IMPACT OF Plasmodium falciparum PARASITAEMIA ON SOME HEMATOLOGICAL PROFILES AMONG CHILDREN 6-59 MONTHS: A CASE STUDY OF SELECTED HOSPITALS IN MAIDUGURI, BORNO STATE, NIGERIA

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ABSTRACT
Plasmodium falciparum is responsible for millions of deaths globally, with children under five (5) years old the most vulnerable. It is associated with some haematological changes. As a result, this study was carried out to evaluate the effects of P. falciparum parasitaemia on certain haematological parameters in Malaria-aﬀected Children in Maiduguri. To ascertain the prevalence and haematological alterations brought on by infection, blood samples were taken from 421 kids during the months of December 2021 and June 2022 (7 months). Overall results show 182 (43.23%) patients were positive to malaria while 239 (56.77%) were negative. Similarly, the PCV, RBC and thrombocytes count respectively (23.95%, 2.94x10^6/µL and 147.15X10^3/µL) of the malaria positives subjects were significantly (p=0.05) lower compared to the malaria negative (34.69%, 4.0 X10^6/µL and 346.23 X10^3/µL) subjects. Furthermore, the mean WBC, lymphocytes and neutrophils respectively of the malaria positive subjects were signiﬁcantly higher compared (18.67 x10^3/µL, 59.88% and 66.05%) to the infected ones (12.92 x10^3/µL, 37.69% and 47.05%). The result also shows the mean of sex comparison of haematological parameters of children infected with malaria, with the PCV and thrombocytes of male positive subject been signiﬁcantly lower than that of the female negative children (24.40% and 145.98X10^3/µL versus (34.82% and 337.00X10^3/µL) appropriately (p=0.05), whereas the mean WBC, lymphocytes and neutrophils were signiﬁcantly higher compared to female positive subjects (17.48X10^3/µL, 59.46% and 63.95%) versus (18.64 x10^3/µL, 60.48% and 69.04%), (p=0.01, 0.05). In conclusion, malaria is highly prevalent among children, 21-30 months old in Maiduguri and it is associated with anemia, thrombocytopenia and leukocytosis.

Keywords: Plasmodium falciparum, Children, Maiduguri, Hematology

INTRODUCTION
Plasmodium species is a blood parasite of the genus Plasmodium, which causes the disease known as malaria. Of the species that infect man, Plasmodium falciparum is the predominant and deadliest in Africa (Andare-Neto et al., 2004). Malaria is a tropical illness with significant public health implications that is endemic to areas of Asia, Africa, and America. According to the World Health Organization, 335 million people worldwide were at risk of acquiring malaria (WHO, 2006). Recent data revealed that globally, there was an estimated 247 million cases of malaria in 2021, of which, Africa alone accounted for about 234 million of total cases. In the same year, malaria is responsible for an estimated 619,000 deaths globally, with Africa accounting for about 95% (593,000) of all deaths worldwide. Sadly, Nigeria has the highest prevalence (27%) and mortality (31%) rates globally (WHO, 2022). Malaria-related morbidity and mortality have a significant negative impact on economic growth and productivity. According to the CDC (2004), the direct expenses of disease, medical care, and premature mortality amount to at least 12 billion US dollars per year worldwide. The disease also accounts for about 60% of outpatient hospital admissions, 30% childhood deaths and 25% of a infant death less than 1 year in Nigeria (Ezeigwe, 2015). Previous research has shown that the hallmark of malaria infection, or haematological abnormalities, are more severe and prevalent in children with Plasmodium falciparum malaria infection. Changes in leucocyte, packed cell volume, various leucocyte counts, platelets, and disseminated intravascular coagulation (DIC) are only a few of the abnormalities that have been noted (Reyburn et al., 2007; Wickramasinghe and Abdalla, 2000). According to Chiwakata et al. (2000), there was no discernible variation in white blood cell counts between groups with and without malaria infection. Leucopenia emerged as a common finding in a patient with Plasmodium falciparum malaria when white blood cell counts can be as low as 1-2X10^9 (Berens-Rha et al., 2014). Other common findings in patients with Plasmodium falciparum malaria include lymphocytosis, leukocytosis, neutrophilia, monocytosis, and eosinophilia. Leucopenia and other changes in leucocyte proliferation have been associated with severe Malaria caused by Plasmodium falciparum (Kokori et al., 2013). Males with malaria often had lower WBC counts than females, according to Imoru et al. (2013). Therefore, the purpose of this study is to ascertain the effects of P. falciparum parasitaemia on children and how they relate to sex among the individuals in the study area.

MATERIALS AND METHODS
Study Area
The study was carried out at the pediatric outpatient department of four hospitals (University of Maiduguri Teaching Hospital, State Specialist Hospital Maiduguri, Mamman Shuwaa Memorial Hospital Maiduguri, and Umara Shehu Ultramodern Hospital Maiduguri, Borno State) within Maiduguri, Borno State, Nigeria, while Maiduguri is located at latitude 110 40’N and longitude 1305E, the state is roughly located between latitudes 100 2’N and 130 4’N and 908 E and 1404E. The northeastern Nigerian state of Borno has borders with Cameroon to the east, the Niger Republic to the north, and the Chad to the northeast. Borno state is located inside the Chad basin and occupies a large portion of it. The state of
Adamawa in Nigeria has borders with Yobe State to the north-west, Gombe State to the west, and Adamawa State to the south. Maiduguri is the Capital of Borno State and lies within the Sahel Savannah region of northeast Nigeria. The mean annual temperature and rainfall of the state is about 32°C and 650 mm respectively. The hottest periods of the year can record temperatures ranging between 30°C and 40°C in the months of March and April. It is usually cold and dry during the harmattan season that runs from November to January, with the latter being the coldest months (Borno State Ministry of Information, 2015).

Study population and sample size determination
The study population comprises patients within the age range of 6 – 59 months, admitted to the hospitals as well as patients in the General outpatients Department (GOPD). The formula given by Naing et al., (2006), was used to determine the sample size of the study.

\[ P = \left( \frac{Z_{\alpha/2}^2 \times P \times (1-P)}{MOE^2} \right)^{0.5} \]

Where: \( P \) is a simple proportion, \( Z_{\alpha/2} \) is the critical value of the Normal distribution at \( \alpha/2 \) (for example, 0.05 and 1.96 for a 95% confidence level), MOE is the alpha margin of error, and accuracy = 0.05 for the normal distribution.

Study design
The study design is a case-control study. Four hundred and twenty-one (421) children within the age of 6-59 months were enrolled in this study. Subjects were randomly selected from both in and outpatients seeking medical care in the study area. A case is defined as malaria-positive individuals while the Malaria Negative Children consist of control individuals. Socio-demographic data (age and sex) were also recorded for each of the study subjects.

Sampling procedure
Four hundred and twenty-one (421) children between the ages of 6 and 59 months who were enrolled in the study locations between December 2021 and April 2022. Parents or guardians provided their consent for their children to take part in the study. Prior to enrollment, local authorities, as well as kids and their guardians, were given information about the study’s processes and aims and were given an explanation in the local tongue. For illiterate participants and their parents or guardians, study staff members read and clarified the permission form in the local language. The participants were then given over to the lab scientists for a doctor to evaluate them clinically.

Blood sample collection and preparation
Exactly three milliliters of venous blood were transferred into vacutainer tubes containing EDTA as anticoagulant. The EDTA tubes consisting of the blood samples were gently rocked to ensure complete mixture of blood cells. This was immediately followed by the preparation of the thick and thin smears. Prepared blood smears were stained with Giemsa.

Examination of blood films was performed systematically under oil immersion using an Olympus CX21 Microscope based on WHO 2010 guidelines to confirm the status of malaria parasite.

Determination of parasite densities
Thick blood film was stained for 30 to 45 minutes using 5% Giemsa Stain. All the slides were examined using the (x100) objectives with the aid of light microscope for the asexual stage of the parasites after counting alongside 200 leukocytes. If the parasite count was less than 10 parasites/200 leukocytes; the count is continued per 500 leukocytes. The parasite density was expressed as the number of asexual parasites per ml of blood by assuming a mean normal leukocyte count of 8000/μl of blood (Gilles & Warrell, 1993). Parasitaemia (per μl) = number of parasites x 8000 / number of leukocytes.

Blood Analysis
The blood samples collected were transferred to the laboratory for the evaluation of blood profiles such as white blood cells, packed cell volume, lymphocytes, monocytes, neutrophils, eosinophils, and platelets by using Sysmex 55XN haematology, Autoanalyzer. The results were recorded alongside the findings of each subject’s data.

Statistical analysis
Data obtained were subjected to descriptive statistics using the statistical package for Social Sciences SPSS Version 22.0 and analytical software Statistics version 8.0 (Microsoft, 2003). Graphs were plotted using GraphPad Prism ver. 8. The measure of central tendencies (standard deviation, percentages) was determined. Statistical significance was set at \( P \leq 0.05 \).

RESULTS AND DISCUSSION
The result presented in Table 1 shows the demographic characteristics of the study population. A total number of 421 children were enrolled in the study out of which 182 (43.23%) tested positive, while 239 (56.77%) tested negative. Exactly 107 (25.42%) males tested positive, 141 (33.49%) males tested negative, 75 (17.81%) females tested positive, and then 98 (23.28%) females tested negative. Based on study location, MSMH (9.98%) recorded the highest prevalence of malaria infection, while UMTH (8.55%) recorded the least prevalence of malaria infection (Table 1).

Generally, parasite density count >1000 was generally low or absent across all age categories. However, children within the age bracket 21-30 months had the highest prevalence of 17.0% (31/182) with regards to PDC ≤500. Lastly, children within the age group of 11-20 months recorded the highest prevalence of 8.8% (16/182) (Table 2). The result shows that male subjects 68 (37.4%), 36 (19.8%) and 3 (1.6%) recorded the highest occurrences of PDC counts of ≤500 (mild), 501 – 1000 (moderate) and 1001 – 1500 (severe) respectively compared to their female counterparts with low prevalence of PDC ≤500 54 (29.7%), 501 – 1000 20 (11.0%) and 1 (0.5%) (Table 3).
Children with malaria had a considerably lower mean packed cell volume (23.95 ± 50) than children without the disease (34.69 ± 8.41) (t = 63.62, P < 0.01). Similarly, the mean erythrocytes (2.94 ± 1.15), and thrombocytes of malaria-parasitized subjects (147.15 ± 59.94) were significantly lower than the non-parasitized erythrocytes (4.01 ± 1.07) and thrombocytes (346.23 ± 166.12), (t = 57.73, P = 0.01), (t = 32.22, p = 0.01) (Table 4). Also, the mean leucocytes in malaria-infected male and female subjects were lower (145.98 ± 31.24, P = 0.01) (t = 23.35, P = 0.01). Moreover, the mean leucocytes in malaria-infected male and female children. The PCV counts were lower in the male and female infected groups (24.40 ± 6.81), (23.30 ± 6.00) compared with the male and female uninfected groups (34.36 ± 7.78), (t = 10.53, P = 0.01), and (38.82 ± 9.89), (t = 8.90, P = 0.01) as indicated in table 4.5. Also, the erythrocytes of malaria-infected male and female children were found to be significantly lower (2.87 ± 1.14), (3.04 ± 1.15) compared to uninfected groups (3.96 ± 1.05), (t = 7.97), (2.2), the thrombocytes of malaria parasitized male and female subject were lower (145.98 ± 53.65), (148.83 ± 68.27) compared to non-parasitized children (352.64 ± 155.82), (t = -13.14, P = 0.01), (337.00 ± 180.32), (t = 8.57, P = 0.01), as designated in table 4.5. Furthermore, the leucocytes of the infected group (17.48 ± 9.74), (18.64 ± 7.30) were higher than the uninfected groups (13.05 ± 7.97), (t = 7.94, P = 0.01), (12.72 ± 8.80), (t = 4.72, P = 0.01), (t = 8.57, P = 0.01). The result also shows that the Plasmodium falciparum parasitaemia had a significant influence on leucocytes as the mean standard deviation recorded in malaria-positive children (18.67 ± 9.86) was significantly higher compared to the mean standard deviation recorded in malaria-negative children (12.92 ± 8.30), (t = 24.05, P = 0.01). A similar finding was also obtained in agramulocytes (lymphocytes and monocytes) of malaria-positive children (59.98 ± 16.41), 13.40 ± 5.06) was significantly higher than the lymphocytes and monocytes of malaria-negative children (37.69 ± 18.65), (8.91 ± 5.90) (t = 31.24, P = 0.01) (t = 23.35, P = 0.01). Moreover, the mean standard deviation of granulocytes (neutrophils and eosinophils) of the malaria-infected group (66.05 ± 21.01), (3.69 ± 3.54) were significantly higher compared to that of the uninfected group (47.05 ± 18.96), (1.64 ± 1.28) (t = 38.36, P = 0.01), (t = 7.30, P = 0.01).

Significant differences were observed in the erythrocytogram of malaria-infected male and female children. The PCV counts were lower in the male and female infected groups (24.40 ± 6.81), (23.30 ± 6.00) compared with the male and female uninfected groups (34.36 ± 7.78), (t = 10.53, P = 0.01), and (38.82 ± 9.89), (t = 8.90, P = 0.01) as indicated in table 4.5. Also, the erythrocytes of malaria-infected male and female children were found to be significantly lower (2.87 ± 1.14), (3.04 ± 1.15) compared to uninfected groups (3.96 ± 1.05), (t = 7.97, P = 0.01), (4.07 ± 1.11), the leucocytes of malaria parasitized male and female subject were lower (145.98 ± 53.65), (148.83 ± 68.27) compared to non-parasitized children (352.64 ± 155.82), (t = -13.14, P = 0.01), (337.00 ± 180.32), (t = 8.57, P = 0.01), as designated in table 4.5. Furthermore, the leucocytes of the infected group (17.48 ± 9.74), (18.64 ± 7.30) were higher than the uninfected groups (13.05 ± 7.97), (t = 7.94, P = 0.01), (12.72 ± 8.80), (t = 4.72, P = 0.01), (t = 8.57, P = 0.01). The result also shows that the Plasmodium falciparum parasitaemia had a significant influence on leucocytes as the mean standard deviation recorded in malaria-positive children (18.67 ± 9.86) was significantly higher compared to the mean standard deviation recorded in malaria-negative children (12.92 ± 8.30), (t = 24.05, P = 0.01). A similar finding was also obtained in agramulocytes (lymphocytes and monocytes) of malaria-positive children (59.98 ± 16.41), (13.40 ± 5.06) which was significantly higher than the lymphocytes and monocytes of malaria-negative children (37.69 ± 18.65), (8.91 ± 5.90) (t = 31.24, P = 0.01) (t = 23.35, P = 0.01). Moreover, the mean standard deviation of granulocytes (neutrophils and eosinophils) of the malaria-infected group (66.05 ± 21.01), (3.69 ± 3.54) were significantly higher compared to that of the uninfected group (47.05 ± 18.96), (1.64 ± 1.28) (t = 38.36, P = 0.01), (t = 7.30, P = 0.01).

Table 1: Baseline Characteristics of the Participant

<table>
<thead>
<tr>
<th>Variables</th>
<th>Tested positive</th>
<th>Tested negative</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. enrollee age (months)</td>
<td>182(43.23%)</td>
<td>239(56.77%)</td>
<td>421(100%)</td>
</tr>
<tr>
<td>Mean</td>
<td>28.33</td>
<td>38.50</td>
<td>66.83</td>
</tr>
<tr>
<td>SD</td>
<td>11.59</td>
<td>21.66</td>
<td></td>
</tr>
<tr>
<td>Range (months)</td>
<td>6-59 months</td>
<td>6-59 months</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>107 (25.42%)</td>
<td>141 (33.49%)</td>
<td>248 (58.91%)</td>
</tr>
<tr>
<td>Female</td>
<td>75 (17.81%)</td>
<td>98 (23.28%)</td>
<td>173 (41.57%)</td>
</tr>
<tr>
<td>HOSPITAL</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UMTTH</td>
<td>36(8.55%)</td>
<td>70(16.63%)</td>
<td>106 (25.18%)</td>
</tr>
<tr>
<td>Sshm</td>
<td>39(9.26%)</td>
<td>66(15.68%)</td>
<td>105(24.94)</td>
</tr>
<tr>
<td>USUMH</td>
<td>38(9.03%)</td>
<td>67(15.91%)</td>
<td>105(24.94)</td>
</tr>
<tr>
<td>SMMH</td>
<td>42(9.98%)</td>
<td>63(14.96%)</td>
<td>105(24.94)</td>
</tr>
</tbody>
</table>

Table 2: Age-based Distribution of Malaria Parasite Infection

<table>
<thead>
<tr>
<th>Parasite density (No of parasites/μL of blood)</th>
<th>6 - 10</th>
<th>11 - 20</th>
<th>21 - 30</th>
<th>31 - 40</th>
<th>41 - 50</th>
<th>51 - 60</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 500</td>
<td>17</td>
<td>26</td>
<td>31</td>
<td>14</td>
<td>10</td>
<td>5</td>
<td>118 (64.8%)</td>
</tr>
<tr>
<td>500 – 1000</td>
<td>9</td>
<td>16</td>
<td>11</td>
<td>8</td>
<td>6</td>
<td>10</td>
<td>60 (32.9%)</td>
</tr>
<tr>
<td>1001 - 1500</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4 (2.2)</td>
</tr>
<tr>
<td>Total</td>
<td>26</td>
<td>43</td>
<td>44</td>
<td>22</td>
<td>16</td>
<td>26</td>
<td>182 (100.0%)</td>
</tr>
</tbody>
</table>

Table 3: Gender based Distribution of Malaria Parasitaemia

<table>
<thead>
<tr>
<th>Parasite density (No of parasites/μL of blood)</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 500</td>
<td>68 (37.4)</td>
<td>54 (29.7)</td>
<td>122 (67.0)</td>
</tr>
<tr>
<td>500 – 1000</td>
<td>36 (19.8)</td>
<td>20 (11.0)</td>
<td>56 (30.8)</td>
</tr>
<tr>
<td>1001 - 1500</td>
<td>3 (1.6)</td>
<td>1 (0.5)</td>
<td>4 (2.2)</td>
</tr>
<tr>
<td>Total</td>
<td>107 (58.8)</td>
<td>75 (41.2)</td>
<td>182 (100.0%)</td>
</tr>
</tbody>
</table>
4.72, P = 0.01), (Table 5). The agranulocytes (lymphocytes and monocytes) of malaria infected male and female children (59.46 ± 16.86), (60.48 ± 15.83), (14.58 ± 5.67), (13.16 ± 7.26) were significantly higher than that of males and females recorded high neutrophil and granulocyte counts (neutrophils and eosinophils) of malaria infected groups were significantly higher (63.95 ± 21.10), (69.04 ± 19.25), (3.02 ± 1.73), than that of the uninfected group (46.90 ± 18.54), (t = 6.62, P = 0.01), (47.26 ± 19.64), (t = 7.29, P = 0.01), (1.43 ± 1.66), (t = 4.93, P = 0.01), (1.96 ± 1.40), (P = 3.01, P = 0.003), (Table 5).

Moreover, the results revealed in Figure 6.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Male Positive</th>
<th>Male Negative</th>
<th>T: Value</th>
<th>P: Value</th>
<th>Female Positive</th>
<th>Female Negative</th>
<th>T: Value</th>
<th>P: Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasite density count x 10^9/µl</td>
<td>441.59±203.86</td>
<td>0.00±0.00</td>
<td>0.00</td>
<td>0.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Packed Cell Volume (%)</td>
<td>23.95±6.50</td>
<td>34.69±8.41</td>
<td>63.62</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erythrocytes x10^9/µl</td>
<td>2.94±1.15</td>
<td>4.01±1.07</td>
<td>57.73</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrombocytes x10^9/µl</td>
<td>147.15±59.94</td>
<td>346.23±166.12</td>
<td>32.22</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leucocytes x10^9/µl</td>
<td>18.67±9.86</td>
<td>12.92±8.30</td>
<td>24.05</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocytes (%)</td>
<td>59.88±16.41</td>
<td>37.69±18.65</td>
<td>31.24</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocytes (%)</td>
<td>13.40±5.06</td>
<td>8.91±5.90</td>
<td>23.35</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophil (%)</td>
<td>66.05±21.01</td>
<td>47.05±18.96</td>
<td>38.36</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophil (%)</td>
<td>3.69±3.54</td>
<td>1.64±1.28</td>
<td>7.30</td>
<td>0.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In general, many children were observed to have low packed cell volume (PCV) and erythrocyte counts within the age groups 6-10, 11-20, 21-30, 31-40, 41-50, and 51-60 months as indicated in figure 1, 2, 3, 4, 5 and 6 respectively.

It was also reported that the children within the age group 11-20, 21-30, 31-40, 41-50, and 51-60 months recorded low thrombocyte counts as shown in figures 11,12,13,14 and 15 accordingly. But the children between 6 – 10 months recorded a moderate number of children with thrombocyte counts as revealed in Figure 6.

Moreover, the results revealed that the children within the age group of 6-10, 11-20, 21-30, 31-40, 41-50, and 51-60 months recorded children with high leucocytes, lymphocytes, and monocytes counts. Whereas other groups 11-20, 21-30, 31-40, 41-50, and 51-60 months recorded high neutrophil and eosinophil counts as designated in figures 1, 2, 3, 4, 5 and 6 respectively.

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Figure 1: Variation of hematological indices from the Normal Counts with age 6-10 months

Figure 2: Variation of hematological indices from the Normal Counts with Age 11-20 Months.
Figure 3: Variation of hematological indices from the normal counts with age 21-30 months.

Figure 4: Variation of hematological indices from the normal counts with age 31-40 months.
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Figure 5: Variation of hematological indices from the normal counts with age 41-50 months.

Figure 6: Variation of hematological indices from the normal counts with age 51-60 months.

Discussion

One of the most frequent consequences of malaria is haematological alteration, which affects the main cell types such as erythrocytes, thrombocytes, and leucocytes (Maina et al., 2010). Malaria has been linked to anaemia, thrombocytosis, leukocytosis, and leukocytopenia; however, the severity of these modifications varies depending on demographic characteristics and immunity to the disease (Wickramasinghe & Abdalla, 2000).

Nigeria has a major public health threat from malaria, which can cause up to 30% of hospitalizations, 25% of infant deaths, and 11% of maternal deaths. A kid in Nigeria may contract malaria between two and four times per year, and malaria is thought to affect 70% of expectant mothers; this increases the risk of maternal anaemia, low birth weight, stillbirth, abortion, and other pregnancy-related issues (FMOH, 2005).

In this study, we discovered that 421 (43.23%) of children who attended the pediatric outpatient clinics of the hospitals between the ages of 6 and 59 months tested positive for *P. falciparum* malaria. This result is in line with an earlier study by Ejezie et al. (1991), which found that malaria accounted for more than 45% of outpatient admissions in rural Nigeria.

The results are in line with those of earlier studies conducted in different regions of Nigeria (Imam et al., 2009; Nwaorgu & Orajiaka, 2010; who found that malaria prevalence among children in communities in Awka, North Anambra State, Nigeria, was 52.40 percent).
Male individuals 107 (58.79%) had a significantly greater frequency of malaria infection than female subjects 75 (41.21%). This result was consistent with research by W and Ejim, 2000; Nwaorgu and Orajaka, 2011; and Okafor and Oko-ose, 2012, all of which noted a greater incidence in men than in females. Krogstad (1996), however, attributed these sex-based variations in malaria infection to genetic and hormonal variables. However, our results contradict those of Mbanugo & Ejim (2000), who claimed that sex had no bearing on the frequency of malaria. A moderate parasite level of 500 to 1500 parasites per microliter of blood was present. This was comparable to the Gentilin and Cauwe (1995) study on reduced parasitaemia in malaria-infected subjects at the University Centre Hospital in Yaoundé. The study’s low parasite density counts are comparable with findings from Nkuo et al. (2002), who found that primary school students in Buea had a high proportion of asymptomatic malaria cases and low hemoglobin levels. This finding is in tandem with an earlier study by Lucien et al., (2010) where they observed a high rate of parasitaemia among children between 21-40 months. The subjects of this said age group were considered as immunocompromised individuals (WHO, 2015). The mean PCV count for malaria-infected children was significantly lower compared to uninfected children, a finding that agrees with the observation of Price et al., (2001) who reported that P. falciparum parasitaemia lowers the PCV in infected subjects compared to negative ones. Furthermore, the study is also consistent with the report by Chiaka et al., (2007), who registered a substantial decrease in PCV and haemoglobin concentration in children with malaria from Gambia and Nigeria. One of the hematopoietic abnormalities linked to childhood malaria infection is thrombocytopenia (Boehlen et al., 2006) and our study also documented a decrease in thrombocytes in infected children, which was attributed to the increase in parasite densities as opined by Nithish et al. (2011). Plasmodium falciparum parasitaemia had a significant influence on leucocytes. This observation is in tandem with Abro et al., (2008) who reported an increasing trend of white blood cell counts in children’s response to parasite densities. This finding contradicted the results obtained by Bashawri et al., (2002) reported no significant difference in leucocyte counts between malaria-infected and uninfected groups. The finding is comparable with an earlier investigation by Chandra and Chandra (2013) and Maina et al. (2010) reported that malaria is one of the commonest causes of lymphocytosis and correlated with the severity of the infection. However, this study contradicted the finding of Wickramasinghe and Abdalla, (2000) reported that the decrease in lymphocyte counts was associated with malaria parasitaemia due to reflecting the distribution of lymphocyte sequestration in the spleen. Additionally, the monocytotes of malaria-positive children were equally found to be significantly higher than that of malaria-negative children. This finding is in line with Abdalla and Pasvol, (2004) who reported monocytosis as one of the most consistent observations from previous studies done on haematological studies that characterize malaria. However, this is not consistent with a study by Ladhani et al. (2002) that linked severe malaria and low levels of monocytotes. It was proposed that the activity of hemozoin from degraded haemoglobin concentration may hinder the function of monocytotes. Additionally, compared to a group that was not infected with malaria, the mean standard deviation of neutrophils in the malaria-infected group was considerably larger. The outcome of this investigation is consistent with Abdalla (1988). Neutrophilic cases were documented by Maina et al. (2010), particularly in pediatric patients. The study’s findings also showed that eosinophil counts in groups with malaria were found to be considerably greater than those in groups without malaria. The results of this study are consistent with those of Abdalla et al. (1998), who found that children with P. falciparum malaria infection had significantly higher eosinophil concentrations than non-infected groups. Male and female malaria-infected children’s erythrogram showed significant disparities. As shown in table 4.5, the male and female infected groups had lower packed cell volumes and thrombocyte counts than did the male and female uninfected groups. This result is consistent with a 2013 study by Imoru et al., who found substantial variations in the mean hematocrit and platelet counts of male and female children who had malaria and their uninfected counterparts. In a similar manner, it was discovered that both male and female children with malaria had considerably lower erythrocyte counts than those who were not infected. This result is in line with earlier research by Maina et al. (2010) and Imoru et al. (2013), which found that parasitized children had a higher rate of anaemia than control children did. Additionally, males and females who had been parasitized by malaria had considerably larger counts of leucocytes, lymphocytes, and granulocytes (neutrophils and eosinophils) than did males and females who had not been parasitized (Table 4.5). The results of this study are comparable to those of a previous study by Imoru et al. (2013), which found that male and female children with malaria had significantly higher white blood cell counts, lymphocytes, and granulocyte (neutrophils and eosinophils) counts than did the male and female participants in the uninfected groups. According to earlier research by Maina et al. (2010) and Abdalla et al. (2000), anaemia was associated with a child’s sex after contracting malaria. The current conclusion conflicts with these earlier studies. One of the distinguishing features for diagnosing malaria infection is haematological abnormalities. According to Reyburn et al. (2007), such anomalies include a change in packed cell volume (anemia/PCV < 33%), erythrocyte, platelet, leucocyte, differential leucocyte counts, and diffuse intravascular coagulation (DIC). Children who tested positive for malaria were found to have considerably lower mean PCVs than malaria-negative children in the same age group, which ranged from 51 to 60 months. The outcome of this result is consistent with Evans et al. (2006) findings that anaemia is associated with P. falciparum malaria, particularly in severe cases in younger (< 5 years) children. Additionally, it was revealed that the percentage of children harbouring malaria parasites across all age groups was much lower than the percentage of unparasitized children. Modes: 2
This finding agrees with Kumar, (2006) and Ovuakporaye (2011) that thrombocytopenia is a common occurrence in children infected with P. falciparum. Similarly, the erythrocytes counts were also found to be in malaria-positive children than in malaria-negative children within age brackets months. However, it was only reported to be significant in children and non-significantly (ns) was also reported in the age group accordingly. This finding is in concordance with Erhabor et al., (2006) who reported that P. falciparum malaria is one of the comment causes of anaemia in children and correlates with its infection. According to Kumar, (2006) and Ovuakporaye (2011), thrombocytopenia is a common occurrence in children who have P. falciparum infection. This finding supports their findings. Within age ranges of months, it was also discovered that erythrocyte counts were higher in children with malaria
The findings reveal a substantial correlation between people in the age ranges of 1 to 20 months and 21 to 30 months, 31 to 40 and 41 to 50 months. However, there was no evidence of a significant association among kids in the 6-to-10-month age range. This is in line with Pavithran's (2007) assertion that severe plasmodium infection causes changes in leucocyte growth and function. In addition, the results of the lymphocyte analysis reveal a favourable correlation between children who tested positive for malaria and those who tested negative in all age categories (6–10 months, 11–20 months, 21–30 months, 31–40 months, 41–50 months, and 51–60 months, respectively). Comparable studies include Chotivanich et al. (2000) and Allen et al. (1997), which found strong evidence that peripheral blood lymphocyte subpopulation counts are affected by malaria infection. Contrary to Maina et al., lymphocytopenia was identified often in children with acute malaria in locations where the disease is endemic in 2010. As a result, the findings from the lymphocyte study indicate a significant correlation between malaria infection and non-infection in the age groups of 11–20 months, 21–30 months, 31–40 months, and 51–60 months, and a non-significant correlation between 6–10 months and 31–40 months. The findings of this study are congruent with those of Abdalla & Pasvol (2004), who identified monocytosis as one of the haematological studies that characterize malaria's most reliable observations made by previous students. In contrast to Christiana (2015), we observed a non-significant connection between malaria positivity and negativity in the age range of 6–10-month-olds. When compared to children without malaria in the same age groups (6–10 months, 11–20 months, 21–30 months, 41–50 months, and 51–60 months), the means SD of relative neutrophil counts were found to be significantly higher in the malaria-positive children in these age groups. Kayode et al. (2011) reported that there was a significant increase in neutrophils level of individuals infected with *P. falciparum* infection compared to those not infected. However, a non-significant relationship was observed among children between 31 and 40 months of age. Moreover, a non-significant correlation between neutrophils of malaria-positive children and negative children was observed by Christiana, (2015). Malaria-infected and non-infected children also reported eosinophils among children within the age range 6–10 months 11-20, 41-50 months, 51-60 months while the non-significant relationship was equally observed within the age range 21-30 months and 31-40 months appropriately. This finding tallies with (Pukrittayakamee et al., 1989) reported that malaria influence changes in eosinophil concentration. But a non-significant relationship between malaria positive and negative observed in this study agrees with Christiana (2015).

Children within the age range 11-20, 21-30, 31-40, 41-50 and 51-60 months recorded high leucocyte counts. Similar findings were made by Adesina et al. (2009) who noted a rise in white blood cells (leukocytosis) as peripheral parasitaemia levels rose. The result presented in Table 4.6 also reported lymphocytosis in all the age groups, except children within 6-10 months. The result is in tandem with WHO, 2012 which reported mild to moderate typical lymphocytosis (lymphocytes > 60%) in children infected with malaria. Similarly, monocytosis was equally reported among the children within the age bracket 11-20, 21-30, 31-40, 41-50 and 51-60 months accordingly. This result tallies with Mandala et. al. (2016) reported that the proportion of circulating HZ containing monocytes increases during malaria infection and this correlate with malaria disease severity Inuwa et al., 2021b). There were a lot of malaria-infected children with normal neutrophil counts among the participants aged 6 to 10 months, but neutrophilia was found in the malaria-infected children aged 11 to 20, 21 to 30, 31 to 40, 41 to 50, and 51 to 60 months. The results are consistent with those of Dole and Wolf (1973), who suggested that enhanced marginalization and sequestration of neutrophils was a contributing factor in the malarial process. The results of the eosinophil test also demonstrate that children in the age groups of 11 to 20, 21 to 30, 31 to 40, 41 to 50, and 51 to 60 had significant levels of eosinophils; this finding is consistent with that of Kokori et al. (2013), who found eosinophils in children with *P. falciparum* malaria. In this study, we find that children visiting 4 hospitals in Maiduguri, Borno state, have a high prevalence of *P. falciparum* malaria. Additionally, a highly significant correlation between *P. falciparum* parasitaemia and various haematological variables in malaria-positive children, including PCV, thrombocytes, and leucocytes, was discovered. This correlation was especially strong in children between the ages of 11 and 20 months.

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**ETHICAL CLEARANCE**

Before the commencement of the fieldwork, ethical clearance was obtained from the Chairmen of the Ethical Committee University of Maiduguri Teaching Hospital Maiduguri, State Specialist Hospital Maiduguri, Mamman Shuaa Memorial Hospital Maiduguri and Umaru Shehu Ultramodern Hospital Maiduguri to carry out the research.

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