own LLINs, they are rarely used. The study found that for effective malaria control and intervention, government and non-government organizations need to focus on key risk factors for malaria prevalence in Edo North, Edo State and Nigeria as a whole. The findings of this study could help stakeholders make appropriate decisions for malaria control and prevention.

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Declarations

Ethical Approval and Participant Consent

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Consent for publication

Permission to publish the findings was verbally seek from the participant through various heads of the study communities after explaining the benefits of publishing the work to them, and they consented to the publication.

Availability of data and materials

The datasets generated and analyzed during this study will be made available to the publisher only on request.

Competing interests

All authors declare no competing interest as per this study.

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Table 1(on next page)

The Prevalence of malaria

The Prevalence of malaria in Edo-North

Status	Symptoms n(%)	No Symptoms n(%)	Total	Odd Ratio	95% CI	p-value
Positive	15 (2.48)	79 (13.06)	94 (15.54)	2.2980	[1.2100, 4.3641]	0.0110
Negative	39 (6.44)	472 (78.01)	511(84.46)			
Total	54	551	605			

Table 1: Prevalence of malaria in Edo-North

Table 2(on next page)

The Relationship Between Malaria Prevalence and Demographic Factors

The Relationship Between Malaria Prevalence and Demographic Factors

Variables	Category	N = 605	n = 94	Chi-square	COR (95% CI)	AOR
		Frequency(%)	Prevalence (%)		p-value	
Gender	**Female**	281(46.4)	36(38.3)	χ^2= 3.00	1.00	
	Male	324(53.6)	58(61.7)		1.49 (0.95, 2.33)	1.229E19
Age-Group(years)	**Infants(0<4)**	19(3.1)	9(9.6)	χ2= 59.93*	18.54 (6.56, 52.40)*	3.833E23
	Children(5–12)	154(25.5)	42(44.7)		7.73 (4.12, 14.47)*	1.207E32
	Teenagers(>13–19)	108(17.9)	28(29.8)		7.21 (3.68, 14.14)*	2.001E32
	Adults(>20)	324(53.6)	15(16.0)		1.00*	
Mean ± S.DAge	**26.40±20.16**					
Location	**Urban**	194(32.1)	21(22.3)	χ2= 2.92	0.56 (0.34, 0.94)*	0.133
	Rural	411(67.9)	73(77.7)		1.00	
Local Government Area	**Akoko-Edo**	110(18.2)	23(24.5)	χ2 = 6.96	1.00	
	Etsako-Central	96(15.9)	10(10.6)		0.440 (0.198, 0.979)*	0.244
	Etsako-East	93(15.4)	11 (11.7)		0.507 (0.233, 1.106)	0.024
	Etsako-West	98(16.2)	19(20.2)		0.910 (0.461, 1.795)	0.062
	Owan-East	103(17.0)	17(18.1)		0.748 (0.373, 1.497)	0.000
	Owan-West	105(17.4)	14(14.9)		0.582 (0.281, 1.203)	0.000
Educational level	**No Education**	90 (14.9)	28(29.8)	χ2 = 25.23*	0.613 (0.269, 1.394)	1.420E6
	Primary	63(10.4)	21(22.3)		0.679 (0.285, 1.614)	0.000
	Secondary	208(34.4)	17(18.1)		0.121 (0.052, 0.283)	0.000
	College of Education	33(5.5)	14(14.9)		1.00	
	Polytechnic	162(26.8)	9(9.6)		0.080 (0.030, 0.209)*	0.076
	University	49(8.1)	5(5.3)		0.154 (0.049, 0.489)*	0.741
Occupation	**Business**	41(6.8)	11(11.7)	χ2 = 49.63*	2.591 (1.078, 6.230)*	0.018
	Farmer	208(34.4)	22(23.4)		0.836 (0.416, 1.680)	0.002
	Civil Servant	36(6.0)	9(9.6)		2.356 (0.931, 5.959)	1.809E29

	Artisans	121(20.0)	15(16.0)		1.00	
	Pupils/ Student	141(23.3)	26(27.7)		1.598 (0.803, 3.179)	9.076E5
	Unemployed	58(9.6)	11(11.7)		1.654 (0.707, 3.871)	0.042
Marital status	**Single**	361(59.7)	43(45.7)	χ2 = 25.23*	0.116 (0.037, 0.361)*	0.385
	Married	204(33.7)	25 (26.6)		0.120 (0.037, 0.385)*	2.128
	Widow/Widower	27(4.5)	19(20.2)		2.036 (0.518, 7.995)	0.313
	Divorced/Single Parent	13(2.1)	7(7.4)		1.00	
Religion	**Christian**	397(65.6)		χ2 = 56.45*		
	Muslim	194(32.2)				
	Traditional	9(1.5)				
	No Religion	5(0.8)				
House type	**Modern/Cement**	452(74.7)	43 (45.7)	χ2 = 43.90*	1.00	
	Mud	153(25.3)	51 (54.3)		4.756 (3.002, 7.534)*	9.353
Household size	**1–5**	296(48.9)	20 (21.3)	χ2 =135.83*	0.027 (0.013, 0.055)*	0.001
	6-10	243(40.2)	26 (27.7)		0.045 (0.023, 0.088)*	0.003
	>10	66(10.9)	48 (51.1)		1.00	
Toilet type	**Water System**	366(60.5)	14 (14.9)	χ2 = 84.40*	0.055 (0.027, 0.110)*	0.000
	Pit Latrine	158(26.1)	46 (48.9)		0.568 (0.325, 0.993)*	3.080
	Bush toilet	81(13.4)	34 (36.2)		1.00	

***Statistically significant association at $p < 0.05$, χ2 = Pearson's Chi square test, S.D = Standard Deviation, COR = Crude Odds Ratio, AOR = Adjusted Odds Ratio.**

Table 3(on next page)

Environmental and Behavioral Characteristics of Residents and Malaria Prevalence

The Environmental and Behavioral Characteristics of Residents and Malaria Prevalence

Variable	Category	N = 605 Frequency (%)	n = 94 Prevalence (%)	Chi-square	COR (95% CI) p-value	AOR
Do you use insecticides spray?	Yes	417(68.9)	63(67.0)	χ2= 0.19	0.901 (0.564, 1.441)	0.120
	No	188(31.1)	31(33.0)		1.00	
Presence of bushes in surroundings	Yes	394(65.1)	76(80.9)	χ2= 26.09*	2.563 (1.487, 4.415)*	1.130E8
	No	211(34.9)	18(19.1)		1.00	
Presence of stream and rivers around home	Yes	54(8.9)	37(39.4)	χ2= 88.83*	18.863 (9.982, 35.643)*	1.531E26
	No	551(91.1)	57(60.6)		1.00	
Use of window-nets	Yes	478(79.0)	60(63.8)	χ2= 14.17*	0.393 (0.244, 0.633)*	0.000
	No	127(21.0)	34(36.2)		1.00	
Types of Ceiling	PVC	174(28.8)	19(20.2)	χ2=20.58*	0.334 (0.186, 0.602)*	0.000
	POP	53(8.8)	5(5.3)		0.284 (0.106, 0.760)*	0.000
	Asbestos	164(27.1)	44(46.8)		1.00	
	Plywood/ Plastic	67(11.1)	9(9.6)		0.423 (0.194, 0.926)*	0.925
	No ceiling	147(24.3)	17(18.1)		0.357 (0.193, 0.658)*	0.362
Source of water	Bore hole	123(20.3)	14 (14.9)	χ2=6.98	1.00	
	River/Stre am	294(48.6)	30(31.9)		0.885 (0.452, 1.733)	6.776E7
	Rain	108 (17.9)	22(23.4)		1.992 (0.962m 4,122)	6.425E17
	Dam/Tap	80(13.2)	28(29.8)		4.192 (2.937m 8,627)*	9.667E8
Types of water storage containers	Closed	172(28.4)	23(24.5)	χ2=8.38*	0.154 (0.046, 0.520)*	1.016
	Open	421(69.6)	65(69.1)		0.183 (0.057, 0.564)*	0.058 *
	Both	12(2.0)	6(6.4)		1.00	

***Statistically significant association at $p < 0.05$, χ2 = Pearson's Chi square test, COR = Crude Odds Ratio, AOR = Adjusted Odds Ratio.**

Table 3: Environmental and Behavioral Characteristics of Residents and Malaria Prevalence

Table 4(on next page)

Malaria Prevalence and Management Factors in Human Populations

The Malaria Prevalence and Management Factors in Human Populations

Variable	Category	Frequency (%)	Prevalence (%)	Chi-square
Have you had malaria before?	Yes	578 (95.5)	82(87.2)	$\chi 2=13.48$*
	No	27 (4.5)	12(12.8)	
If yes, when last were you sick of malaria?	1-5monthago	243 (40.2)	67(71.3)	$\chi 2=52.67$*
	6-12monthsago	324 (53.6)	19(20.2)	
	Over 1 year ago	38 (6.3)	8(8.5)	
Where did you take treatment?	Medical Hospital	91 (15.0)	21(22.3)	$\chi 2=27.35$*
	Health Center	185 (30.6)	38(40.4)	
	Pharmacy/Chemist Shop	228 (37.7)	19(20.2)	
	Tradomedical/Herbs	101 (16.7)	16(17.0)	
What drugs did you use in treating malaria?	Athermeter Family	304 (50.2)	53(56.4)	$\chi 2=6.27$*
	Chloroquine/Quinine	45 (7.4)	11 (11.7)	
	Use of Herbs (Agbo)	101 (16.7)	12 (12.8)	
	Don’t know	155 (25.6)	18(19.1)	

***Statistically significant association at $p < 0.05$, $\chi 2$ = Pearson’s Chi square test.**

Table 4: Malaria Prevalence and Management Factors in Human Populations

Table 5(on next page)

Geometric Mean Malaria Parasite Density in Relation to Demographic Factors

The Geometric Mean Malaria Parasite Density in Relation to Demographic Factors

Characteristics	Category	Number examined	GMPD (Parasites/µL)	Statistics
Overall GMPD			**5146**	
Sex	Female	281	5786.66	W= 55.0*
	Male	324	7765.48	
Occupation	Business	41	7237.45	H = 2.00*
	Farmer	208	6654.43	
	Civil Servant	36	4765.76	
	Artisans	121	5434.21	
	Student/Pupils	141	5436.37	
	Unemployed	58	3237.65	
Marital status	Single	361	6542.32	H = 12.45*
	Married	204	5432.43	
	Widow/Widower	27	2242.65	
	Divorced/Single Parent	13	1221.32	

***Significant association at $p < 0.05$.**

Table 5: Geometric Mean Malaria Parasite Density in Relation to Demographic Factors

Figure 1

Map of Hospitals and Health Centers in Edo-North Senatorial District, Edo State, Nigeria.

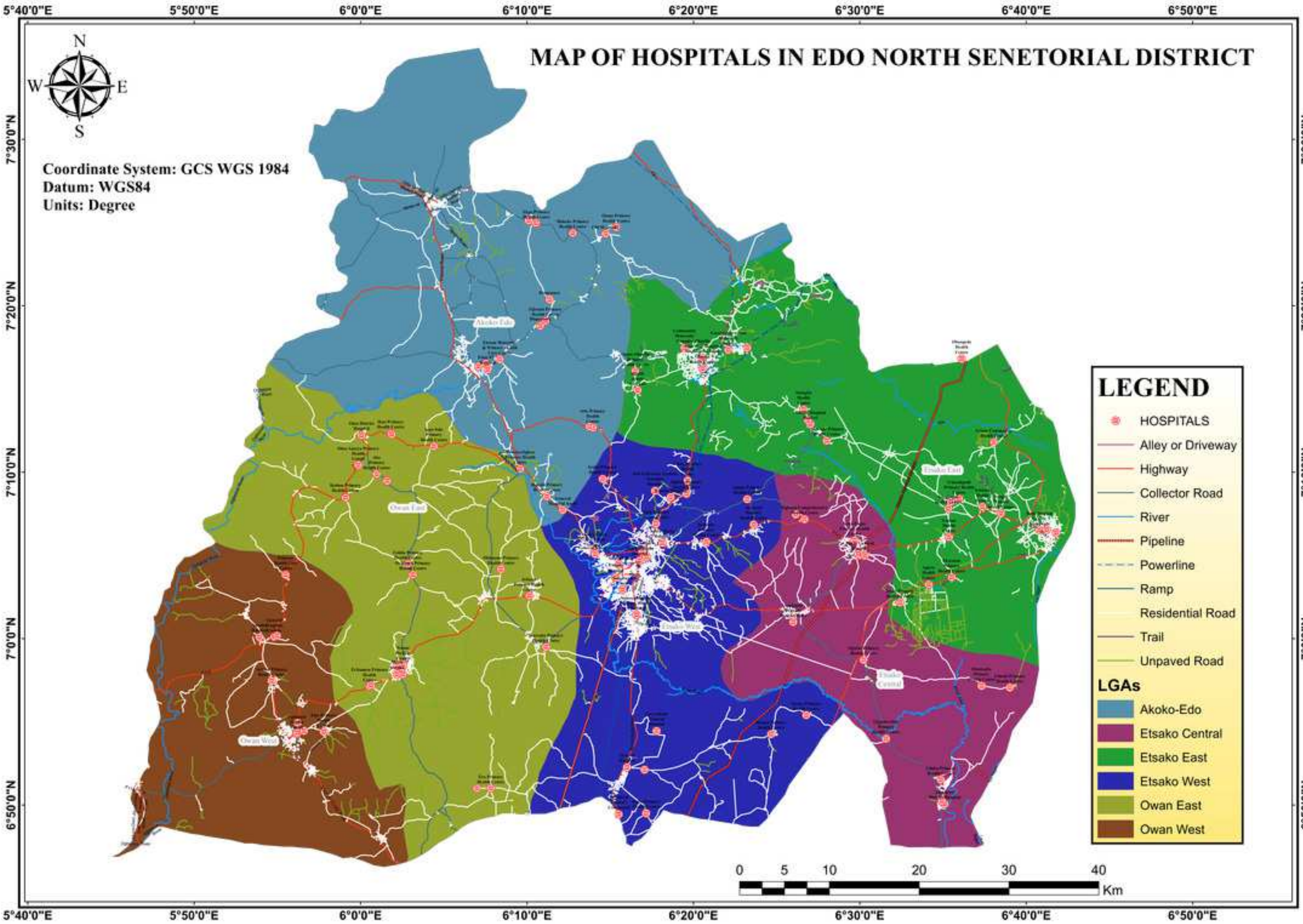

Figure 2

Source of acquisition of LLINs; Mode of LLNs acquisition; Local government area of residence GMPD; Age group GMPD

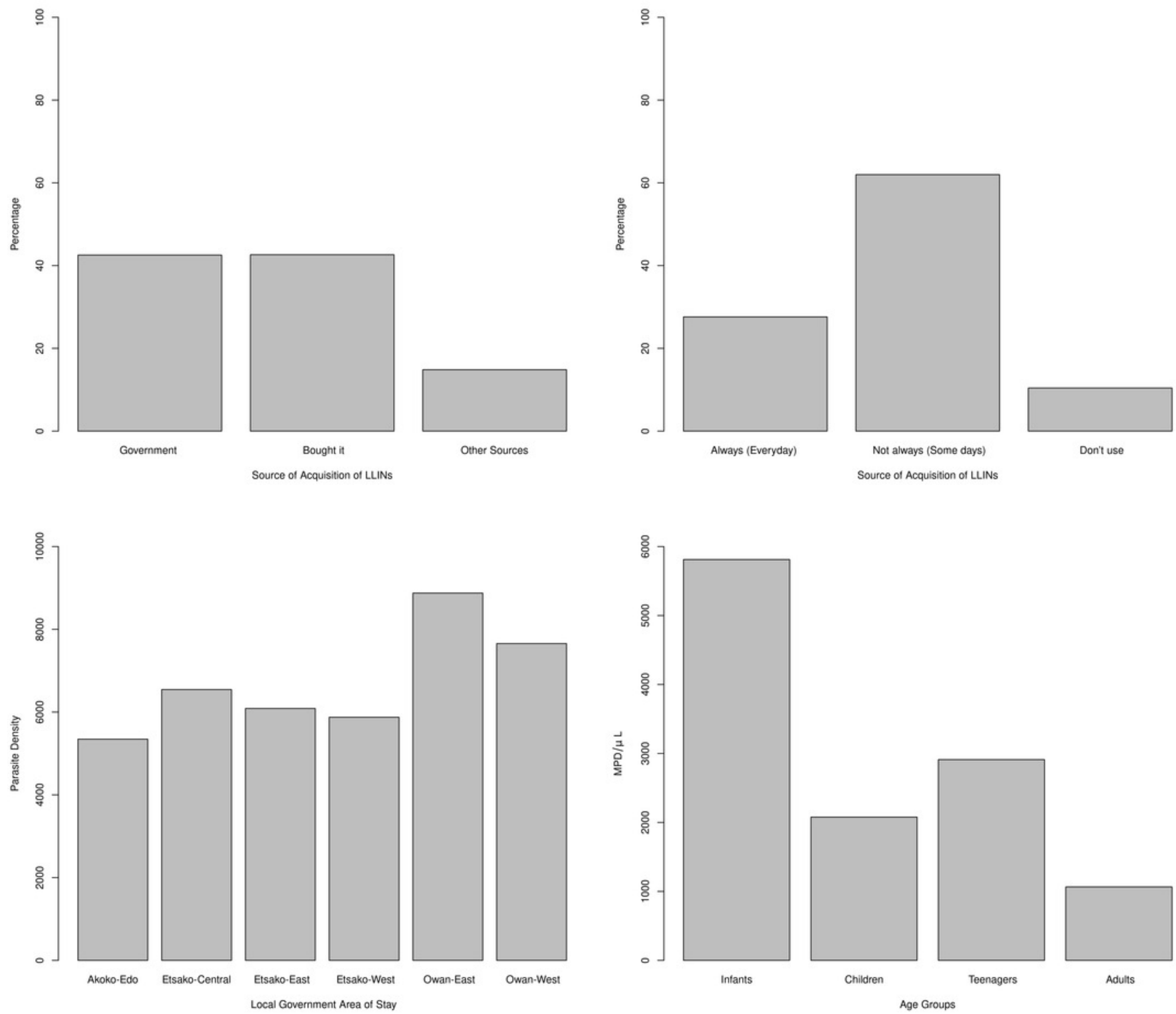

Figure 3

Duration of stay in relation to parasite density and Trend of prevalence of malaria from 2000 to 2023 in Edo-North