MIKAILALSYS
Journal of Multidisciplinary Sciences

e-ISSN : 2987-2286
p-ISSN : 2987-3924

Index : Dimensions, Scilit, Crossref, Garuda, Semantic, Lens,Google Scholar,Base, etc

https://doi.org/10.58578/mikailalsys.v3i2.5466

Prevalence of *Plasmodium falciparum* Infection Among Patients Attending Health Facilities in Northern Taraba State, Nigeria

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Article Info:

Submitted:	Revised:	Accepted:	Published:
Mar 29, 2025	Apr 13, 2025	Apr 25, 2025	Apr 30, 2025

Abstract

Plasmodium falciparum remains the primary cause of malaria-related mortality, particularly in sub-Saharan Africa, representing a significant global health challenge. This study aimed to assess the prevalence of *P. falciparum* infection among patients attending health facilities across the Northern Local Government Areas of Taraba State. Employing a prospective cross-sectional design, the study enrolled 1,500 participants who underwent testing for *P. falciparum* using Giemsa-stained blood film examination, Rapid Diagnostic Tests (RDT), and Polymerase Chain Reaction (PCR). Hematological parameters, including Packed Cell Volume (PCV), white blood cell counts, and erythrocyte sedimentation rate (ESR), along with biochemical markers such as albumin, bilirubin, and electrolyte levels, were also assessed. The results indicated that Jalingo had the highest prevalence at 25.4%, followed by Lau with 18.8%, which is lower than the 45% reported in the same local government area (Adiel *et al.*, 2021). Zing exhibited the lowest prevalence at 16.6%, marking this study as the first reported malaria investigation in the Zing

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Local Government Area. Contrary to expectations, Jalingo, the state capital, showed a higher prevalence of malaria, suggesting factors such as socio-environmental lifestyles, rural-urban migration, artificial vector breeding sites, urban agriculture, and reduced immunity among urban dwellers may contribute to this trend. The overall prevalence of malaria across the three sites was 20.27%. These findings emphasize the need for comprehensive diagnostic strategies and advocate for the integration of adjunct tools into malaria treatment protocols to improve patient care and outcomes.

Keywords: Malaria; Infection; *Plasmodium falciparum*; Health facilities; Northern Taraba State.

INTRODUCTION

Several species of intracellular protozoa of the genus *Plasmodium* cause malaria in humans. Among them are *Plasmodium ovale*, *Plasmodium vivax, Plasmodium falciparum*, and *Plasmodium malariae*. (Joshi *et al*., 2008; WHO, 2019) and more recently, *P. knowlesi* (World Malaria Report, 2018). *P. falciparum* and *P. vivax* cause the most serious forms of the disease (World Health Organization, 2010; Elhassan *et al*., 2009; Idonije *et al*., 2011; WHO, 2022). Humans contract diseases from the bite of female Anopheles mosquitoes, which spread the disease around the world. These disease cuasing organisms have a complicated life history that requires a vertebrate host for the asexual cycle and female *Anopheles* mosquitoes for completion of the sexual cycle. Malaria poses a threat to public health with 80 to 90% of morbidity and mortality occurring in Africa, afflicting both young and old (Federal Ministry of Health, 2005; Adeneye *et al*., 2007; Kamau *et al*., 2015). In addition, reports showed that malaria could be transmitted by transfusion of infected blood (Ali & Kadaru, 2005; WHO, 2010), sharing needles (Tracy and Webster, 2001) and congenital transmission (Ezechukwu *et al*., 2004).

In 2020, there were 241 million cases of malaria, compared to 227 million cases in 2019, according to the most recent World Malaria Report. An estimated 627 000 people died from malaria in 2020, an increase of 69 000 over the year before. A recent modification in WHO's technique for measuring malaria mortality accounts for one third of these deaths (22,000), while about two thirds of these deaths (47 000) were caused by interruptions during the COVID-19 pandemic (irrespective of COVID-19 disruptions). 32

sub-Saharan African nations, which account for almost 93% of all malaria fatalities worldwide, were subjected to the new cause-of-death methodology (World Malaria Report, 2021). Applying the methodology revealed that malaria has taken a considerably higher toll on African children every year since 2000 than previously thought (WHO, 2022). The WHO African Region continues to carry a disproportionately high share of the global malaria burden. In 2020, the Africa region was home to 95% of all malaria cases and 96% of deaths. About 80% of all malaria deaths in the region were in children under the age of five. Just over half of all malaria deaths globally occurred in four African countries: Mozambique (3.8%), the Democratic Republic of the Congo (13.2%), Nigeria (31.9%), and the United Republic of Tanzania (4.1%) (WH0, 2022).

Approximately 24% of Nigerians reside in low transmission zones, while 76% of the country's population lives in high transmission areas. Malaria is contagious across the country. The transmission season can last all year round in the south and is about 3 months or less in the northern part of the country.

With its elevated morbidity and mortality, malaria continues to be one of the most common parasite diseases in the tropics. In sub-Saharan Africa, *Plasmodium falciparum* is the most common malarial parasite; outside of Africa, *Plasmodium vivax* is the most common parasite and accounts for over 30% of cases in South-East Asia (World Malaria Report, 2018). According to Khuraiya *et al.* (2016), there is typically a significant morbidity and mortality rate in instances of severe malaria as well as those with changed haematological and biochemical parameters, which typically result in frequent malaria sequelae. However, infection with *P. falciparum* represented more than 90% of the global malaria mortality and thus it is still a relevant global threat to public health (Snow, 2015). Furthermore, an estimated of 781,000 deaths and 225 million cases of *falciparum* malaria were recorded annually (WHO, 2010). Moreover, *P. falciparum* infection is frequently correlated to cerebral malaria and mortality that promote neurological sequelaes (Schiess *et al.*, 2020). Although clinical presentations are common in malaria diagnosis particularly in poor countries, however, those symptoms of fever are reasonable for malaria diagnosis due to lack of specificity as it is common with other illnesses making clinical diagnosis more confront (Erhart *et al.*, 2004). Furthermore, this results in an overuse of antimalarial medications, decreasing their specificity and lowering the standard of treatment provided to patients (Reyburn *et al.*, 2007). While, microscopic diagnosis continues to be the gold standard, most economical technique for malaria diagnosis, but its sensitivity and specificity for parasite

detection are still weak particularly in endemic areas in Africa, as this technique needs a qualified technical expertise, consumes more time and deficient for a satisfactory health care issues (Reyburn *et al*., 2007; WHO, 2009; Maina *et al*., 2010).

Malaria causes a variety of haematological alterations, which differ depending on the Plasmodium species, age, gender, and a number of other variables. In individuals with malaria, anemia is a significant pathology that exacerbates the disease situation in the infected hosts when it coexists with other related haematological changes (Abdulkareem *et al*., 2017). Anaemia, thrombocytopenia, leucocytosis, leukopenia, moderate atypical lymphocytosis, monocytosis, eosinophilia, and neutrophilia are among the haematological abnormalities that have been linked to malaria (Das *et al*., 2017; D'souza, 2018). According to Kurtzhals *et al*. (1998), there was a positive correlation between the malaria patients' levels of inflammatory biomarkers and eosinophilia, suggesting that inflammatory processes or T cell activation may be involved in the generation of eosinophils during acute sickness. It has been shown that thrombocytopenia is a frequent finding in both falciparum and vivax malaria. Additionally, it has been noted that the degree of illness is closely correlated with leukopenia and leukocytosis, lymphopenia, monocytosis, and neutrophilia (Tobó´n-Castaņo *et al*., 2015). Since severe falciparum malaria reduces platelet survival, the degree of thrombocytopenia is thought to be significant to the disease's prognosis (D'souza, 2018).

P. falciparum invades red blood cells (RBCs) to form intra-erythrocytic trophozoite stages, which devour almost 70% of the hemoglobin in red blood cells to produce a crystalline form of hemomagglutinin (Tilley *et al*., 2011). Thus, hemoglobin (Hgb) levels in individuals with *P. falciparum* infection decrease, leading to anemia, particularly in severe cases (Sakzabre *et al*., 2020). As a result, malaria infections disrupt the physiology of the hematopoietic system, which in turn modifies hematological parameters that could be linked to malaria immunity, hemoglobinopathy, nutritional condition, and demographic factors (Awoke & Arota, 2019). While thrombocytopenia was more significant and frequent in *P. falciparum* malaria patients from Pakistan, Khan *et al*. (2018) found that there were global hematological abnormalities during malaria infections. Additionally, (Awoke and Arota, 2019) found that malaria patients had considerably lower mean values of Hgb, Hct, platelets, WBCs, RBCs, and lymphocytes than did non-infected individuals. Due to ideal breeding conditions, such as high humidity, high temperatures, high rainfall, and lots

of stagnant water, malaria primarily affects tropical locations. This is because these variables facilitate the life cycle of mosquitoes, which transmits the diseases (WHO, 2018).

METHODS

Study Area

Taraba state is the third largest state in terms of landmass in Nigeria. It is located in the Southern part of northeastern Nigeria along the eastern borderland between Nigeria and Cameroon. The state lies roughly between latitude 6° 25'N and 9° 30'N and between longitude 9°30'E and 11° 45'E. It is bordered on the west by Nasarawa and Plateau States, to the north by Bauchi and Gombe States and by Adamawa State to the northeast. It also shares its southwestern boundary with Benue State. Taraba State is bounded on the south and southeast by the Republic of Cameroon (an international boundary). The state covers a land area of about 60,291 km2 with a population of about 2,300,736 people according to the 2006 census. Taraba state is made up of 16 Local Government Areas (LGAs) and 3 Senatorial districts (northern Taraba, southern Taraba, and Taraba central). Northern Taraba consists of six LGAs, Ardo Kola, KarimLamido, Lau, Jalingo, Yorro and Zing.

Study Sites

The study was conducted in three centres of three Local Government Areas selected randomly in Taraba State which include Federal Medical Centre in Jalingo, General Hospital in Lau and General Hospital, Zing. The residents of the Local Governments are predominantly Mumuye, Yandang, with few minor tribes viz Jenjo, Fulani and Hausa among others and they are mostly farmers. The climate in the area can be described as tsub-humid type with two distinct (wet and dry seasons). It has an average rainfall of 7 months annually with total range between 1,200mm and 2000mm in the months of April and October. The temperature is relatively high throughout the year averaging 28-32°C with occasional peak at 44.0 °C between March and April.

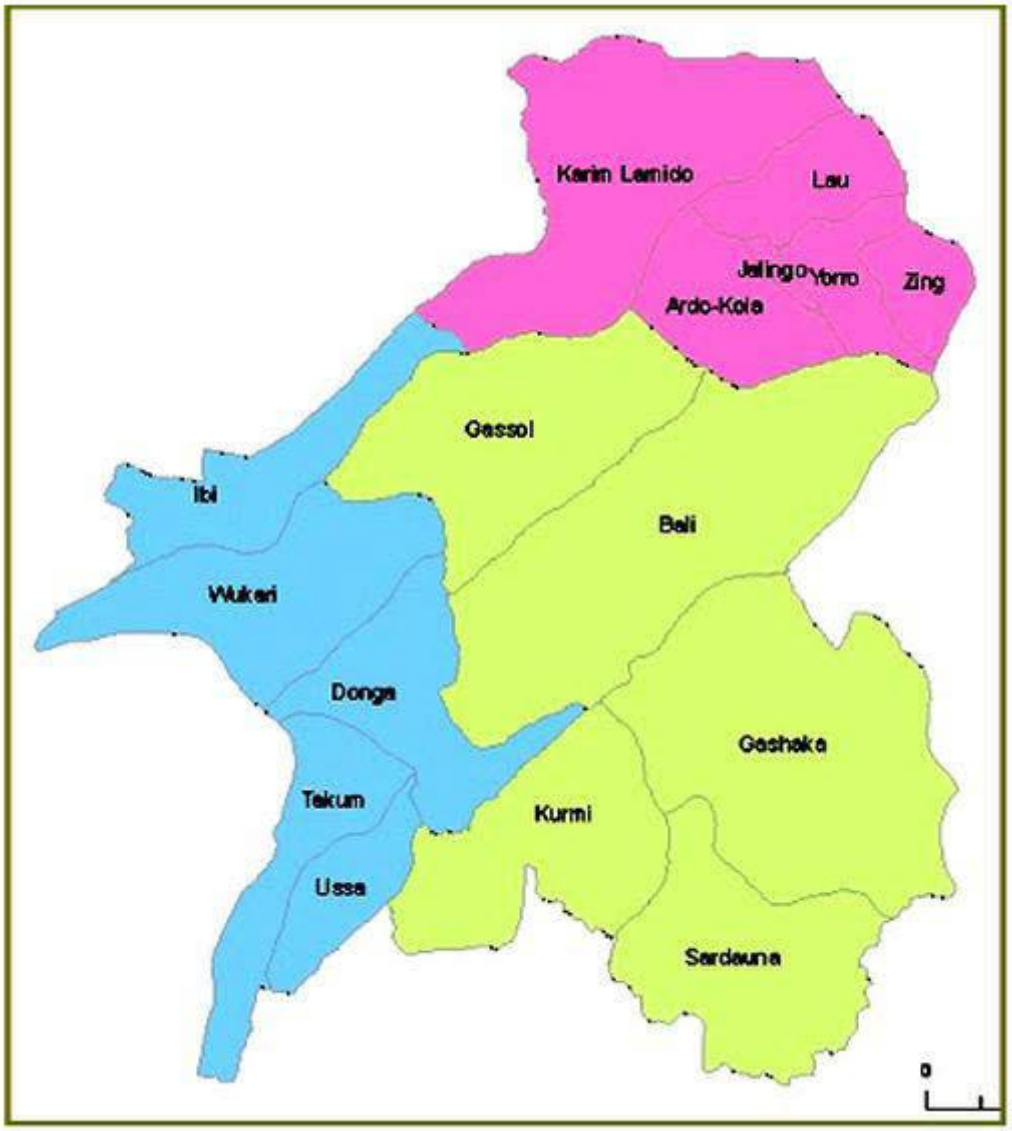


Figure 1: Map of Taraba State showing the study area

Study population and Selection of subjects

A total of 1,500 patients who were diagnosed for the presence of *Plasmodium species*, by the routine laboratory methods, that is, giemsa stained blood film examination, as per WHO protocol (WHO, 2018) and Immunochromatography was included in this study. A total of 500 participants was selected randomly from each centre in the three Local Government Areas chosen for the study.

Inclusion criteria

Only subjects who consent to the study were included. Only individuals with *P. falciparum* infection were included as test subjects

Exclusion criteria

Subjects who refuse to give consent were excluded. Subjects who are infected with or who have co-infection with other types of *Plasmodium* species were excluded. Subjects with underlying medical condition(s) inimical to biochemical or haematological indices including liver and kidney problems were excluded as well. Children below the age of 1 year were excluded as well.

Research Design

This is a prospective cross-sectional study involving subjects with *Plasmodium falciparum* (*P. falciparmn*) malaria infection serving as tests while *P. falciparum* negative subjects serving as controls.

Data Collection

Sample collected was given a coded number without the patient's name and labelled appropriately taking note of the centre of collection, Local Government Area, gender, age group, marital status, educational status etc. Data were collected for a period of 12 months concurrently in the three study sites.

Sample Handling and Disposals

All the samples collected for this research work was handled discretely by professional Laboratory Technicians or scientist who determine the infection status of participants. After testing, the samples were incinerated with the aid of Kerosene. The Data collected was kept confidential and only use for research purpose only. The test result of each individual was made known to them following request.

Sample Size Estimation

The sample size was determined from a z-test formula for the calculation of sample size.

Sample size (n)

$$\frac{(Z_{1-a})^2 \, x \, P(1-P)}{d^2}$$ ----------Equation 1

Where n = minimum sample size,

Z_{1-a} value of standard normal deviation which is at 95% confidence level has been found to be 1.96.

P=best estimate of the population prevalence obtained from the literature review.

d=proportion of sample error in a given population.

At prevalence rate of *Plasmodium* malaria of 19.2.0% (Yakubu *et al.*, 2019), using 5% precision

at 95% confidence level, the minimum sample size n for this study is calculated as follows:

Where Z=1.96,

P=19.2%, 0.192 d= 5%, 0.05

Therefore, n= (1.96) x 0.192 x (1-0.192)

$$0.05^2$$

n=238

The minimum sample size is 238

Added attrition was = 110% of 238

Total sample size=500 x 3 =1500

Questionnaire

A structured questionnaire was administered for all consenting participants to capture their demographic characteristics which included sex, age, marital status, educational level, whether or not they are on any form of condition they are managing.

Validation of Questionnaire

Content validity was carried out by experts in the subject matter by reviewing the questionnaire to ensure that it covers all relevant topics comprehensively. The questionnaire was also compared with existing validated questionnaire and literature to ensure it covers all aspects. A pilot study was conducted with a small sample of the target population to check for clarity and relevance.

Reliability Test

Cronbach's Alpha test was used to measure the internal consistency of the questionnaire. The reliability was retested by administering the questionnaire to the same group of people at two different points in time and the correlation between the two sets was calculated.

Informed Consent

Written informed consent for participation in the study was sought from the patients in accordance with standards for human experimentation and the Helsinki Declaration.

Ethical Approval

The Ethical approval was sought from the Taraba State Ministry of Health Ethical Committee and presented to the health facilities where the blood samples were collected in compliance with the Declaration on the Right of the Patient (Foster *et al.*, 2001). Before enrolment for the study, the patients/subjects involved signed an informed consent form. Guardian/Parent sign the consent form on behalf of participants below the age of 18 years old.

Collection and preparation of blood specimen

All blood samples were collected by a phlebotomist or Laboratory Technician and screened by a Laboratory Scientist or Technician. With sterile aseptic precaution, about 5mL of venous blood was collected from the cubital vein of adult and/or by pricking the hand or leg in children. Three milliliters (3mL) of the blood samples were transferred into plain bottles to allow for coagulation, whereas the remaining 2mL was transferred into ethylenediaminetetraacetic acid (EDTA) bottles for malaria parasite tests and haematological studies. The coagulated blood samples were centrifuge at 3000 rpm for 10 minutes, the serum transferred into Bijou bottle and stored frozen until required for biochemical analyses (Onyesom *et al.*, 2010). The researcher in Collaborations with the laboratory Technicians or Scientist were responsible for safety issues during sample collection. Participants who reacted negatively or whose skins were damaged during sample collections were referred to a doctor in the facility and the cost implications was handled by the researcher. The researcher did not provide medications for malaria positive participants but were referred to a physician for proper treatment. The participants were made aware and given a typed or written test result regardless whether positive or negative.

Preparation of thick and thin blood films

Thick and thin blood films were prepared on the same slide for each subject and stained using 10% Giemsa stain as described by Cheesebrough (2006). Using a completely clean grease free microscope slide a small drop of blood was added to the centre of the slide and a large drop about 15mm to the one end of the slide. Using a smooth edge slide spreader,

the thin blood film was spread immediately without delay, the large drop was spread to make a thick film to cover an area of about 15 x 15mm. the slide was allowed to air dry. The thin film was fixed with absolute methanol for two minutes without touching the thick films.

Giemsa Staining Technique

The giemsa stain was diluted to 10% solution (90ml buffered distilled water pH 7.0 to 10ml Giemsa stain in a measuring cylinder and mixed). The slides were placed on a staining rack. The diluted stain was flooded on the slides and allowed to stain for 45-60 minutes. The slides were washed using buffered distilled water pH 7.0. The back of the slides were wiped off with cotton wool and placed in a clean rack. A drop of oil immersion was applied to an area of the film. An area that was well stained and not too thick was selected and examined for malaria parasites and malaria pigments and was confirmed by examining the thin blood films (WHO, 2020).

Parasite Density Test

Measurement of parasite density of peripheral blood smear was done via Giemsa stained techniques. The films were examined microscopically using x100 objective under oil immersion (Cheesbrough, 2006) as reported by Sumbele *et al.* (2010). Level of parasitaemia was in microliter (µl) of blood thick film preparation (Erhart *et al.*, 2004). According to WHO (2005), level of parasitaemia were graded as low+ (1 to 999/µl), moderate++ (1000 to 9999/µl) and severe++++ (>200,000/µl).

Molecular Genotyping of Parasite

All molecular analysis were performed at the Malaria Genomic Research & Training Center (MGRTC) of the Department of Biochemistry and Nutrition of the Nigerian Institute of Medical Research (NIMR), Yaba, and Lagos State, Nigeria.

Statistical analysis

The data obtained was analysed using SPSS V28. Chi-square was used to compare the prevalence of malaria infection between age, sex, occupation and educational status of the subjects. The Odd Ratio (OR) was determined using logistic regression to find the relation between the malaria infection and the haematological parameters. The general linear model was used for differentiation of haematological parameters of patients examined likewise biochemical parameters. T-test was also used to determine relationship between

haematological and biochemical parameters of malaria parasitized and non-parasitized subjects. Statistical significance was set at 0.05.

RESULTS

Overall pattern of Distribution of falciparum Malaria in the Study Area

Table 1 presents the distribution of malaria in three different study areas: Jalingo, Lau, and Zing. Each study area had 500 individuals examined for malaria. In Jalingo, 127 out of 500 individuals were infected, accounting for 25.4% prevalence. In Lau, 94 out of 500 individuals were infected, with an infection rate of 18.8%. In Zing, 83 out of 500 individuals were infected, resulting in a 16.6% prevalence. Across all study areas, a total of 304 out of 1500 individuals were infected, making up a 20.3% prevalence. The Chi-square distribution shows a significant difference in malaria distribution among the study areas (χ^2 =12.979; P<0.05)

Table 1: Overall pattern of Distribution of Malaria in the Study Area

Study Area	No. Examined	No. Infected (%)
Jalingo	500	127 (25.4)
Lau	500	94 (18.8)
Zing	500	83 (16.6)
Total	1500	304 (20.3)

χ^2 =12.979; P<0.05

A chi-square (χ^2) statistic is a measure of the difference between the observed and expected frequencies of the outcomes of a set of events or variables.

Gender-related prevalence of Malaria in the Study Area

Table 2 presents the prevalence of malaria based on sex across the study areas. In Jalingo, among males, 64 out of 241 individuals were infected with malaria, resulting in a prevalence of 26.6%. Among females, 63 out of 259 individuals were infected, with a prevalence of 24.3%. In Lau, among males, 50 out of 203 individuals were infected, resulting in a prevalence of 24.6%. Among females, 44 out of 203 individuals were infected, with a prevalence of 21.6%. In Zing, among males, 39 out of 237 individuals were infected, resulting in a prevalence of 16.5%. Among females, 44 out of 263 individuals were infected,

with a prevalence of 16.7%. Overall male respondents had the highest prevalence of 20.9% (153/731) whiles females had a slight lower prevalence of 19.6% (151/769)

Table 2: Gender-related Prevalence of Malaria in the Study Area

Study Area	Sex	No. Examined	No. Infected (%)
Jalingo	Male	241	64 (26.6)
	Female	259	63 (24.3)
Lau	Male	203	50 (24.6)
	Female	203	44 (21.6)
Zing	Male	237	39 (16.5)
	Female	263	44 (16.7)
Total	Male	731	153 (20.9)
	Female	769	151 (19.6)
Overall Total	Male + Female	1500	304 (20.3)

χ^2 =12.979; P<0.05

Age related Distribution of Malaria in the Study Area

The table provides the distribution of malaria cases based on age groups and gender within the study area. For the age group 1-5 years: Among males, 15 individuals were examined and 14 (93.3%) were infected while among females, 37 individuals were examined, and 17 (45.9%) were infected. Overall, 52 individuals were examined, and 31 (59.6%) were infected.

For the age group 6-10 years: Among males, 4 individuals were examined, and 3 (75.0%) were infected while among females, 11 individuals were examined, and 5 (45.4%) were infected. Overall, 15 individuals were examined, and 8 (53.3%) were infected.

For the age group 11-17 years: Among males, 78 individuals were examined, and 20 (25.6%) were infected while among females, 198 individuals were examined, and 26 (13.1%) were infected. Overall, 276 individuals were examined, and 46 (16.6%) were infected.

For the age group 18-30 years: Among males, 429 individuals were examined, and 83 (19.3%) were infected among females, 263 individuals were examined, and 65 (24.7%) were infected. Overall, 692 individuals were examined, and 148 (21.4%) were infected.

For the age group 31-40 years: Among males, 113 individuals were examined, and 15 (13.2%) were infected while among females, 132 individuals were examined, and 20

(15.1%) were infected. Overall, 245 individuals were examined, and 35 (14.2%) were infected.

For the age group 41-50 years: Among males, 71 individuals were examined, and 10 (14.1%) were infected while among females, 70 individuals were examined, and 11 (15.7%) were infected. Overall, 141 individuals were examined, and 21 (14.8%) were infected.

For the age group >50 years: Among males, 21 individuals were examined, and 8 (38.1%) were infected while among females, 58 individuals were examined, and 7 (12.1%) were infected. Overall, 79 individuals were examined, and 15 (18.9%) were infected.

Table 3: Age related Distribution of Malaria in the Study Area

Age (Years)	Male		Female		Total	
	No. Examined	No. Infected (%)	No. Examined	No. Infected (%)	No. Examined	No. Infected (%)
1-5	15	14 (93.3)	37	17 (45.9)	52	31 (59.6)
6-10	4	3 (75.0)	11	5 (45.4)	15	8 (53.3)
11-17	78	20 (25.6)	198	26 (13.1)	276	46 (16.6)
18-30	429	83 (19.3)	263	65 (24.7)	692	148 (21.4)
31-40	113	15 (13.2)	132	20 (15.1)	245	35 (14.2)
41-50	71	10 (14.1)	70	11 (15.7)	141	21 (14.8)
>50	21	8 (38.1)	58	7 (12.1)	79	15 (18.9)
Total	731	153 (20.9)	769	151 (19.6)	1500	304 (20.3)

χ^2 =70.748; P<0.05

Age specific prevalence of *P. falciparum* in Jalingo LGA

Table 4 presents the age-specific prevalence of *P. falciparum* malaria in Jalingo Local Government Area of Taraba State, Nigeria. For the age group 1-5 years, 7 individuals were examined, and all 7 (100%) were infected with *P. falciparum*. For the age group 6-10 years, 2 individuals were examined, and both (100%) were infected. For the age group 11-17 years, 117 individuals were examined, and 35 (29.9%) were infected. For the age group 18-30 years, 207 individuals were examined, and 42 (20.3%) were infected. For the age group 31-40 years, 80 individuals were examined, and 18 (22.5%) were infected. For the age group 41-50 years, 52 individuals were examined, and 11 (21.2%) were infected. For the age group >50 years, 35 individuals were examined, and 12 (34.2%) were infected. Overall, out of 500

individuals examined across all age groups, 127 (25.4%) were infected with *P. falciparum* malaria in Jalingo LGA. The Chi-square distribution (χ^2 = 32.853; P<0.05) indicates a significant association between age-specific prevalence of *P. falciparum* malaria and the age groups in Jalingo LGA.

Table 4: Age specific prevalence of *P. falciparum* in Jalingo LGA

Age (Years)	No. Examined	No. Infected (%)
1-5	7	7 (100.0)
6-10	2	2 (100.0)
11-17	117	35 (29.9)
18-30	207	42 (20.2)
31-40	80	18 (22.5)
41-50	52	11 (21.1)
>50	35	12 (34.2)
Total	500	127 (25.4)

(χ^2 = 32.853; P<0.05)

Age specific prevalence of *P. falciparum* in Lau LGA

Table 5 presents the age-specific prevalence of *P. falciparum* malaria in Lau Local Government Area (LGA). For the age group 1-5 years, 19 individuals were examined, and 12 (63.2%) were infected with *P. falciparum*. For the age group 6-10 years, 4 individuals were examined, and 1 (25.0%) was infected. For the age group 11-17 years, 78 individuals were examined, and 6 (7.6%) were infected. For the age group 18-30 years, 242 individuals were examined, and 51 (21.1%) were infected. For the age group 31-40 years, 83 individuals were examined, and 13 (15.6%) were infected. For the age group 41-50 years, 54 individuals were examined, and 10 (18.5%) were infected. For the age group >50 years, 20 individuals were examined, and 1 (5.0%) was infected. Overall, out of 500 individuals examined across all age groups, 94 (18.8%) were infected with *P. falciparum* malaria in Lau LGA. The Chi-square distribution (χ^2 = 34.748; P<0.05) indicates a significant association between age-specific prevalence of *P. falciparum* malaria and the age groups in Lau LGA.

Table 5: Age specific prevalence of *P. falciparum* in Lau LGA

Age (Years)	No. Examined	No. Infected (%)
1-5	19	12 (63.1)
6-10	4	1 (25.0)
11-17	78	6 (7.6)
18-30	242	51 (21.1)
31-40	83	13 (15.6)
41-50	54	10 (18.5)
>50	20	1 (5.0)
Total	500	94 (18.8)

(χ^2 = 34.748; P<0.05)

Age specific prevalence of *P. falciparum* in Zing LGA

Table 6 presents the age-specific prevalence of *P. falciparum* malaria in Zing Local Government Area. For the age group 1-5 years, 26 individuals were examined, and 12 (46.2%) were infected with *P. falciparum*. For the age group 6-10 years, 9 individuals were examined, and 5 (55.6%) were infected. For the age group 11-17 years, 81 individuals were examined, and 5 (6.2%) were infected. For the age group 18-30 years, 243 individuals were examined, and 55 (22.6%) were infected. For the age group 31-40 years, 82 individuals were examined, and 4 (4.9%) were infected. For the age group 41-50 years, 35 individuals were examined, and none were infected. For the age group >50 years, 24 individuals were examined, and 2 (8.3%) were infected. Overall, out of 500 individuals examined across all age groups, 83 (16.6%) were infected with *P. falciparum* malaria in Zing LGA. The Chi-square distribution (χ^2 = 55.309; P<0.05) showed a significant association between age-specific prevalence of *P. falciparum* malaria and the age groups in Zing LGA.

Table 6: Age specific prevalence of *P. falciparum* in Zing LGA

Age (Years)	No. Examined	No. Infected (%)
1-5	26	12 (46.2)
6-10	9	5 (55.6)
11-17	81	5 (6.2)
18-30	243	55 (22.6)
31-40	82	4 (4.9)
41-50	35	0 (0.0)
>50	24	2 (8.3)
Total	500	83 (16.6)

(χ^2 = 55.309; P<0.05)

Overall Occupation related Prevalence of *P. falciparum* infection in the study area

Table 7 provides the overall occupation-related prevalence of *P. falciparum* infection in the study areas. Traders had the highest prevalence of 26.3% (103/391) followed by Farmers with a prevalence of 6.8% (112/603), students 18.5% (23/138) and the least been civil servant 16.8% (62/368). The Chi-square distribution (χ^2 =12.348; P<0.05) showed a significant association.

Table 7: Overall Occupation related Prevalence of *P. falciparum* infection in the study area

Occupation	No. Examined	Prevalence (%)
Civil Servants	368	62 (16.8)
Farmers	603	112 (18.5)
Students	138	23 (16.6)
Traders	391	103 (26.3)
Total	1500	304 (20.3)

(χ^2 =12.348; P<0.05)

Prevalence of *P. falciparum* infection based on Marital Status in Jalingo LGA

Table 8 presents the prevalence of *P. falciparum* infection based on marital status within Jalingo Local Government Area of Taraba State, Nigeria. The table showed that participants who are divorced and widowed had the highest prevalence of 100.0% (8/8) and 100.0% (1/1) respectively followed by the single participants with a prevalence of 31.8% (81/254) and the least been those who are married with a prevalence of 15.6% (37/237). The Chi-square distribution (χ^2 = 44.062; P<0.05) indicates a significant association between marital status and *P. falciparum* infection prevalence within Jalingo LGA.

Prevalence of *P. falciparum* infection based on Marital Status in Lau LGA

The table 9 presents the prevalence of *P. falciparum* infection based on marital status within Lau Local Government Area of Taraba State, Nigeria. The table showed that participants who are divorced/separated had the highest prevalence of 100.0% (2/2) followed single participants with a prevalence of 24.9% (66/265), married 11.1% (26/233) and the least been those who are widowed 0.0% (0/0). Overall, out of 500 individuals examined across

all marital statuses in Lau LGA, 94 (18.8%) were infected with *P. falciparum* malaria. The Chi-square distribution (χ^2 = 24.021; P<0.05) indicates a significant association between marital status and *P. falciparum* infection prevalence within Lau LGA.

Prevalence of *P. falciparum* infection based on Marital Status in Zing LGA

Table10 presents the prevalence of *P. falciparum* infection based on marital status specifically within Zing Local Government Area. The table showed that participants who are single had the highest prevalence of 24.8% (60/241) followed by married participants with a prevalence of 8.8% (23/259) and the least been those who are divorced/separated 0.0% (0/0) and those who are widowed 0.0% (0/0). Overall, out of 500 individuals examined across all marital statuses in Zing LGA, 83 (16.6%) were infected with *P. falciparum* malaria. The Chi-square distribution (χ^2 = 23.130; P<0.05) indicates a significant association between marital status and *P. falciparum* infection prevalence within Zing LGA.

Table 8: Prevalence of *P. falciparum* infection based on Marital Status in Jalingo LGA

Occupation	No. Examined	Prevalence (%)
Single	254	81 (31.8)
Married	237	37 (15.6)
Divorced/Separated	8	8 (100.0)
Widowed	1	1 (100.0)
Total	500	127 (25.4)

(χ^2 = 44.062; P<0.05)

Table 9: Prevalence of *P. falciparum* infection based on Marital Status in Lau LGA

Occupation	No. Examined	Prevalence (%)
Single	265	66 (24.9)
Married	233	26 (11.1)
Divorced/Separated	2	2 (100.0)
Widowed	0	0 (0.0)
Total	500	94 (18.8)

(χ^2 = 24.021; P<0.05)

Table 10: Prevalence of *P. falciparum* infection based on Marital Status in Zing LGA

Occupation	No. Examined	Prevalence (%)
Single	241	60 (24.8)
Married	259	23 (8.8)
Divorced/Separated	0	0 (0.0)
Widowed	0	0 (0.0)
Total	500	83 (16.6)

(χ^2 = 23.130; P<0.05)

DISCUSSION

Prevalence of falciparum Malaria based on the study locations in the Northern Zones of Taraba State

Jalingo has the highest prevalence of 25.4% which is higher than 14.02% prevalence reported by Agere *et al.* (2019) in Jalingo. Lau has a prevalence of 18.8%, which is lower than the 45% prevalence reported in the same local government (Adiel *et al.*, 2021). Zing has the lowest prevalence of 16.6% of the three study location investigated, however, this study seems to be the first reported malaria study in Zing Local Government Area of Taraba State. Hence, more study is recommended in the region. Jalingo the state capital which was expected to have a lower prevalence of malaria due to urbanicity (Kigozi *et al.*, 2015) was on the contrary found with the highest prevalence of malaria compared to the other sites, which are relatively rural, a pattern that corroborates what was observed in a study in Libreville (Mourou *et al.*, 2012). Almost the same prevalence observed in this study in Jalingo has been reported in Ouagadougou (24.1%), the capital urban city of Burkina Faso (Wang *et al.*, 2005). The observed increased prevalence of malaria in urban areas may be due to factors such as socio-environmental life style of urban dwellers, rural-urban migration, artificial vector breeding sites, urban agriculture, clogged drainage and reduced immunity of urban dwellers (De Silva and Marshall, 2012). The total prevalence of malaria in the three study sites was 20.27%.

Prevalence of falciparum Malaria based on Demographic Indices of the participants

Despite the considerable progress made since 2000, morbidity and mortality caused by malaria have not reduced significantly yet (Choi *et al.*, 2019). It is a major health problem,

especially in underdeveloped nations such as Nigeria. According to this study, the prevalence of malaria through microscopy was 20.27%. This study showed that malaria is still prevalent in many urban and rural communities of Jalingo, Zing and Lau Local Government Areas of Taraba State, Nigeria. The prevalence of 20.27% is a reflection that Taraba is a risk area for malaria transmission, since the figure obtained is within the Nigerian malaria risk map estimates of less than 20% in certain zone to more than 70% in other zones as stated by Onyiri (2015). The study is corroborated by other studies reported from Ibadan (Okonko *et al*., 2010; Okonko *et al*., 2012; Bello and Ayede, 2019), in Akure (Adepeju, 2017; Awosolu *et al*., 2019), in Taraba (Houmsou *et al*., 2010; Sambo *et al*., 2020;) and other Nigerian States (Adefioye *et al*., 2007, Oladeinde *et al*., 2012, Amuta *et al*., 2014, Singh *et al*., 2014, Dawaki *et al*., 2016). In the same vein, a very high malaria prevalence rate of 99.2%, 80%, 81.5% and 76.23 was recorded in Enugu, Awka, Abeokuta and Taraba (Ardo-kola) respectively (Ibekwe *et al*., 2009, Okonko *et al*., 2009, Gunn *et al*., 2015; Obiorah *et al*., 2021). This high malaria prevalence can be as a result of many prevailing factors such as favourable environmental condition, presence of open stagnant water for mosquito proliferation, ignorance, inability to purchase recommended drug of treatment due to poverty and different occupations that expose people to mosquito bite as reported by Awosolu *et al*. (2020). In fact, it has been reported that prevalence of malaria in Nigeria ranges from 20% and less in some part of the country to over 70% in other parts (Onyiri, 2015).

The finding of this study in relation to sex shows that malaria prevalence was higher in males (20.85%) compared to females (19.71%). This finding corroborates with results reported by Al- Mekhlafi *et al*. (2011), Winskill *et al*. (2011), Loha and Lindtjørn (2012), Hailemariam and Gebre (2015), Alemu *et al*. (2012), Gebretsadik *et al*. (2018) and Awosolu *et al*. (2019). In contrast, the report of Ibekwe *et al*. (2009) and Elkanah *et al*. (2020) indicated that female respondents recorded higher malaria infection unlike their male counterparts. The difference may be attributed to the fact that males are mostly engaged in outdoor activities more often than the females. This finding also contradicts the results reported by Legesse *et al*. (2007) who reported higher prevalence in females. More than often control interventions especially treatment and prevention through bed net are directed towards female and children.

The prevalence of 23.49% from rural area of Taraba State is significantly ($P < 0.05$) higher compared to the prevalence in urban and semi-urban communities. This result is supported

by the reports of Wang *et al.* (2005) and Baragatti *et al.* (2009) who reported lower malaria prevalence of 24.1% and 26.1% in urban areas of the Republic of Benin and Burkina Faso respectively compared to rural communities. Prevalence as high as 74% and 71.4% have been reported by Awosolu *et al.*, (2019) and Woldearegai *et al.* (2019) in some rural settings. Even though evidence abounds on malaria prevalence in urban areas, prevalence is generally significantly ($P < 0.05$) lower than in rural areas (Anumudu *et al.*, 2006; Pond, 2013). This lower malaria prevalence in urban areas could result from better access to health facilities, well-designed houses that can protect against mosquito vectors, improved basic amenities, and reduced mosquito breeding sites (Klinkenberg *et al.*, 2008).

Our findings on age-specific malaria prevalence shows that age group 1-10 years has the highest malaria infection. Similar findings have been reported in previous studies (Hailemariam *et al.*, 2015; Zgambo *et al.*, 2017). The reason for this may be as a result of the various working or occupational conditions that enhance exposure to mosquitoes. Working late nights and under dirty conditions is not uncommon among this age group and this may expose them to the malaria infection. The World Health Organization has emphasized the fact that children between the age of 5 years and below are the most vulnerable group of people, particularly in Africa (WHO, 2018). This can be attributed to the gradual loss of maternal immunity, coupled with a low level of acquired immunity among children compared to adults. Thus, as age and exposure increase, malaria infection decreases except among the elderly and the immunocompromised. Thus, the focus should be on these children be- tween the age five years and below, even in urban centers. Prevention against mosquito bites should be intensified through the provision of mosquito nets to such households with children. Additionally, the sex pattern of infection in this study shows that males have higher malaria prevalence and mean parasite density than their female colleagues. This is related to previous reports from other studies in malaria-endemic areas such as Ethiopia and Chile (Gebretsadik *et al.*, 2013; Escobar *et al.*, 2020).

CONCLUSION

Understanding how Nigeria's malaria situation fits into various reports on *Plasmodium falciparum* genetic variation can improve treatment and immunization options. A significant alteration was observed in the blood and biochemical parameters of the *Plasmodium falciparum* infection cases. These data provide valuable information for surveillance of *P.*

falciparum infection and assessing the appropriateness of the current malaria control strategies in the endemic area. Results of this study suggest that the conventional diagnostic methods for the detection of malaria parasite (microscopy and RDT) are not adequate when accurate epidemiological data are needed to monitor, control and develop malaria elimination interventions. PCR permitted for the accurate diagnosis, confirming it as a valuable tool for epidemiological surveys, mass screening, and assessment of interventions for malaria elimination. This research will be helpful for future treatment strategies that would be tailored to the specific needs of Taraba and Nigeria's malaria- endemic populations.

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