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

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ABSTRACT

Plasmodium falciparum is responsible for millions of deaths globally, with children under five 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%, 2.94 x 10^{-9}/µL and 346.23 x 10^{-9}/µL and 147.15 x 10^{-9}/µL) of the malaria positives subjects were significantly (*P*=0.05) lower compared to the malaria negative (34.69%, 4.0 x 10^{-9}/µL and 346.23 x 10^{-9}/µL) subjects. Furthermore, the mean WBC, lymphocytes and neutrophils respectively of the malaria positive subjects were significantly higher compared (18.67 x10^{-9}/µL, 59.88% and 66, 05%) to the infected ones (12.92 x 10^{-9}/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 145.98 x 10^{-9}/µ) versus (34.82% and 337.00 x 10^{-9}/µl) appropriately (p=0.05), whereas the mean WBC, lymphocytes and neutrophils were significantly higher compared to female positive subjects (17.48 x 10^{-9}/µl, 59.46% and 63.95%) versus (18.64 x 10^{-9}/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

Malaria is a deadly parasitic disease caused by infection with a blood parasite of the genus *Plasmodium* belonging to the apicomplexan phylum (de Andare-Neto *et al*, 2004). Five species of *Plasmodium* (including *P. falciparum*, *P. vivax*, *P. knowlesi*, *P. ovale* and *P. malariae*) are known to infect humans. Of the species that infect humans, *Plasmodium falciparum* (*P. falciparum*) is the predominant and deadliest in Africa (de 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 out-patient hospital admissions, 30% childhood deaths and 25% of infant death less than l year old 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 *P. 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 e*t 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 *P. falciparum* malaria when white blood cell counts can be as low as 1-2 x 10^9 (Berens-Riha *et al.*, 2014). Other common findings in patients with *P. falciparum* malaria include lymphocytosis, leukocytosis, neutrophilia, monocytosis, and eosinophilia. Leucopenia and other changes in leucocyte proliferation have been associated with severe Malaria caused by *P. 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 Shuwa Memorial Hospital Maiduguri, and Umaru Shehu Ultramodern Hospital Maiduguri, Borno State) within Maiduguri, Borno State, Nigeria, while Maiduguri is located in the North-Eastern part of Nigeria which lies within latitude

11.15°N and longitude 30.05°E in the Sudano-Sahelian savanna zone with a dense population who are mostly crop farmers, fishermen, herdsmen and traders. The state has an area of 71.210sq km with the population of 4,151,193 according to the National census conducted in 2006 (NPC, 2006).

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 32^0C and 650 mm respectively. The hottest periods of the year can record temperatures ranging between 30^0C and 40^0C 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 is a simple proportion

$X = (Z\alpha/2)^2 * P * (1 – P)/MOE^2$

$(1.96)^2 * 50\% (1 – 50\%) / (0.05)^2$

$384 * 0.5 (1 – 0.5) / 0.0025$

$384 * 0.5 * 0.5 \div 0.0025 = 384$

$Z\alpha$ 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 leucocytes; the count is continued per 500 leucocytes. 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 leucocytes.

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).

Table 1: Baseline Characteristics of the Participant

Variables	Tested positive	Tested negative	Total
No. enrollee age (months)	182(43.23%)	239(56.77%)	421(100%)
Mean	28.33	38.50	66.83
SD	10.07	11.59	21.66
Range (months)	6-59 months	6-59 months	6-59 months
Gender			
Male	107 (25.42%)	141 (33.49%)	248 (58.91%)
Female	75 (17.81%)	98 (23.28%)	173 (41.57%)
HOSPITAL			
UMTH	36(8.55%)	70(16.63%)	106 (25.18%)
SSHM	39(9.26%)	66(15.68%)	105(24.94)
USUMH	38(9.03%)	67(15.91%)	105(24.94)
MSMH	42(9.98%)	63(14.96%)	105(24.94)

Table 2: Age-based Distribution of Malaria Parasite Infection

Parasite density (No of parasite/ µL of blood)	6 - 10	11 – 20	21 - 30	31 - 40	41 - 50	51 – 60	Total
≤ 500	17 (9.3)	26 (14.3)	31 (17.0)	14 (7.7)	10 (5.5)	20 (5.5)	118 (64.8)
500 – 1000	9 (4.9)	16 (8.8)	11 (6.0)	8 (4.4)	6 (3.3)	10 (5.5)	60 (32.9)
1001 – 1500	0 (0.0)	1 (0.5)	02 (7.7)	0 (0.0)	0 (0.0)	1 (0.5)	4 (2.2)
Total	26	43 (8.8)	44 (24.2)	22 (12.1)	16 (8.8)	26 (17.0)	182 (100.0)

Table 3: Gender based Distribution of Malaria Parasitaemia

Parasite density (No of parasite/ µL of blood)	Male	Female	Total
≤ 500	68 (37.4)	54 (29.7)	122 (67.0)
500 – 1000	36 (19.8)	20 (11.0)	56 (30.8)
1001 – 1500	3 (1.6)	1 (0.5)	4 (2.2)
Total	107 (58.8)	75 (41.2)	182 (100.0)

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).

Parasitaemia due to *P. falciparum* had a significant influence on the mean leucocytes in malaria-positive children (18.67 ± 9.86), which was significantly higher compared to malaria-negative children (12.92 ± 8.30), (t = 24.05, $P = 0.01$). A similar finding was also obtained in agranulocytes (lymphocytes and monocytes) in malaria-positive children (59.98 ± 16.41), (13.40 ± 5.06) which was significantly higher than in the malaria-negative children (37.69 ± 18.65), (8.91 ± 5.90) (t = 31.24, $P = 0.01$) (Table 4). Also, the mean 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 4 compares the haematological parameters between children who had malaria and those who did not. In comparison to children who were not infected with malaria (34.69 + 8.41), children who were malaria-infected had a considerably reduced mean standard deviation of packed cell volume (23.95 + 50) (t = 63.62, $P < 0.01$). Similarly, the mean SD of the 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, $P = 0.01$).

The result also shows that *P. 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 agranulocytes (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 erythrogram 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 = -7.90, $P = 0.01$), (4.07 ± 1.11), 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 = 3.94, *P* = 0.01), (12.72 ± 8.80), (t = 4.72, *P* = 0.01), (t = 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 female infected groups (38.37 ± 18.61), (t = 9.20, *P* = 0.01), (36.71 ± 18.76), (t = 8.83, *P* = 0.01), (9.46 ± 6.89), (t = 6.25, *P* = 0.01), (8.13 ± 3.99), (t = 5.81, *P* = 0.01), (Table 5). Moreover, the 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), (t = 3.01, *P* = 0.003) (Table 5).

Table 4: Haematological parameters in *P. falciparum*-infected and non-infected children

Haematological parameters	Malaria positive (n=182)	Malaria Negative (n=239)	T. value	P. value
Parasite density count x 10^{-9}/µL	441.59±203.86	0.00±0.00	0.00	0.00
Packed Cell Volume (%)	23.95±6.50	34.69±8.41	63.62	0.01
Erythrocytes x10^{-9}/µL	2.94±1.15	4.01±1.07	57.73	0.01
Thrombocytes x10^{-9}	147.15±59.94	346.23±166.12	32.22	0.01
Leucocytes x10^{-9}/µL	18.67±9.86	12.92±8.30	24.05	0.01
Lymphocytes (%)	59.88±16.41	37.69±18.65	31.24	0.01
Monocytes (%)	13.40±5.06	8.91±5.90	23.35	0.01
Neutrophil (%)	66.05±21.01	47.05±18.96	38.36	0.01
Eosinophil (%)	3.69±3.54	1.64±1.28	7.30	0.01

Table 5: Malaria Parasite Status and Haematological Parameters of Different Sexes

Hematological Parameters	Male Positive N = 107	Male Negative N = 141	T: Value	P. Value	Female Positive N = 75	Female Negative N = 98	T: Value	*P* Value
PCV (%)	24.40 ± 6.81	34.36 ± 7.78	-10.53	0.01	23.30 ± 6.00	34.82 ±9.89	-8.90	0.0
Erythrocytesx10-9/µl	2.87 ± 1.14	3.96 ± 1.05	-7.90	0.01	3.04 ± 1.15	4.07 ± 1.11	-5.93	0.0
Thrombocytes x10-9	145.98±53.65	352.64±155.82	-13.14	0.01	148.83±68.27	337.00±180.32	-8.57	0.0
Leucocytes x10-9/µl	17.48 ± 9.74	13.05 ± 7.97	3.94	0.01	18.64 ± 7.30	12.72 ± 8.80	4.72	0.0
Lymphocytes (%)	59.46 ± 16.86	38.37 ± 18.61	9.20	0.01	60.48 ± 15.83	36.71 ± 18.76	8.83	0.0
Monocytes (%)	14.58 ± 5.67	9.46 ± 6.89	6.25	0.01	13.16 ± 7.26	8.13 ±3.99	5.81.	0.0
Neutrophil (%)	63.95 ± 21.10	46.90 ± 18.54	6.62	0.01	69.04 ± 19.25	47.26 ± 19.64	7.29	0.0
Eosinophil (%)	3.02 ± 1.73	1.43 ± 1.66	4.93	0.01	4.06 ± 3.76	1.96 ± 1.40	3.01	0.0

In general, many children were observed to have low packed cell volume 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.

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 count as reported in figure 1, 2, 3, 4, 5 and 6 appropriately.

However, children within the age bracket 6 – 10 months recorded a high number of children with normal neutrophil 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.

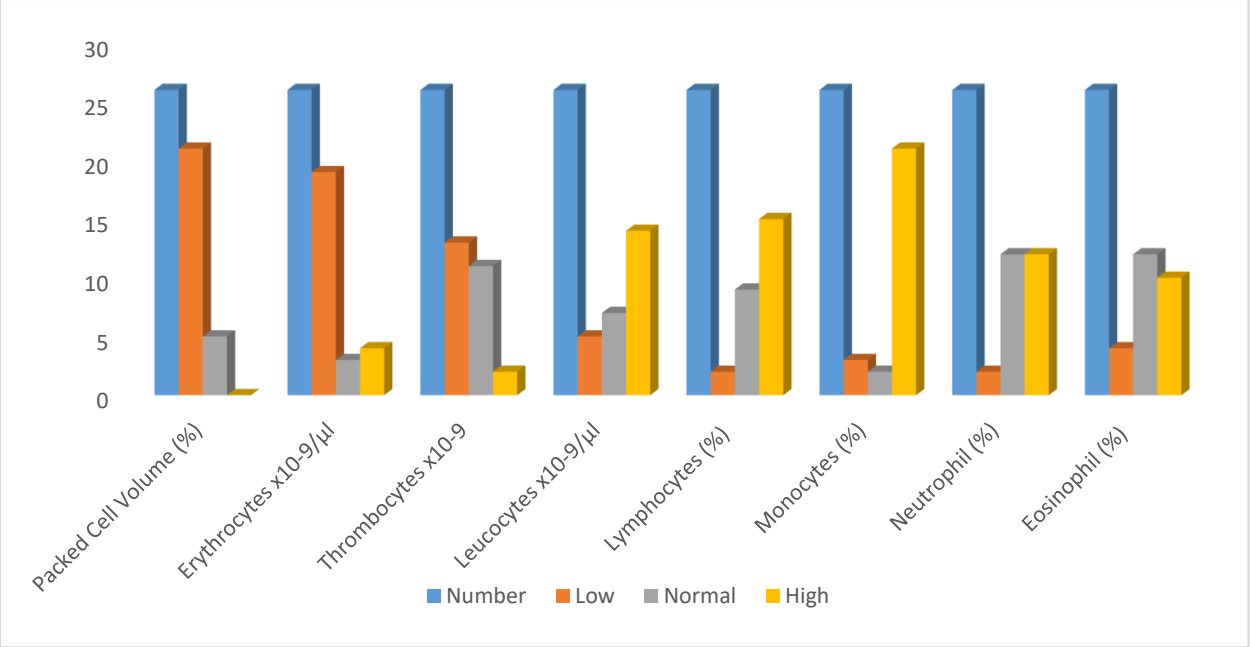

Figure 1: Variation of hematological indices from the Normal Counts with age 6-10 months

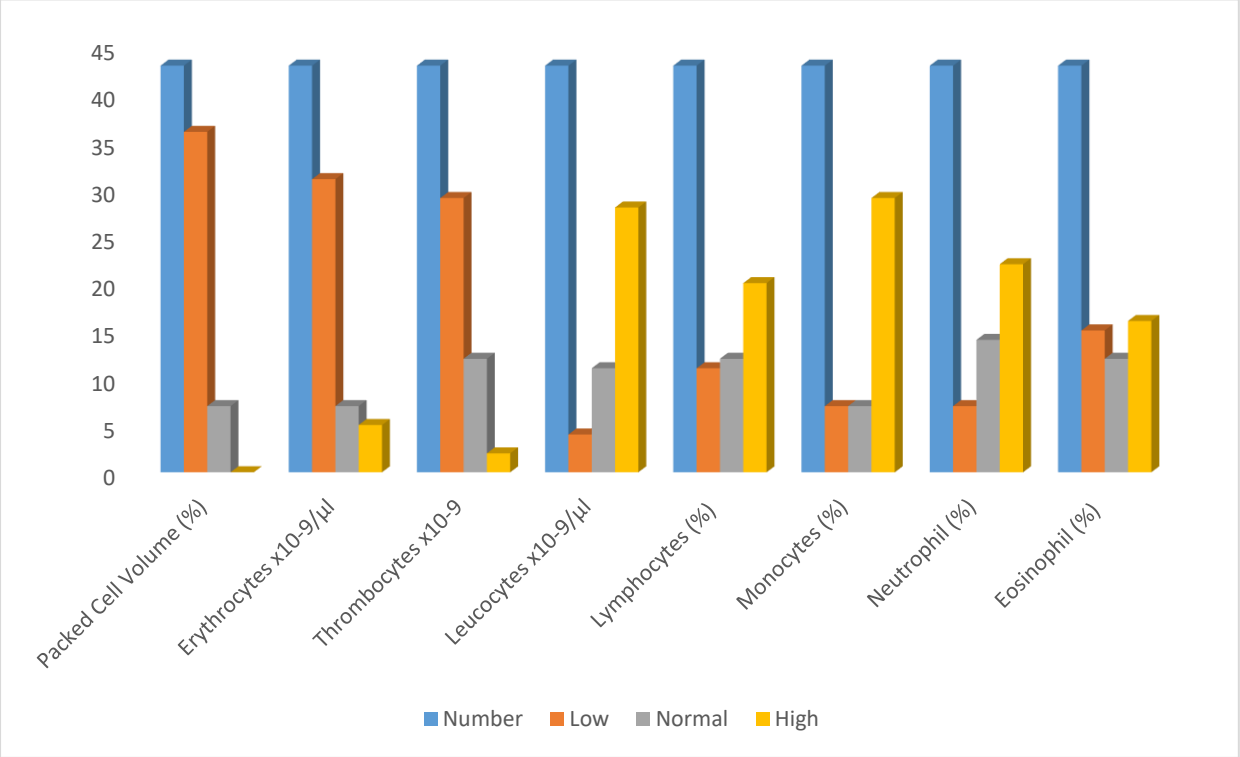

Figure 2: Variation of hematological indices from the Normal Counts with Age 11-20 Months.

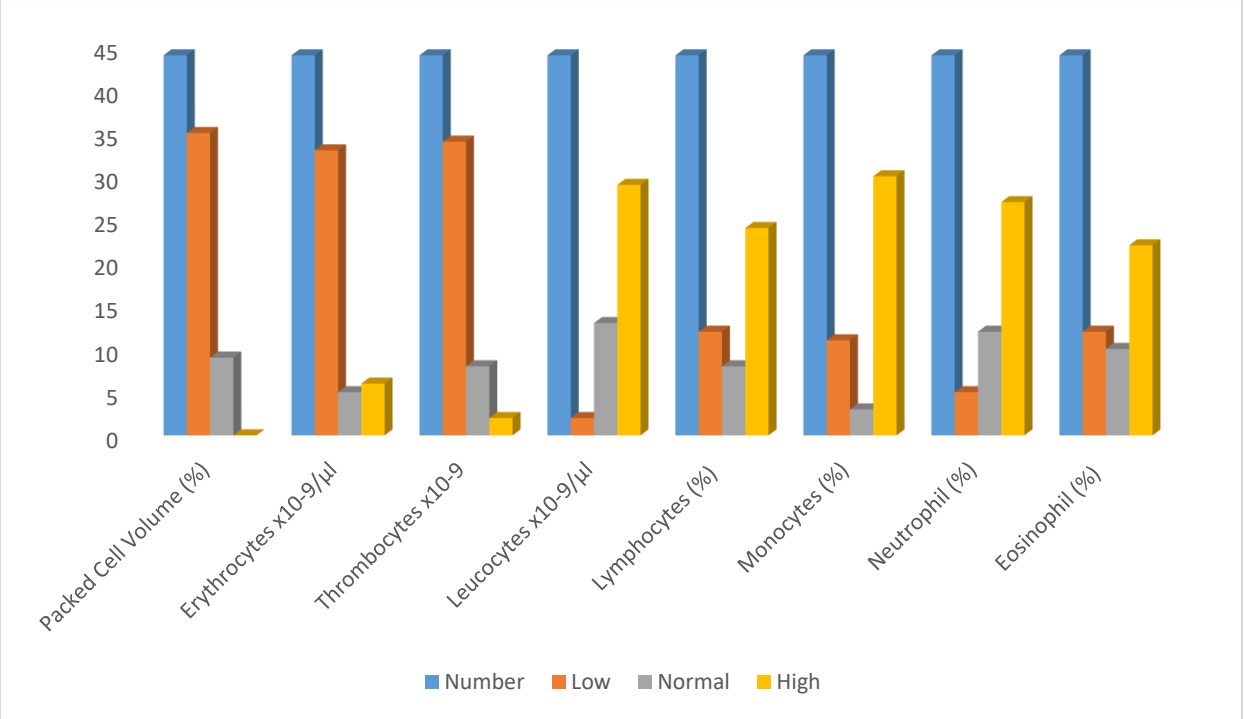

Figure 3: Variation of hematological indices from the normal counts with age 21-30 months.

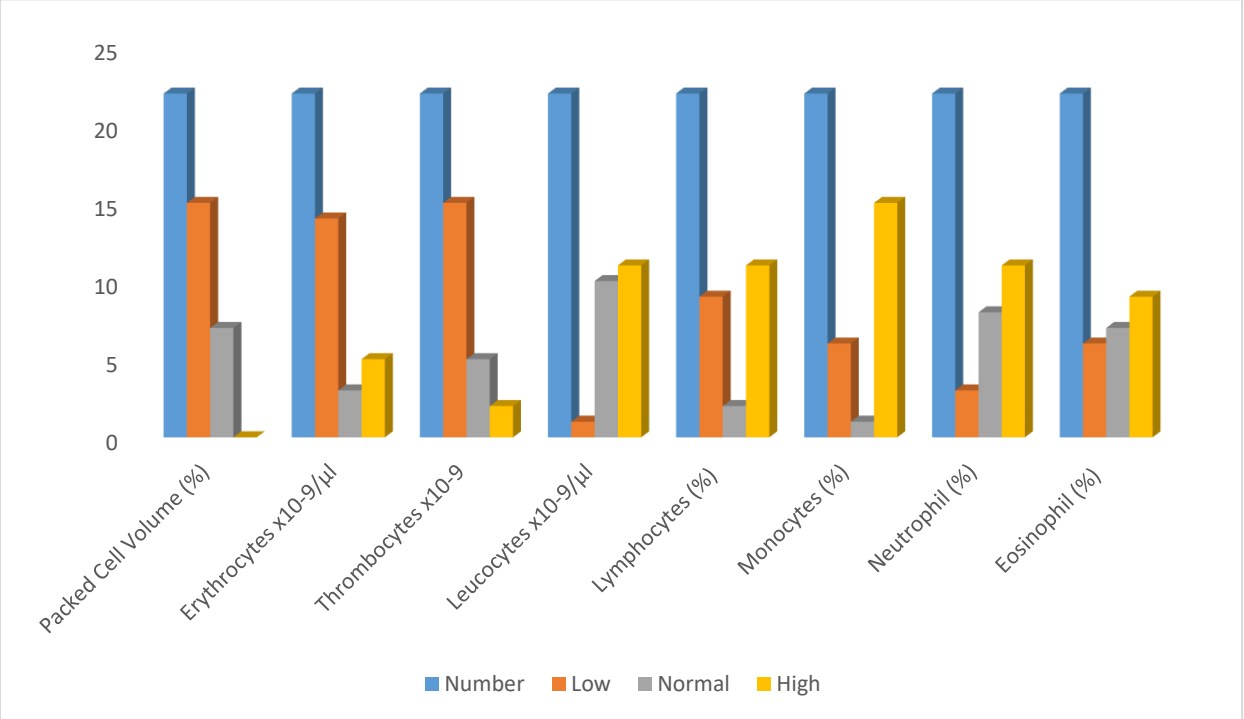

Figure 4: Variation of hematological indices from the normal counts with age 31-40 months.

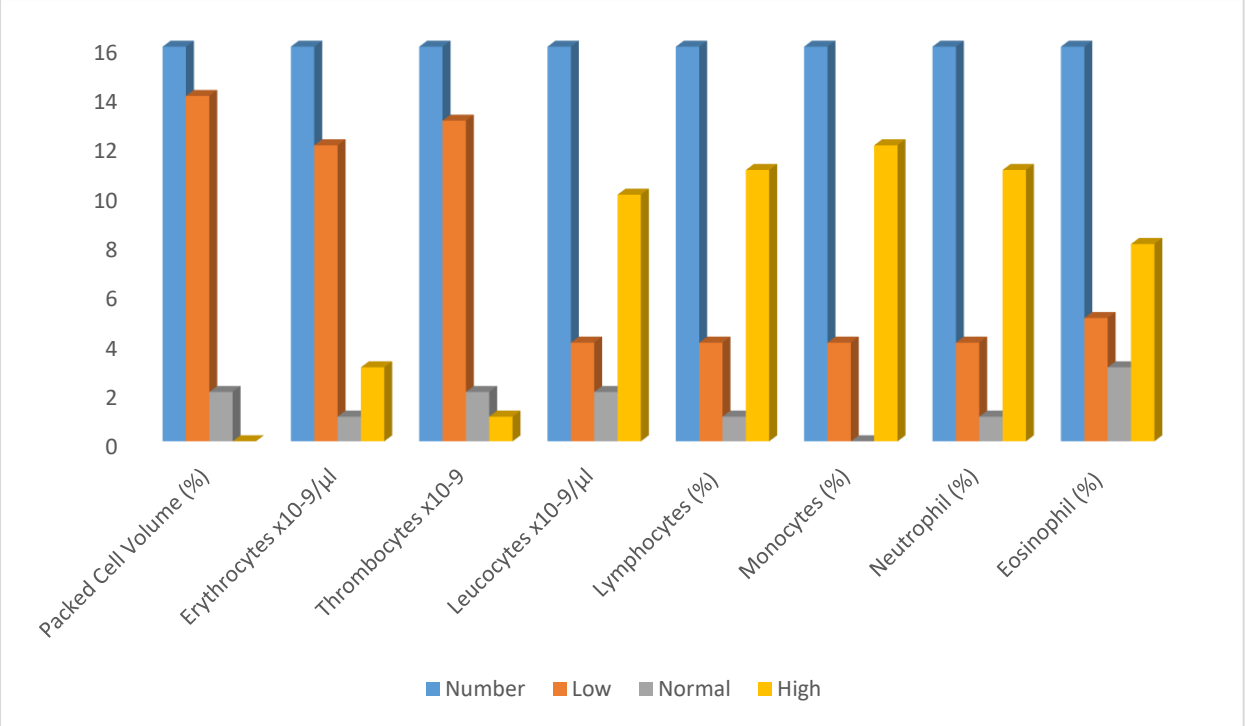

Figure 5: Variation of hematological indices from the normal counts with age 41-50 months.

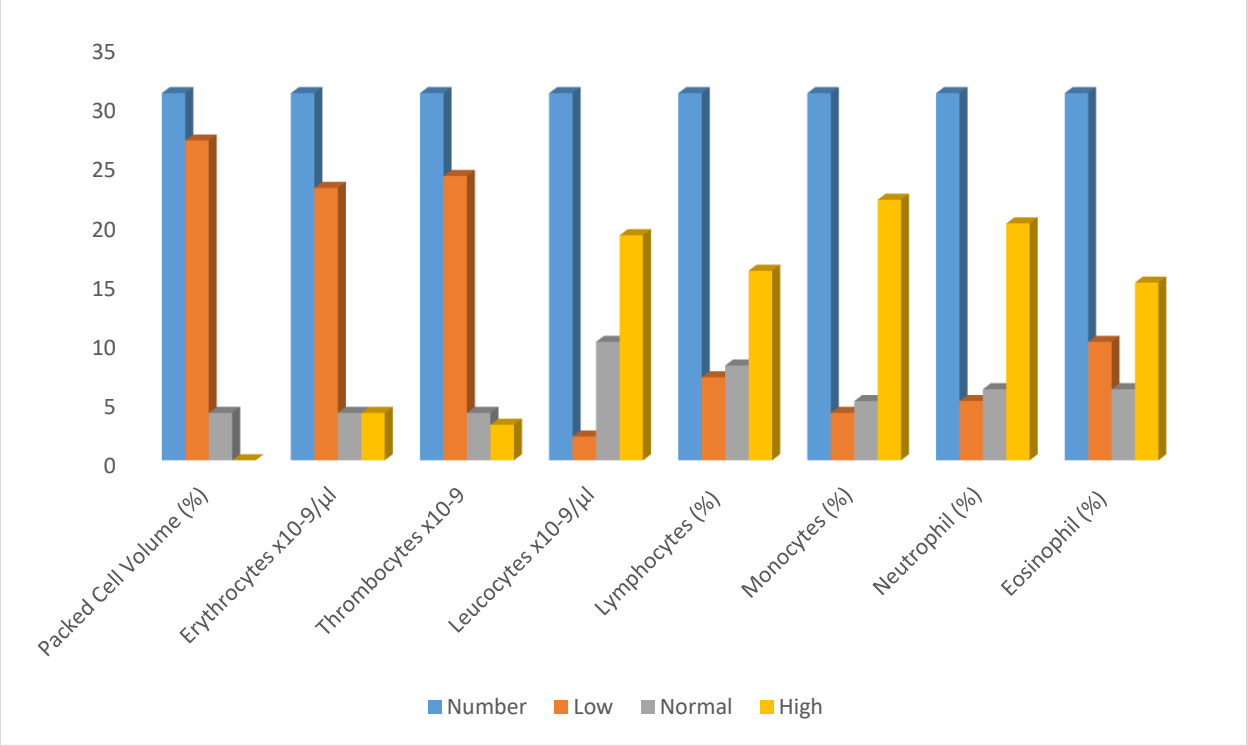

Figure 6: Variation of hematological indices from the normal counts with age 51-60 months

Discussion

One of the most frequent consequences of malaria is haematological alteration, which affects the main cell types such 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 and 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 and Orajiaka, 2010; who found that malaria prevalence among children in communities in Awka, North Anambra State, Nigeria, was 52.40 %).

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 Nwaorgu and Orajiaka, (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 and 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 affected 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). Our study also documented a decrease in thrombocytes in affected 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 monocytes 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 monocytes. It was proposed that the activity of hemozoin from degraded haemoglobin concentration may hinder the function of monocytes. 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 (1988), monocytopenia 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 study 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.

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.

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. This finding agrees with Kumar, (2006) and Ovuakporaye (2011) that thrombocytopenia is a common occurrence in children infected with *P. falciparum*. 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 than in those without it. However, it was only noted to be significant in youngsters, and the age group was noted to be non-significant (ns). This result is consistent with Erhabor *et al.,* (2006) observation that *P. falciparum* malaria is one of the common causes of childhood anaemia and that its infection is correlated with anaemia.

However, the findings showed that children with malaria had higher leucocyte counts than children without the disease. The findings reveal a substantial correlation between people in the age ranges of 11 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 a 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.,* (2010) 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 monocyte study indicate a significant correlation between malaria infection and non-infection in the age groups of 11–20 months, 21–30 months, 41–50 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 and 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- to 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 (Pukrittayakarnee *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 Shuwa Memorial Hospital Maiduguri and Umaru Shehu Ultramodern Hospital Maiduguri to carry out the research.

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