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Haematological Derangements Due to *Plasmodium falciparum* Among Sickle Cell Anaemia Patients in Taraba State Nigeria

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ABSTRACT

Malaria infection is recognized as a severe public health problem linked to most cases of morbidity and mortality in malaria endemic areas. The study was used to determine the hematological derangement of plasmodium falciparum among sickle cell anaemia patients in Taraba state. The study employed a community and laboratory based cross sectional study. The findings shows that malaria infection was highest in the southern senatorial zone (29.1%) than in the north and central zones ($p<0.05$). Infection was high with the males (21.2%), age-related malaria infection was significant ($p<0.05$) with age 1-10yrs recording the highest infection (28.0%). No significant difference ($p>0.00$) was recorded in the marital status of the patient with the widows/widower having 23.4% while degree of infection was significant for education-related infection ($p<0.05$) with the non-educated subjects recording highest infection (34...4%). Occupational related prevalence was significant ($p<0.05$) with high infection among traders (162 (28.7%). Significant difference was recorded in the marital status with the widow/widower recording a high prevalence of malaria 112 (23.4%). Haematological parameters show no significant association in malaria parasitized packed cell volume ($t=0.284$, $p>0.05$) and monocytes ($t=1.361$, $p>0.05$). Significant association was recorded in total white blood count ($t=3.647$, $p<0.05$), neutrophil ($t=20.794$, $p<0.05$), erythrocyte sedimentation rate ($t=30.017$, $p<0.05$), eosinophil ($t=4.847$, $p<0.0.07$), basophil ($t=11.35$, $p<0.05$), platelet ($t=30.378$, $p<0.05$) and lymphocytes ($t=21.369$, $p<0.03$).Our finding for this current study confirm that malaria remains a major challenge and there is need for periodic prophylactic administration of malaria drugs in the treatment regime of sickle cell anaemia patients.

Keywords: Malaria infection, hematological derangement, plasmodium falciparum, Taraba State, Nigeria.

INTRODUCTION

Background to the Study

Malaria caused by the protozoan parasite belonging to the species Plasmodium falciparum is considered the most significant public health problem worldwide and ranks top in its socio-economic, community and public health burden in tropical, sub-tropical areas, sub- Saharan Africa and South-West Asian countries (Minakawa *et al* 2006; Hochman & Kim 2009; WHO 2011). It is a major cause of

morbidity and mortality in malaria endemic communities in many African countries (Aninagyei *et al* 2022). *Plasmodium falciparum* accounts for the greater part of malaria linked mortality in Nigeria since more than 90% of the populace lives in malaria endemic areas (Guerra *et al* 2008 & Aninagyei *et al* 2022). *Plasmodium falciparum* is vectored by the female *Anopheles* mosquito and is the most dangerous form of malaria accounting for the highest rates of complications and mortality.

Plasmodium falciparum infection is more prevalent in sub-Saharan Africa than in other regions of the world. And almost every malarial death is caused by this unicellular protozoa (WHO 2017 & WHO 2021). In 2019, malarial cases were estimated to about 229 million globally in 87 malaria endemic countries, declining from 238 million in 2000 while malarial deaths reduced from 736,000 in 2000 to 409,000 in 2009. Nigeria accounts for 27% and 23% global cases and deaths respectively (WHO 2020). The endemicity of *Plasmodium falciparum* in Nigeria was established by the World Health Organization in 2017 and the population at risk includes children, pregnant women and the non-immune (Carrington 2001 & WHO 2017). *Plasmodium falciparum* infection is associated with serious co-infections, it causes severe anaemia leading to high mortality rates, impaired physical and cognitive development in children as well as reduced immune functioning (WHO 2011). *Plasmodium falciparum* infection is characterized by acute or intermittent or continuous fever which is accompanied by shivering, sweating, fatigue, vomiting, joint pains and headache. In severe infection, it causes yellow discoloration of the skin, seizures, coma and death (Caraballo 2014 & WHO 2017). A high malaria infection rate within a country is attributed to poverty promoting condition (Hotez *et al* 2006).

The factors that contribute to the spread and transmission of malaria depend on the interaction between the human host, the anopheles vector, malaria parasite and environmental conditions (Arora & Arora 2009). However, there is significant risk of infection in urban areas, where indiscriminate waste disposal and the presence of swamps, gutters and thick vegetation encourage the breeding of the mosquito vector that causes malaria (Anumudu 2006). In rural and urban areas, breeding sites of the female Anopheles mosquito is common during the rainy season where there is abundant of bushes, stagnant water around residential homes, while in the dry season, stagnant and smelling streams, irrigation ponds for dry season farming, indiscriminate disposal of domestic, commercial and industrial waste provides suitable environment for the infected mosquito to breed and proliferate. In the northern parts of Nigeria, due to the high shortage of water, many residents in both urban and rural areas harvest and store their water in commercial plastic tanks, clay pot, open buckets and basins. These water storage containers have been identified as good breeding sites of the mosquito vector.

In Nigeria, *Plasmodium falciparum* malaria exist all year round since hospitals have reported to treating malarial cases in all seasons and months of the year. The problems of rural-urban migration, persistence of poverty, environmental degradation and intractable problems of providing decent housing, potable water and sanitation are common in many cities and they cumulatively encourage the risks of malaria infection and parasite resistance through inconsistent malaria treatment options (Koram *et al* 1995 &Anumudu 2006).

The connection between sickle cell disease and malaria was first discovered in the 1940s (Esoh &Wonkam 2021). Patients with sickle cell traits (AS) have shown some resistance to severe forms of malaria (Depetris-Chauvin & Weil, 2018) because the sickle cell traits confer some resistance to malaria (Piel *et al*., 2010). Individuals with sickle cell anaemia (SS) do not have protection from malaria. Malaria is both a

precipitating factor of vaso-occlusion and a cause of haemolytic anaemia. Malaria causes destruction of erythrocytes by direct red cell lysis, phagocytosis and immune destruction with liberation of the parasites and erythrocyte material into the circulation, thus resulting in haemolytic crisis ((Serjeant, 2001., Gullet, 2001 & Luzzatto, 2012). Haematological derangements such as low platelet count, low white blood cell count and low lymphocyte counts are the most important predictors of *Plasmodium falciparum* infection.

The association of Plasmodium falciparum malaria with sickle cell anaemia is well described in Sub-Saharan Africa but is rare in the United States of America (Glickman *et al* 2021). However, this relationship has remained undocumented in Nigeria.

Sickle cell anaemia (SCA), an autosomal recessive disorder due to the presence of a mutated form of hemoglobin S (HbS) and is a neglected non-communicable disease of public health concern worldwide (Lopez *et al* 2014; Pecter *et al* 2021 & Sedrak *et al* 2023). Sickle cell anaemia is an inherited blood disorder from two abnormal copies of the β-globin gene which occurs in chromosome 11. The disease alters the shape of the red blood cells to a sickle shape which makes the red blood cells sticky and rigid and prone to getting trapped in small vessels, hence blocks blood from reaching the different parts of the body to cause pain and tissue damage (Lopez *et al* 2010). Sickle cell anaemia is a serious public health concern, present mainly in African countries (Makani *et al* 2007 & Rees *et al* 2010). The World Health Organization (WHO) estimates that 300,000 children are born of sickle cell disease each year, 75% of whom are in sub-Saharan Africa (Silver-Nunes & Ferreira 2007; Roucher *et al* 2012). Malaria remains a menace and is a public health concern in Nigeria, because it impacts on the health of the populace, affects income and capital which in turn constitutes a huge burden on the dwindling economy and result in poor health outcomes and an increasing severity of diseases among patients with sickle cell anaemia (Carrington, 2001 & WHO 2021).

Statement of problem

Despite the various interventions introduced by WHO, UNICEF, governmental and non-governmental organizations, malaria still remains a disease of public health concern since it continuously inflicts tremendous medical, social and economic burden on human population resulting in millions of death globally (WHO 2011; Minakawa *et al*, 2006). Malaria accounts for a quarter proportion of malaria linked morbidity and mortality in sickle cell patients. Some sickle cell patients are symptomatic while some are asymptomatic of *Plasmodium falciparum* malaria. Individuals with sickle cell anaemia are more vulnerable to life threatening malaria in malaria endemic countries hence, require hospitalization. Malaria infection causes haematological derangement hence patient with HbSS had a least chance of surviving malaria infection because even low-level malaria infection can precipitate severe anaemic crises that would likely prove fatal without rapid access to blood transfusion services (Uyoga *et al*, 2022). Malaria infection could lead to changes in the haematological status alongside other conditions such as anaemia, thrombocytopenia, leukocytosis, leukopenia, lymphocytosis, eosinophilia and neutropenia (Surve *et al* 2017). Thrombocytopenia is among the major haematological aberrations frequently observed among malaria patients and usually disappears when the malaria infection is treated (Ifeanyichukwu & Esan 2014). Parasite multiplication results in decreased haematocrit level due to rupture of the red blood cells during release of the different stages of maturing parasites (Akinosoglou *et al* 2012). However, the severity of malaria anaemia, in which the haematocrit level may approach 15% or less, does not correlate with the degree of parasitaemia and is often far less in excess of what can be accounted for by the loss of infected red blood cells (iRBCs) alone

(Dondorp *et al* 1999 & Das *et al* 1999 & Akinosoglou *et al* 2012). Therefore, this must by inference, include increased destruction of both infected and uninfected cells and implicate decreased erythropoiesis or potential miscalculation of actual parasitaemia due to sequestered parasite population in the deep vasculature of subcutaneous tissues (Nakazawa *et al* 1995 & Akinosoglou *et al* 2012).

Thrombocytopenia is one of the most persistent features of severe malaria, found in approximately 50–80% of malarial patients (Maina *et al* 2010 & Shaikh *et al* 2009). Normal platelet count in combination with a normal C-reactive protein (CRP) usually excludes the diagnosis (Alfandari *et al* 1996 & Patel *et al* 2004). Several mechanisms have been proposed for the low platelet counts observed in malaria. Demonstration of high molecular weight Von Willebrand factor in the plasma of patients suggested that thrombocytopenia in malaria is associated with endothelial damage and isolated platelet consumption (Horstmann & Dietrich 1989). Acute *P. falciparum* malaria also appears to activate or derange the coagulation pathways by diverse mechanisms (Francischetti *et al* 2007 & Mohanty *et al* 1997). Seventeen per cent (17%) of cases show evidence of intravascular coagulation (Sharma *et al* 1992) whilst generalized bleeding or disseminated intravascular coagulopathy (DIC) are rare in these patients, despite accompanying thrombocytopenia (Srichaikul *et al* 1975 & Clemens *et al* 1994). White blood cell counts during malaria are generally characterized as being low to normal (McKenzie *et al* 2005; Tangpukdee *et al* 2008 & Taylor *et al* 2008). Observations show that WBC count decreases to its minimum at roughly the same time that fever begins and infection becomes detectable by microscopy (Rzepczyk *et al* 1996 & Church *et al* 1997). WBC counts have been used for the microscopic estimation of parasitaemia (Greenwood & Armstrong 1991) (even though ultimately found wanting), while automated detection of malaria pigments in WBC has been utilized for malaria diagnosis (Hanscheid *et al* 2001).

Since diagnosis of sickle cell anaemia is often overlooked and delayed until the disease becomes chronically manifested, studies could not have linked -malaria deaths in undiagnosed sickle cell anaemia patients resulting in dearth of information in the study location. Although, several epidemiological studies have been carried out on the prevalence of malaria in most parts of Taraba State, no research study have been carried out on *Plasmodium falciparum* malaria infection in sickle cell patients in the study area resulting in limited knowledge related to malaria, thus hindering appropriate and effective malaria intervention program to the targeted vulnerable population.

MATERIALS AND METHODS

Study Area

The study was carried out in Taraba State, located in the north-eastern part of Nigeria. The state lies within the coordinates $8^{0}00$'N10^{0}'E with total area of 54,437km and the total population of 2,294,800 (National Population Commission, 2017). The river Taraba, Benue, Ibi and Donga which arises from the Cameroun Mountain supplies the state with adequate water supplies for its agricultural activities. The climate of the state is tropical with vegetation characterized by a typical Guinea Savannah. There are two distinct seasons, the wet and dry season. The residents of the state are mostly involved in commercial and subsistence farming and in livestock production. Communities living on the banks of the rivers engage in fishing all year round. Other occupational activities include: pottery, cloth-weaving, dyeing, mat-making, carving, embroidery and blacksmithing.

The Mumuye, Fulani, Jenjo, Wurkum and Kona tribes are predominantly located in the northern part of the state. While the Jukun, Chamba, Tiv, Kuteb and Ichen are the tribes that inhabits the southern parts of the state.

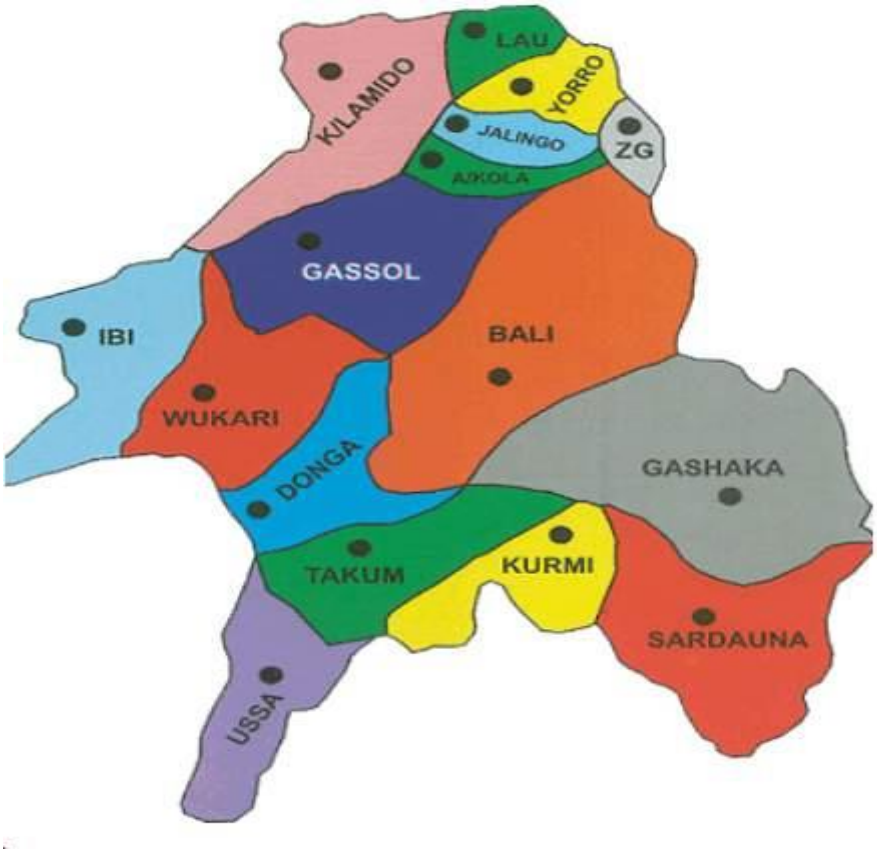

Fig 1: Map of Taraba State showing the selected study areas

Study Design

This was a cross-sectional research study designed to determine the haematological derangements due to *Plasmodium falciparum* among patients with sickle cell anaemia in health facilities in three senatorial zones in Taraba State. Sickle cell anaemia (SS) patients with *Plasmodium falciparum* infection will serve as the test subjects while patients with the sickle cell trait (AS) without *Plasmodium falciparum* infection will serve as the control.

Research Instrument

Structured questionnaire was used to collect information on the respondents' age, gender, occupation status, educational status, use of malarial chemoprophylaxis, use of long lasting insecticide treated nets and proximity of residence to mosquito breeding sites.

Informed consent

Informed consent for participation is sought from all participants according to the standards for human experimentation and the Helsinki declaration.

Study Population

The study population comprises all consenting patients who present themselves in the Out-Patients Department (OPD) in designated hospitals and Primary Health Care Centres with various ailments from April 2022 to April 2024.

Sample size determination

The method of Sapoka (2006) was used to determine the sample size at 0.05 significant levels.

$N = \frac{z^2pq}{d^2}$

Where:

N= Desired sample size

z^2= Standard normal deviate set at 1.9^2

P= Proportion in the target population estimated to have a particular characteristic.

q= 1-p (either the patient has or does not have the characteristics)

d= Degree of accuracy set at 0.05.

Substituting the numbers into the formula

$$N=\frac{1.9^2 \times 820 \times 0.5}{0.5^2}$$

$$=\frac{3.61 \times 830 \times 0.5}{0.0025}$$

$$=\frac{1498.15}{0.0025}$$

$$=599.260$$

The calculated sample size N was approximately 600

Ethical Permission

Ethical permission was obtained from the ethical committee of the State Ministry of Health and the directors of the health facilities where blood specimens will be collected.

Specimen collection

Blood samples was collected from sickle cell consenting participants in the three senatorial zones who have not received any anti-malarial drugs for the past two months but with clinical presentation of fever, headache, rigors, vomiting, diarrhea, general malaise, weakness, enlarged spleen and liver. The method of sample collection was by venipuncture (Cheesebrough, 2006). A 10.0ml of blood was collected aseptically into labeled EDTA containers.

Screening of Blood Samples

Blood samples was introduced into acetate paper and place in the gel electrophoresis machine to determine the genetic status of the patient. All blood samples carrying the sickle cell traits (AS) and the sickle cell anemia (SS) was be screened for *Plasmodium falciparum* infection using the rapid diagnostic test (RDT). The RDT test that was positive for malaria was further subjected to the gold standard microscopy for malaria parasite using the thick and thin blood films flooded with Giemsa stain and examined under the x100 objective lens microscope. A rough estimate of parasitaemia was made from the positive blood films. The level of parasitemia was quantified as low (+), moderate (++) and high (+++). Blood samples showing large ring stage of *Plasmodium falciparum* was further processed for other haematological parameters (WHO, 2022).

Preparation of Thin Blood Films

Thin blood film was prepared according to the method described by Cheesbrough (2006) and Baker *et al* (2007). A drop of blood was placed on a clean grease free microscope slide, about 1cm from one end of the slide and a spreader with smooth edge was placed in front of the drop of blood inclined at angle 45^0. The spreader was drawn backward to make contact with the blood. A quick forward movement was made to enable the blood spread out. This film was made to cover about half of the slide and to assume a tongue shape. The thin film was air-dried and labeled accordingly.

Haematological parameter was carried out using the haematological auto-analyzer (Sysmex XTI 2000). The parameters include the haemoglobin (Hb), red blood cell (RBC) count, means corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), mean corpuscular haemoglobin concentration (MCHC), total white blood cell (WBC) count, differential count, total platelet count and the absolute eosinophil count (AEC).

Hemoglobin concentration was determined based on cyanomethaemoglobin reaction method by Baure (1980) as adopted by Chikezie (2009). Packed cell volume (PCV) was measured using whole blood in 10µl capillary pipette and centrifuged at 3000rpm for 30 minutes. The packed cell volume was read with a haematocrit reader and the result was recorded as normal range (men 40-52%, women 37-47%). Wintergreen's method was used to estimate erythrocyte sedimentation rate (ESR) according to the method described by Tishkowski & Gupta (2022).

STATISTICAL ANALYSIS

The data obtained from this study was entered into Microsoft Excel and exported to Statistical Package for Social Sciences (SPSS) version 20.0 for data analysis. Chi

square (χ^2) test was used to compare the relationship between malaria infection and demographic profiles of the participants.
Pearson correlation coefficient was also used to find the relationship between malarial infection and haematological parameters. The t-test was used to differentiate haematological parameters of patients examined.

RESULTS

Distribution of Plasmodium falciparum in Relation to three Senatorial Zones

Table 1 shows the distribution of *Plasmodium falciparum* in relation to 3 senatorial zones. Results obtained indicated *Plasmodium falciparum* infection in South zone is 29.1%, Central zone had 19.0.1% and North zone had 12.3. The degree of distribution was significant for *Plasmodium falciparum* infection (χ^2= 90.754, P<0.05).

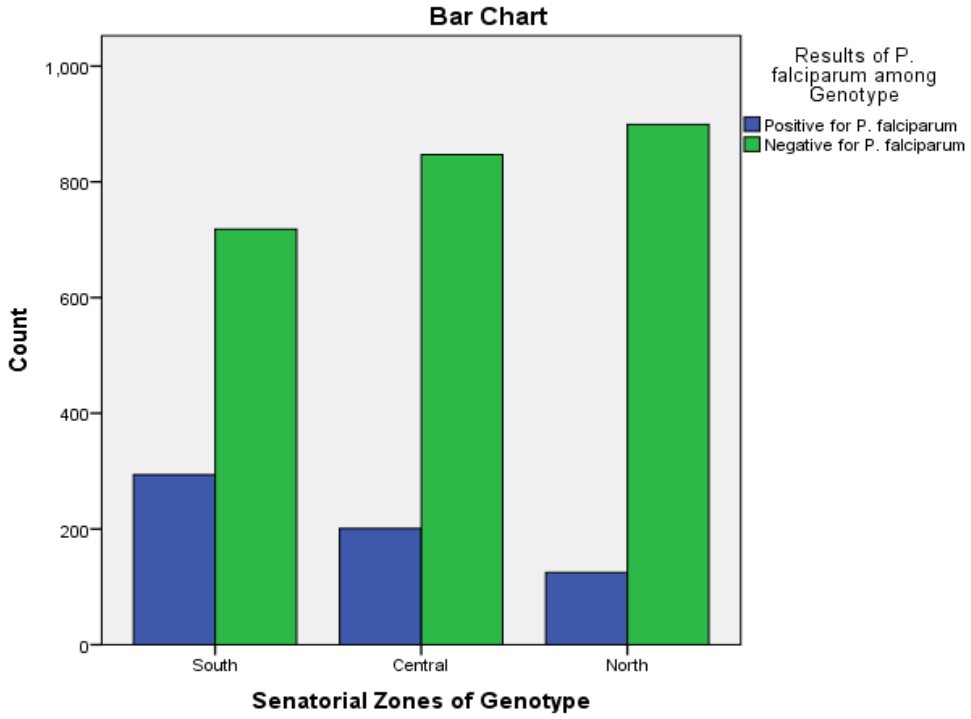

Chart 1: Distribution of malaria infection in the three senatorial zones of Taraba state.
χ^2 = 90.754; df=2, P <0.05 for distribution of *P. falciparum*

Distribution of malaria infection among different genotypes according to gender

Table 8 shows the distribution of malaria infection among different genotypes according to gender. Results indicated Male genotypes were AA genotype (83.4%), AS (7.3%) and SS (9.3%). The female genotypes were AA (85.0%), AS (7.2%) and SS (7.8%). The degree of distribution of malaria infection among genotypes was not significant for gender-related (χ^2= 0.436, P>0.05).

Table 2: Distribution of Malaria infection among different genotypes according to gender

Gender	Overall Number Examined	Genotype AA No Infected (%)	AS No Infected (%)	SS No Infected (%)	Total Number Infected (%)
Male	1419	251(17.6)	22(1.5)	28(2.0)	301(21.2)
Female	1665	271(16.2)	23(1.3)	25(1.5)	319(19.2)
Total	3084	522(16.9)	45(1.5)	53(1.7)	620(20.1)

χ^2 = 0.436; df=1, P >0.05 for distribution of Malaria infection of age-related

Distribution of Malaria infection among different genotypes according to age

Table 9 shows the distribution of malaria infection among different genotypes according to age. Results obtained indicate age group 1-10yrs old with AA genotype had 76.7%, AS had 9.7%, SS had 13.6%, 11-20yrs old with AA genotype had 83.3%, AS had 8.7%, SS had 8.0%, 21-30yrs old with AA genotype had 92.4%, AS had 3.2%, SS had 4.4%, 31-40yrs old with AA genotype had 87.8%, AS had 6.1%, SS had 6.1% and >40yrs old with AA genotype had 87.5%, AS had 8.3%, SS had 4.2%. The degree of distribution of malaria infection among genotypes was significant for age-related genotype (χ^2= 19.197, P<0.05).

Table 3: Distribution of Malaria infection among different genotypes according to age

Age group	Total No Examined	AA No Infected (%)	Genotype AS No Infected (%)	SS No Infected (%)	Total Number Infected
1-10	736	158(76.7)	20(9.7)	28(13.6)	206(28.0)
11-20	704	125(83.3)	13(8.7)	12(8.0)	150(21.3)
21-30	637	146(92.4)	5(3.2)	7(4.4)	158(24.8)
31-40	650	72(87.8)	5(6.1)	5(6.1)	82(12.6)
>40	657	21(87.5)	2(8.3)	1(4.2)	24(3.7)
Total	3084	522(16.9)	45(1.5)	53(1.7)	620(20.1)

χ^2 = 19.197; df=4, P<0.05

4.1.10 Distribution of Malaria infection among different genotypes according to marital status

Data in Table 10 shows the distribution of Malaria infection among different genotypes according to marital status. Results obtained, indicated Single genotypes with AA genotype had 81.2%, AS had 8.0%, SS had 10.8%, Married genotypes with AA genotype had 87.7%, AS had 5.3%, SS had 7.0%, Widow/Widower genotypes with AA genotype had 83.0%, AS had 8.0%, SS had 8.9% and Divorced genotypes with AA genotype had 82.8%, AS had 9.0%, SS had 8.3% respectively for distribution of malaria infection among genotypes according to marital status. The degree of distribution of malaria infection among genotypes was not significant for marital status-related (χ^2= 3.756, P>0.05).

Table 4: Distribution of malaria infection among different genotypes according to marital status

Marital Status	Total No Examined	AA No Infected (%)	Genotype AS No Infected (%)	SS No Infected (%)	Total No Infected
Single	965	145(14.8)	14(1.4)	16(1.6)	175(18.1)
Married	906	164(18.1)	10(1.1)	13(1.4)	187(20.6)
Widow/Widower	479	93(19.4)	9(1.8)	10(2.0)	112(23.4)
Divorced	734	120(1.6)	12(0.2)	13(1.7)	145(19.8)
Total	3084	522(16.9)	45(1.5)	53(1.7)	620(20.1)

χ^2 = 3.756; df=3, P>0.05 for distribution of Malaria infection of marital status-related

4.1.11 Distribution of Malaria infection among different genotypes according to Educational status

Data in Table 10 shows the distribution of Malaria infection among different genotypes according to Educational status. Results obtained, indicated Non-educated genotypes with AA genotype had 77.7%, AS had 8.9%, SS had 13.4%, Primary genotypes with AA genotype had 84.8%, AS had 7.9%, SS had 7.3%, Secondary genotypes with AA genotype had 86.7%, AS had 6.3%, SS had 7.0% and Tertiary genotypes with AA genotype had 91.9%, AS had 4.5%, SS had 3.6% respectively for distribution of malaria infection among genotypes according to educational status. The degree of distribution of malaria infection among genotypes was significant for educational status-related (χ^2= 13.460, P<0.05).

Table 5: Distribution of Malaria infection among different genotypes according to educational status

Educational Status	Total No Examined	AA No Infected (%)	Genotype AS No Infected (%)	SS No Infected (%)	Total No Infected (%)
Non educated	587	157(26.7)	18(3.0)	27(4.6)	202(34.4)
Primary	765	139(18.2)	13(1.7)	12(1.5)	164(21.4)
Secondary	804	124(15.4)	9(1.1)	10(1.2)	143(17.7)
Tertiary	928	102(11.0)	5(0.5)	4(0.4)	111(11.9)
Total	3084	522 (83.9)	45(7.4)	53(8.7)	620(20.1)

χ^2 = 13.460; df=3, P<0.05 for distribution of Malaria infection of educational status-related.

4.1.12 Distribution of Malaria infection among different genotypes according to Occupational status

Data in Table 10 shows the distribution of Malaria infection among different genotypes according to Occupational status. Results obtained, indicated Artisan genotypes with AA genotype had 78.3%, AS had 10.1%, SS had 11.6%, Trader genotypes with AA genotype had 84.6%, AS had 6.8%, SS had 8.6%, Farmer genotypes with AA genotype had 86.0%, AS had 7.6%, SS had 6.4%, Students genotypes with AA genotype had 84.6%, AS had 5.8%, SS had 9.6% and Civil servant genotypes with AA genotype had 90.7%, AS had 3.7%, SS had 5.6% respectively for distribution of malaria infection among genotypes according to occupational status. The degree of distribution of malaria infection among genotypes was not significant for occupational status-related (χ^2= 6.656, P>0.05).

Table 6: Distribution of Malaria infection among different genotypes according to Occupational status

Occupational Status	Total No Examined	AA No Infected (%)	Genotype AS No Infected (%)	SS No Infected (%)	Total No Infected
Artisan	569	101(78.3)	13(10.1)	15(11.6)	129(22.7)
Trader	563	137(84.6)	11(6.8)	14(8.6)	162(28.7)
Farmer	700	147(86.0)	13(7.6)	11(6.4)	171(24.4)
Students	650	88(84.6)	6(5.8)	10(9.6)	104(16.0)
Civil servant	602	49(90.7)	2(3.7)	3(5.6)	54(9.0)
Total	3084	522 (83.9)	45(7.4)	53(8.7)	620(20.1)

χ^2 = 6.656; df=4, P>0.05 for distribution of Malaria infection of occupational status-related

Table 13: Mean of Parasitized and Non parasitized Subjects

Cells	Mean of Parasitized	Mean of non-parasitized	T-test	P-value
PCV	0.27	0.45	0.284	0.068
TWBC	3.04	3.22	3.647	0.017
Neutrophils	43.64	47.2	20.794	0.002
Eosinophils	1.73	1.52	4.847	0.007
Basophils	0.10	0.00	11.35	0.000
Platelets	90.0	110.00	30.378	0.000
ESR	29.91	27.55	30.017	0.000
Lymphocytes	30.21	34.91	21.359	0.003
Monocytes	1.29	1.32	1.361	0.170

Table 13 shows the mean values of the heamatological parameters in malaria parasitized and non-parasitized subjects. PCV (t=0.284, p=≥0.05 and monocytes (t=1.361, p=≥0.05) were not statistically significant.). TWBC (T=3.647, P=≤0.05), neutrophils (t=20.794, p=≤0.05), ESR (t=30.017, p=≤0.05), eosinophil (t=4.847, p≤0.007), basophil (t=11.35, p=≤0.000), platelet (t=30.378, p=≤0.000), lymphocytes = (t=21.359, p≤0.003) were statistically more significant. among the non-parasitized when compared to the parasitized patients.

DISCUSSION

Malaria and sickle cell anaemia are major public health concern because they are attributed to high rates of morbidity and mortality in sub-Saharan Africa and especially among citizens with low socio-economic status and illiteracy.

The current study corroborates with the research findings of previous researchers on the endemicity of malaria infection in different communities in Nigeria. The prevalence of 620 (20.1%) falls within the Nigerian malaria risk map estimates of less than 20% in certain zones to more than 70% in other zones (Okonko *et al* 2010). The 20.1% prevalence is lower than those reported in previous study in Akure in Southwestern Nigeria and among rural inhabitants of Gabon (Awosulu *et al*., 2019 & Woldearegal *et al*., 2019). The low prevalence is attributed to the use of local/indigenous plants and tea as malaria prophylactic treatments and reduced mosquito breeding sites due to the dry weather condition.

High malaria infection 522 (19.9%) was recorded in the AA haemoglobin variant than in the AS 45 (1.5%) and the SS 53 (1.7%). This is consistent with the results among Kenyan children (Sultana *et al*., 2017), among children in Korea (Kuesap & Na-Bangchang 2018), among children in Jos (Njila *et al.*, 2022) and in Yemen (Albiti & Nsiah., 2014). The current result from this study and previous study shows that malaria infection is low for the HBSS (Kepha *et al*., 2016 & Ebadan et al., 2017). The high prevalence of malaria in the AA haemoglobin variant as compared to the SS variant may be due to the fact that the red blood cells create favorable environment for the Plasmodium parasite to thrive than the SS genotype. This could be due to the high rate of oxygen consumption and a large amount of haemoglobin ingested in the peripheral blood during the mosquito vector replication stage. (Njila *et al*., 2022, Albiti *et al* 2014 & Ebadan *et al* 2017).

Gender distribution of malaria infection reveals that males have higher infection301 (21.2%) than their female counterparts (19.2%). this agrees with previous research findings from other malaria endemic areas in Nigeria (Gebretsadik *et al* 2018 & Escobar *et al*., 2020). The mosquito vector is mostly active in its biting activities in the night when males are engaged in outdoor activities that exposes them to the mosquito bites, they are move without wearing clothes that covers/protects them from mosquito bites and they are less concerned about malaria prevention than the females.

The age-related prevalence of malaria infection shows that malaria was higher in

the 1-10yrs old 206 (28.0%), 11-20yrs old 150 (21.3%) and 21-30yrs 158(24.8%) than the 31-40yrs old 82(12.6%) and the >40 yrs old 24 (3.7%) in all the haemoglobin variants. This agrees with research findings of 97 (53.9%) among ages 1-10yrs by Ibrahim *et al* (2023) in rural southwestern Nigeria. According to WHO (2018), children between ages 1-5yrs are more susceptible to malaria infection and this could be attributed to low level of immunity while children between 6-10yrs suffer malaria infection due to exposure to the mosquito vector by playing in stagnant water bodies habouring the mosquito vector, and playing without clothes. Malaria infection decreases with age (Ibrahim *et al* 2023).

Concerning education related prevalence, this study revealed that malaria infection is higher among the non-educated subjects 202 (34.4%) than the educated subjects, primary 164 (21.4%), secondary 143 (17.7%) and tertiary 111 (11.9%). This agrees with the findings of Obimakinde *et al* (2018) who revealed that non educated have high malaria infection than the educated. The non-educated are not knowledgeable about the preventive practices of malaria infection. They engage in outdoor activities especially in the evenings and night during the active biting period of the female anopheles mosquito.

Result from this study shows that malaria infection is high among low-income earners such as traders' 167 (28.7%), farmers 171 (24.4%) and artisans 129 (22.7%) than students 104 (18.0%) and civil servants 54 (9.0%). This agrees with the findings of Obimakinde *et al* (2018). Low-income earners are mostly exposed to mosquito bites in their daily quest for survival. Majority of them work bare-bodied and late into the night. While the students and civil servants make use of mosquito repellant creams, socks, long sleeves and sleep under long lasting insecticide treated nets to protect themselves against mosquito bites.

This study revealed that malaria infections along with other co-infections may elicit haematological changes. The result of the present study shows that PCV, ESR and platelets were out of normal ranges in malaria infections when compared to the control (WHO, 2015). PCV and platelets were significantly lower than in malaria patients than in the control. A low PCV in malaria infected patients indicates anaemia due to mechanical destruction of parasitized red blood cells as well as defective erythrocytes.

A significant lower platelets count was observed among the infected subject this could be due to hyper-reactive splenomegaly especially in *Plasmodium falciparum* malaria, combined with humoral immune response may have contributed to lower platelet counts in this study. This differs from the study of Echonwere-Uwikor *et al*., 2022 in Port Harcourt, Rivers State where there is increased platelet counts. But agrees with the findings of Sasithon *et al* (2007) in India and Elkanah *et al* (2020) in Ardo-kola L.G.A, Taraba state where low platelet counts were observed in malaria infected patients in rural communities. The low platelet count and PCV in the patients conform with the report of Bhawna (2013) whose report showed parasitemia and haematological alterations in malaria infected patients. The report from this finding supports the works of other researchers in different parts of Nigeria but differ with the report from Jos North L.G.A in Plateau state, where there was no significant difference between haematological parameters of *P. falciparum* infected and non-infected patients (Chuban, 2009). These studies from the highly affected zone shows that infected patients tend to have a lower platelet count and PCV. Durand et al (2005) reported a low PCV and platelet count in malaria infected patients indicating that anaemia might be involved. haematological parameters as an investigating tool for cases of early malaria infection may help in early detection of complications associated with severe malaria infection in order to help in patients' management, treatment and

prevention of mortality that may result from complication. This current study on the haematological derangements in malaria infected blood samples have been reported by Alexander et al., (2009) whose study revealed that infected patients tend to have a lower platelet count and PCV. The mean values of haematological parameters between the malaria infected and non-infected patients revealed that these parameters should be considered in malaria infections as infected patients tends to have lower haematological values than the control patients.

CONCLUSION

The findings from this study reveals that malaria infection caused by *Plasmodium falciparum* is endemic in different parts of Taraba state and it impacts on the haematological parameters of the patients. Comparing the diagnostic tools, PCR was more sensitive and specific than microscopy and RDT. The different family clones of *Plasmodium falciparum* using *msp-1* and *msp-2* marker is indicative of genetic diversity of *Plasmodium falciparum.*

Contribution to knowledge

The current study which is believed to be the first attempt to document systematically the distribution of genotypes and quantitative analysis of Plasmodium falciparum among sickle cell anaemia patients in three senatorial zones in Taraba state has the following contributions to knowledge.

1. The finding has shown that Taraba state has a high distribution of sickle cell anaemia patients (both diagnosed and undiagnosed). The data collected could provide baseline information necessary for reducing and eliminating this genetic disorder in the state.
2. The significant association in the prevalence of malaria in HbAA, HbAS and HbSS genotype variant could be used as a criterion for including malaria prophylaxis in the treatment regime of sickle cell patients.
3. The haematological derangements observed calls for regular medical checkups and routine blood testing (FBC) among patients suffering from malaria and sickle cell anaemia.
4. The high sensitivity of the PCR over the RDT and the gold standard microscopy calls for the reduction of the cost of PCR testing in early testing and detection of the malaria parasite.
5. The low sensitivity of the RDT should be a call to WHO to liaise with manufacturers, clinicians and laboratory scientist to produce a more accurate and cheaper RDT device that can detect malaria parasite at very low density.

RECOMMENDATION

Based on the findings of this study, the following recommendations were made:

1. There is need to introduce genetic counselling and testing in all health facilities in the state.
2. There is need to intensify the malaria control programs by the PMI, USAID and all donor organizations and improve strategies to reduce/eradicate malaria morbidity and mortality among patients with sickle cell anaemia.
3. Regular public enlightenment campaigns, health education workshops and mass media campaign should be organized to educate the populace on the risk factors of malaria infection.
4. Monthly environmental sanitation should be organized and embarked upon to keep all drainages clean and clear the bushes around homes.
5. There should be yearly distribution of mosquito repellants and long lasting insecticide treated nets.
6. The health sector should advocate the wearing of protective clothing.
7. Sickle cell anaemia patients should be placed of regular malaria prophylaxis at all times.
8. The findings on the genetic diversity of *Plasmodium falciparum* could be a useful tool in the surveillance program for monitoring drug resistant malaria

infections, development of new drugs and vaccines against malaria parasite.

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