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 distribution of malaria infection among the different genotypes in three senatorial zones in Taraba state. The study employed a community and laboratory based cross sectional study. The electrophoresis machine was used to determine the genotypes of the research subjects while Rapid diagnostic technique and the gold standard microscopy was used to determine the prevalence of malaria infection. The haematology auto-analyzer (Sysmex XTI 2000) was used to determine the haematological parameters of the subjects. A total of 3084 blood samples was obtained by venepuncture. The distribution of the genotypes is AA 1721 (55.8%), AS 966 (31.3%) and SS 397 (12.9%). The overall prevalence of malaria was 620 (20.1%). 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%). Our finding in the 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, genotypes, distribution, senatorial zones, 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.
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 (Depetriss-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; Pectar 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). 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°00'N10°E with total area of 54,437km² 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.

Study Design
This study employed a cross-sectional research study designed to quantify the level of *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,
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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 of all consenting patients who present themselves in the Out-Patients Department (OPD) in designated hospitals and Primary Health Care Centres with various ailments from December 2022 to November 2023.

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

\[ N = \frac{1.9^2 \times 0.820 \times 0.5}{0.0025} \]

\[ = 3.61 \times 0.830 \times 0.5 \]

\[ = 1498.15 \]

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 consenting participants in the three senatorial zones. Blood samples will be collected from the participants regardless of their age, gender, religion, occupational and educational status, 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 will be by venepuncture (Cheesebrough, 2006). A 10.0ml of blood will be 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).

Hb Electrophoresis for Screening of Sickle Cell Trait (AS) and Sickle Cell Anaemia (SS)
The collected blood samples were centrifuged at 1200g for 5 minutes, the electrophoresis tank is prepared with TEB buffer, and the cellulose acetate was soaked in the buffer for 5 minute. The well plate
was filled with diluted samples and covered with glass slide to prevent evaporation. A second well plate was loaded with Zip Zone Prep solution. Both was applied to a blotting paper and the cellulose acetate strip was blotted twice between two layers of clean blotting paper. The cellulose acetate strip was not allowed to dry. The applicator was loaded by depressing the tips into the sample wells twice and the cellulose acetate plates was placed across the bridges. After 25 minutes of electrophoresis, the cellulose acetate was immediately transferred to ponceau S, fixed and stained for 5 minutes. Excess stain was removed by washing for 5 minutes in the first acetic reservoir. The result was interpreted according to the manufacturer’s instruction.

Preparation of Thin Blood Films for Malaria Investigation
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°. 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.

Parasite/µl= \( \text{number of parasites counted x8000 white cells/µl} \)

\( \text{Number of white cells counted} \)

Where 8000 = putative means of leucocytes. The level of parasitemia will be quantified as low (+), moderate (++) and high (+++).

**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 (\( \chi^2 \)) test was used to compare the relationship between infection and demographic profiles of the participants.

**RESULTS**

**Distribution of genotype in 3 Senatorial Zones**
Table 1 shows the distribution of genotype in the 3 Senatorial Zones. Results obtained indicated south zone had genotype AA (56.0%), AS (31.5%) and SS (12.5%). The central zone had genotype AA (51.3%), AS (32.7%) and SS (16.1%). North zone had genotype AA (60.2%), AS (29.7%) and SS (10.0%). The degree of distribution was significant for genotype in the 3 senatorial zones (\( \chi^2 = 24.092, P<0.05 \)).

<table>
<thead>
<tr>
<th>Senatorial Zones</th>
<th>AA</th>
<th>AS</th>
<th>SS</th>
<th>Total Examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>South</td>
<td>567</td>
<td>319</td>
<td>125</td>
<td>1012</td>
</tr>
<tr>
<td>Central</td>
<td>542</td>
<td>345</td>
<td>170</td>
<td>1056</td>
</tr>
<tr>
<td>North</td>
<td>612</td>
<td>302</td>
<td>102</td>
<td>1016</td>
</tr>
<tr>
<td>Total</td>
<td>1721</td>
<td>966</td>
<td>397</td>
<td>3084</td>
</tr>
</tbody>
</table>

\( \chi^2 = 24.092; \text{df}=2, P <0.05 \) for distribution of Genotype
Distribution of genotype in relation to gender
Table 2 shows the distribution of genotype in relation to sex. Results obtained indicated male had genotype AA (44.6%), AS (48.0%) and SS (47.3%). The Females genotype AA (55.3%), AS (52.0%) and SS (53.0%) respectively. The degree of distribution was not significant for genotype of sex-related ($\chi^2=2.791$, $P>0.05$).

<table>
<thead>
<tr>
<th>Gender</th>
<th>AA</th>
<th>Genotype AS</th>
<th>SS</th>
<th>Total Examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>769(44.6)</td>
<td>462(48.0)</td>
<td>188(47.3)</td>
<td>1419</td>
</tr>
<tr>
<td>Female</td>
<td>952(55.3)</td>
<td>504(52.0)</td>
<td>209(53.0)</td>
<td>1665</td>
</tr>
<tr>
<td>Total</td>
<td>1721(55.8)</td>
<td>966(31.3)</td>
<td>397(12.9)</td>
<td>3084</td>
</tr>
</tbody>
</table>

$\chi^2 = 2.791$; df=1, $P>0.05$ for distribution of Genotype

Distribution of genotype in relation to age
Table 3 shows the distribution of genotype in relation to age. Results obtained indicated age group 1-10yrs genotype had AA (55.0%), AS (25.1%) and SS (20.0%) respectively. 11-20yrs had genotype AA (54.8%), AS (30.8%) and SS (14.3%). The 21-30yrs had genotype AA (54.5%), AS (34.4%) and SS (11.1%). 31-40yrs had genotype AA (51.2%), AS (39.8%) and SS (9.0%). While the >40yrs had genotype AA (70.0%), AS (24.1%) and SS (6.0%) respectively for distribution of genotype in relation to age group. The degree of distribution was significant for age-related genotype ($\chi^2= 99.947$, $P<0.05$).

<table>
<thead>
<tr>
<th>Age</th>
<th>AA</th>
<th>Genotype AS</th>
<th>SS</th>
<th>Total Examined</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
<td>405(55.0)</td>
<td>185(25.1)</td>
<td>146(20.0)</td>
<td>736</td>
</tr>
<tr>
<td>11-20</td>
<td>386(54.8)</td>
<td>217(30.8)</td>
<td>101(14.3)</td>
<td>704</td>
</tr>
<tr>
<td>21-30</td>
<td>347(54.5)</td>
<td>219(34.4)</td>
<td>71(11.1)</td>
<td>637</td>
</tr>
<tr>
<td>31-40</td>
<td>333(51.2)</td>
<td>259(39.8)</td>
<td>58(9.0)</td>
<td>650</td>
</tr>
<tr>
<td>&gt;40</td>
<td>250(70.0)</td>
<td>86(24.1)</td>
<td>21(6.0)</td>
<td>357</td>
</tr>
<tr>
<td>Total</td>
<td>1721(55.8)</td>
<td>966(31.3)</td>
<td>397(12.9)</td>
<td>3084</td>
</tr>
</tbody>
</table>

$\chi^2 = 99.947$; df=4, $P<0.05$ for distribution of Genotype

The results obtained indicates *Plasmodium falciparum* infection in the South zone is 29.1%, Central zone had 19.0.1% and North zone had 12.3. The result also indicated that male genotypes were AA genotype had malaria infection of (83.4%), AS (7.3%) and SS (9.3%). The female genotypes show malaria infection of AA (85.0%), AS (7.2%) and SS (7.8%).

The results obtained revealed that age group 1-10yrs old with AA genotype had malaria infection of 76.7%, AS had malaria of 9.7%, SS had malaria 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%.

Marital status revealed that single genotypes with AA genotype had malaria infection of 81.2% AS had 8.0%, SS had 10.8% Married genotypes with AA had 87.7%, AS had 5.3%, SS had 8.3%.

Malarial infection result indicated that non-educated patients with AA genotype had 77.7% AS had 8.9%, SS had 13.4% primary genotypes with AA had 84.8%, AS had 7.9%, SS had 7.3%, secondary genotype 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%.

Malaria infection according to patients occupation indicated that artisan with the
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AA genotype had 78.3% SS had 16.6%. Traders with AA genotype had 84.6%, AS had SS had 7.6%, SS had 6.4%. Students with AA genotype had 84.6%, AS had 9.6% and Civil servant with AA genotype had 90.7%, AS had 3.7, SS had 5.6%.

Distribution of malaria according to patients socio-demographic profile

<table>
<thead>
<tr>
<th>Socio-demographic profile</th>
<th>Overall sample examined</th>
<th>AA No. infected (%)</th>
<th>AS No. infected (%)</th>
<th>SS No. infected (%)</th>
<th>( \chi^2 )</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1419</td>
<td>251 (17.6)</td>
<td>22 (1.5)</td>
<td>28 (2.0)</td>
<td>0.436</td>
<td>0.005</td>
</tr>
<tr>
<td>Female</td>
<td>1665</td>
<td>271 (16.2)</td>
<td>23 (1.3)</td>
<td>25 (1.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-10</td>
<td>736</td>
<td>158 (76.7)</td>
<td>20 (9.7)</td>
<td>28 (13.6)</td>
<td>19.19</td>
<td>0.005</td>
</tr>
<tr>
<td>11-20</td>
<td>704</td>
<td>125 (83.3)</td>
<td>13 (8.7)</td>
<td>12 (8.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21-30</td>
<td>637</td>
<td>146 (92.4)</td>
<td>5 (3.2)</td>
<td>7 (4.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>31-40</td>
<td>650</td>
<td>72 (87.8)</td>
<td>5 (6.1)</td>
<td>5 (6.1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40</td>
<td>657</td>
<td>21 (87.5)</td>
<td>2 (8.3)</td>
<td>1 (4.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marit. status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single</td>
<td>965</td>
<td>145</td>
<td>14 (1.4)</td>
<td>16 (1.6)</td>
<td>3.756</td>
<td>0.005</td>
</tr>
<tr>
<td>Married</td>
<td>906</td>
<td>164</td>
<td>10 (1.1)</td>
<td>13 (1.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Widowed</td>
<td>479</td>
<td>93</td>
<td>9 (1.8)</td>
<td>10 (2.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separated</td>
<td>734</td>
<td>120</td>
<td>12 (0.2)</td>
<td>13 (1.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edu. Status</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Non-edu</td>
<td>587</td>
<td>157 (26.7)</td>
<td>18 (3.0)</td>
<td>27 (4.6)</td>
<td>13.460</td>
<td>0.005</td>
</tr>
<tr>
<td>Pr. sch</td>
<td>765</td>
<td>139 (18.2)</td>
<td>13 (1.7)</td>
<td>12 (1.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sec. sch</td>
<td>804</td>
<td>124 (15.4)</td>
<td>9 (1.1)</td>
<td>10 (1.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>tertiary</td>
<td>928</td>
<td>102 (11.0)</td>
<td>5 (0.5)</td>
<td>4 (0.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occu. status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artisan</td>
<td>569</td>
<td>101 (78.3)</td>
<td>13 (10.1)</td>
<td>15 (11.6)</td>
<td>6.656</td>
<td>0.005</td>
</tr>
<tr>
<td>Trader</td>
<td>563</td>
<td>137 (84.6)</td>
<td>11 (6.8)</td>
<td>14 (8.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmer</td>
<td>700</td>
<td>147 (86.0)</td>
<td>13 (7.6)</td>
<td>11 (6.4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student</td>
<td>650</td>
<td>88 (84.6)</td>
<td>6 (5.6)</td>
<td>10 (9.6)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Civil serv</td>
<td>602</td>
<td>49 (90.7)</td>
<td>2 (3.7)</td>
<td>3 (5.6)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comparison of RDT and Microscopy

A total of three thousand and eighty-four blood samples were examined using the stained blood film microscopy and the rapid diagnostic test. 596 (96.1%) was positive for the gold standard microscopy while in rapid diagnostic test, 330 (13.4%) was positive for malaria infection. This shows that the gold standard microscopy was more sensitive to malaria infection.

Comparison of RDT and Microscopy

<table>
<thead>
<tr>
<th>RDT Microscopy</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>-ve</td>
<td>+ve</td>
</tr>
<tr>
<td>Negative 2134 (86.6%)</td>
<td>2158</td>
</tr>
<tr>
<td>Positive 330 (13.4%)</td>
<td>926</td>
</tr>
<tr>
<td>Total 2464</td>
<td>620</td>
</tr>
</tbody>
</table>
| 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 revealed a high haemoglobin genotype AA 1721 (55.8%), AS 966 (31.3%) and SS 397 (12.9%). This differs with the haemoglobin distribution of AA 84 (84.0%), AS 16 (16.0%) and SS 0.0% in Buea Health district of Cameroon (Ngwengi et al 2020), and the haemoglobin genotype distribution AA 81.54%, AS 16.92% and SS 1.54% in Madonna University, Okija, Anambra state (Eledo et al 2018). Also, the AA 88.1%, AS 10.2% and SS 0.7% in Akure, Ondo.
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state, Nigeria (Akinboro et al 2016). Mustapha & Abubakar (2001) recorded high SS genotype (17.1%) in Kano metropolis and Tukur et al (2017) recorded AA (63.1%) AS (26.0%) and SS (6.8%). The high rate of AS and SS haemoglobin genotype in the study area is attributed to the fact that the research was focused in the rural areas where there is high rate of illiteracy, ignorance, early forced marriages/child birth, out of wedlock teenage pregnancies and also the lack of genetic testing facilities. While the high AA variant could be due to intermarriages between families, tribes and ethnic groups. The study recorded high haemoglobin variant among females AA (55.3%) AS (55.0%) and SS (53.0%) than males AA (44.6%), AS (48.0%) and SS (47.3%). This differs with the study of Mohammed-Nafiu et al., (2020) where more males had low haemoglobin variants among newborn infants in National Hospital Abuja. There was no explanation proffered for the gender predilection.

High prevalence was recorded in the AA genotypes 250 (70.0%) among this >40yrs while low prevalence 333 (51.2%) was recorded among 31-40 yrs group. The prevalence of AS increases with age such that 1-10yrs had 185 (25.1%), 11-20yrs recorded 217 (30.8%), 21-30yrs had 219 (34.4%), while 31-40yrs had 259 (39.8%). This agrees with the study of Weatherall & Clegg (2001), Modell & Darlison (2008), Otoikhian (2019) and Mohammed-Nafiu et al (2020). This could be attributed to high mortality associated with the SS in childhood. In this study, the SS genotypes decreases with age;1-10yrs 146 (20.0%), 11-20yrs 101 (14.3%), 21-30yrs 71 (11.1%), 31-40yrs 58 (9.0%) and >40yrs 21 (6.0%). The decrease in the SS genotype could be due to high mortality associated with SS in childhood resulting in few survivors among adults especially in rural areas where there is no routine screening, early diagnosis, blood transfusion services and other medical interventions.

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 old 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 harbouring 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.
CONCLUSION
Findings from the study revealed a high distribution of HbAS but low HbSS among the study populace despite increased awareness of genetic counselling and testing advocated by the World Health Organization. The 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.

**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.

**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.

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