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(RESEARCH ARTICLE)

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Impact of Malaria Parasiteamia and Haematologic parameters in Ilorin metropolis, North central Nigeria

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Abstract

Background: Malaria is main cause of cause of Anaemia and thrombocytopenia and those with platelet counts less than 150,000/µL have a 12–15 times higher risk of contracting malaria than those with counts greater than 150,000/µL.

Methodology: A prospective crossectional study was employed in this study. 331 patients at the University of Ilorin Teaching Hospital, Kwara State University Teaching Hospital, Sobi Specialist Hospital, Okelele Comprehensive Health Centre and Civil service Clinics in Ilorin Metropolis with age range 1-60 years who presented with malaria were recruited. While those on antimalaria drugs, those with cases of complicated malaria, pregnant women and those that refused consent were excluded from the study. Ethical clearances were obtained from both the state Ministry of Health (MOH/KS/EU/777/493) and The University of Ilorin Teaching Hospital Ilorin, (UITH PAN/2022/12/0223). The study followed ethical code of conduct 2019 (Helsinki). Blood samples were collected from all the participants, both thick and thin blood films were made, stained with diluted Giemsa 1:10 and these were then confirmed by Polymerase Chain Reaction (PCR). Blood counts were carried out using the Haematology Analyzer BC-5200 following manufacturer instructions,

Results: Out of 331 patients screened, 103 (31.6%) were positive for parasitaemia and parasites density of >120000 was detected in 8 participants, *P. falciparum* was the only species detected. The mean values of Hb, Hct, platelet, WBC, lymphocytes and RBC were significantly low in malaria patients compared to non-infected controls and the difference is statistically significant.

Keywords: Malaria; Heamatologic Parameters; *P. falciparum;* Blood films

1. Introduction

Malaria is a protozoan parasite that is transmitted through the bite of an infected female *Anopheles* mosquitoes to man [(1)]. It was estimated that about 229 million cases of malaria were reported in 2019 globally with 409 thousand deaths according to the World Health Organization (WHO). Africa carried the highest burden of malaria followed by Southeast Asia. Pregnant women and children under 5 years of age are mostly affected. Among these, children under the age of five represented approximately 78% of all cases and 95% of the fatalities [(2).] Haematological alterations that are thought to characterize malaria are related to the overt biochemical changes that occur during the asexual stage of the life cycle of the malaria parasite [(3)] Patients infected with malaria tend to have significantly lower platelet, leukocyte, lymphocyte, eosinophil, red blood cell, and haemoglobin (Hb) counts, while the number of monocytes and neutrophils was significantly higher than that in nonmalaria-infected patients [(4)]. Anaemia, leukopenia and thrombocytopenia are commonly seen in *P. falciparum* infection, probably as a result of the higher levels of parasitaemia found in these

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patients [5]. According to previous report [6], Nigeria is the country in Africa with the greatest rate of malaria infection. The most prevalent cause of thrombocytopenia is malaria infection, and those with platelet counts less than 150,000/μL have a 12–15 times higher risk of contracting malaria than those with counts greater than 150,000/μL[7]. The most frequent complication in individuals with malaria is a change in leukocyte parameters, which has a significant impact on both the disease's clinical severity and death[8]. Clinicians can avert serious sequelae by establishing early and effective treatment approaches based on the prediction of haematologic changes in malaria, particularly in nonendemic areas where malaria transmission is diminishing [9]. Haematologic parameters can help provide a presumption of treatment, especially if the results of parasitological examinations are not immediately available or are uncertain to decide malaria treatment [9]. This generally helps to prevent possible complications which may result to eventual death. The development of drug-resistant strains of *P. falciparum*, particularly artemisinin-resistant strains, has further complicated the malaria burden in Nigeria and made treating severe cases of the disease more difficult. As a result, alternative treatment options must be developed. Environmental factors like bushy environment that provides breeding place for mosquito vector, and the intensity of malaria transmission, as well as host characteristics like age, nutritional state, and immunological status, can all be risk factors for severe malaria [10]. The aim of this study is to determine the current prevalence of malaria and to investigate variations in the haematological parameters of the affected individuals with malaria infection in the study area.

2. Materials and methods

2.1. Study Area

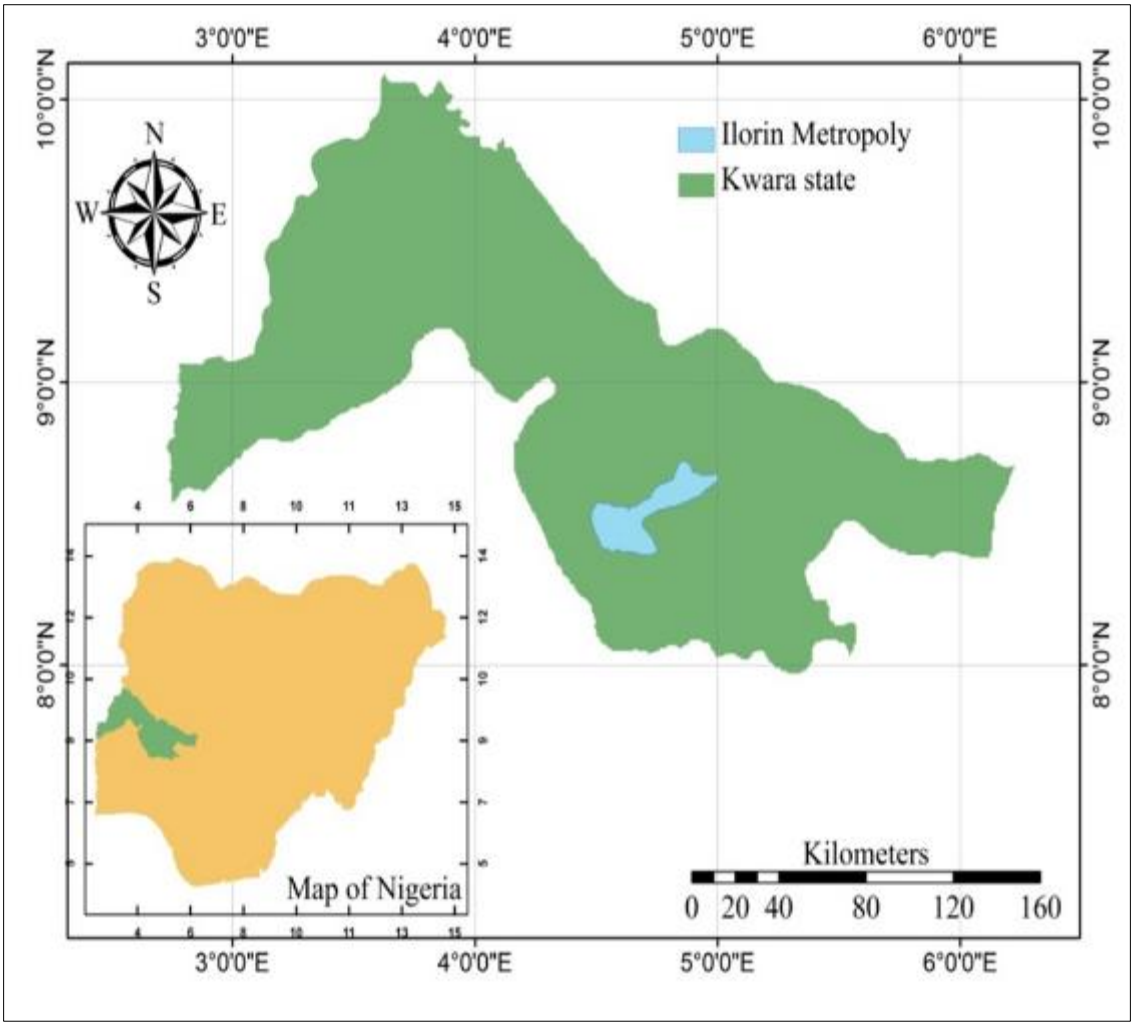

Figure 1 Map of Nigeria showing Kwara State and Ilorin metropolis

Together with the Federal Capital Territory (FCT), Kwara is one of the six states that comprise Nigeria's North Central geographical zone. In addition to its interstate borders with Niger State to the north, Oyo State to the southwest, Osun and Ekiti States to the southeast, and Kogi State to the east, it shares an international border with the Republic of Benin to the west. Ilorin serves as its capital. The state is split into three (3) senatorial zones and sixteen (16) Local Government Areas (LGA). It is located at latitude 8°30' north and longitude 5°00' east, and it occupies 34,467.5 square kilometers.

Kwara State's capital, Ilorin, has a population of approximately one million, which translate to roughly 2.67% increment from 2021[11] . The research region usually has a tropical climate with six-month-long wet and dry seasons that alternate. The dry season lasts from October to March, whereas the rainy season lasts from April to September, peaking in June and July. Like other parts of Nigeria, this area is endemic for malaria. Transmission of malaria is severe, year-round, and slightly more frequent from May to October. The city is divided into 20 political wards and three Local Government Areas. The people's main professions include weaving, farming, pottery manufacturing, and commerce. These occupations were dominated by women, and labor was divided along gender lines. The primary language used in Ilorin is Yoruba.

2.2. Study Area

The study was conducted across some few selected public healthcare facilities in Ilorin metropolis. These hospitals include; University of Ilorin Teaching Hospital (**UITH**), Oke-Oyi, Ilorin, Kwara State University Teaching Hospital General Surulere, Ilorin (**KWASUTH**), Sobi Specialist Hospital. Ilorin (**SSHI**), Kwara State Civil Service Clinics (**CSC**) and Comprehensive Health Centre Okelele (**CHCO**). The selected facilities have a very good turn-out of malaria cases at the General Out-patient Department (GOPD) and mix of competent personnel including Family Physicians, Medical Laboratory Scientists to manage routinely, both acute and severe cases of malaria episode.

2.3. Study Population

A total of three hundred and thirty-one (331) suspected malaria patients were recruited for the study from all the five facilities chosen for the study. Patients were recruited from General Out Patient Department (GOPD), Staff Clinics and National Health Insurance Scheme (NHIS) Clinics. The participants age ranges from 1-65 years who belong to either Muslim or Christian faith. These participants are from various field of endeavors such as civil servants' artisans, Students, Business man and women and housewives. Majority of them are Yorubas and others tribes were also encountered like Hausa, Nupe, Fulani, Igbo, Baruten, Ebira and etc.

The study employed an epidemiological, longitudinal hospital-based study design involving quantitative research methods and participants were selected by proportional allocation. Quantitative design because the research involved laboratory-based screening and diagnosis of malaria parasite using stained blood films and confirmed by polymerase chain reaction (PCR) and also determined the Full blood counts. Any sample with malaria parasites greater than 1000/µl of blood was identified and about 2 to 3 drops was dispensed on Whatman filter paper number 3.

2.4. Exclusion criteria

Individuals with complicated severe malaria symptoms or those who are asymptomatic of malaria infection, pregnant women, those who have taken antimalarial medications, and people who have refused to provide their permission

2.5. Sample Size Determination

Sample size was determined using formula described by [13], using proportion allocation

$N = Z^2 \times P\ (1-P)/\ e^2$. Where, N Represents the required sample size, Z is the confidence interval at 95% (standard value of 1.96), P represents prevalence of previous study which is 26.7% [11] and e is margin of error at 5% (Standard value of 0.05). $N=1.96^2 \times 0.267(1-0.267)/0.05^2$

$N=3.8416 \times 0.267(0.733)/0.05^{2-} 300.7 = (301)$ The minimum sample size is 301. However, this number was increased by 10 % in order to take care of those with incomplete information and attritions. The sample size is now 331.

2.6. Sample Collection

Patients (1-60 years, n= 331) presenting with malaria at these five facilities: University of Ilorin Teaching Hospital (UITH), Oke-Oyi, Ilorin, Kwara State University Teaching Hospital General Surulere, Ilorin (KWASUTH), Sobi Specialist Hospital. Ilorin (SSHI), Kwara State Civil Service Clinics (CSC) and Comprehensive Health Centre Okelele (CHCO) in

Ilorin Metropolis were recruited for this research. Blood samples were collected from January, 2021 to April, 2022. Five milliliters (5ml) of whole blood were collected by venipuncture from each participant into vacutainer bottle coated with Potassium Ethyl diaminetetraacetic acid (EDTA) which was used to prepared both thick and thin blood films.

2.7. Malaria Microscopy and Parasite Density Determination

Both thick and thin blood films were prepared on a clean and grease-free microscope glass slide, stained with diluted Giemsa stain diluted (1:10). Following the procedure outlined by [13], the presence of malaria parasites was detected, and the parasites were speciated based on their morphological traits in the thin and thick blood films. Identification of parasites and parasite density estimation was carried out at the Medical Microbiology& Parasitology Laboratory Department, University of Ilorin Teaching Hospital.

2.7.1. Patient Recruitment

For the study, participants were chosen if they had a *P. falciparum* infection with a parasite density of at least 1000/µl of blood.

2.7.2. Parasite Density Estimation

Parasite count per microliter of blood was calculated using the formula described by [14]

$$\text{Parasites count per microliter of blood} = \frac{Number\ of\ parasites\ counted\ x\ TLC}{Number\ of\ Leucocytes\ (200)}$$

TLC means Total Leucocytes Count. (TLC)

2.8. Determination of Haematological Parameters

Following manufacturer instructions, blood counts were carried out using the Haematology Analyzer BC-5200 (Mindray, Nanshan, Shenzhen, China). WBC, RBC, platelet counts, Hb level, MCV, MCH, MCHC, RDW, and five-part differentials were all provided by the analyzer. The hematology analyzer performs external quality control (EQC) three times a year in addition to internal quality control (IQC) twice a day, once in the morning before running the sample and once in the afternoon.

2.9. Parasite DNA extraction

DNA was extracted from blood samples (103) in total which are selected for molecular studies. Genomic DNA was extracted from the samples using method previously described [15]**.** The quality and the yield of the extracted DNA were determined by nano spectrophotometer. The extraction was carried out at the Department of Biochemistry and Nutrition, Malaria Genomic Unit, National Institute for Medical Research (NIMR), Yaba, Lagos, Nigeria.

2.10. Confirmation of Plasmodium falciparum Infection by PCR

Confirmation of *Plasmodium falciparum* parasites in all samples was done using the forward and reverse primers for parasites 18S ribosomal RNA (rRNA) gene. The method involved the first PCR with primers rPLU_5 R1 5' CCTGTTGTTGCCTTAAACTTC 3' and rPLU_6 5' TTAAAATTGTTGCAGTTAAAAC 3' that amplify the 18S rRNA gene of the human Plasmodium parasite. Following this step, the main PCR result was amplified independently using the species-specific primer pairs: rFAL1 5' TTAAACTGGTTTTGGGAAACC 3' and RAL 2 5' ACACAATGAACTCAATCATGA 3' to recognize *P. falciparum* as a species. The following cycle conditions were used to amplify the Pf-18SrRNA gene: 35 cycles of 1 minute annealing at 55 degrees Celsius, 2 minutes extension at 72 degrees Celsius, and a final extension at 72 degrees Celsius were performed after 10 minutes of initial denaturation at 94 degrees Celsius. To amplify species-specific primers, 2µl of the ten-fold diluted primary PCR result was employed in nested PCR (FAL1 and 2). 5' TTAAACTGGTTTTGGGAAACC 3' 5'and ACACAATGAACTCAATCATGA 3'. With the exception of the one-minute extension at 72ºC, the cycle conditions for the nested PCR were identical to those for the primary PCR primers. A total of 50µl was used for all PCR reactions, which included 0.2 m dNTPs, 2 m Mgcl2, 1 µM of each primer, and 1 unit of AmpliTaq polymerase (Perkin Elmer, England). With the exception of the one-minute extension at 72ºC, the cycle conditions for the nested PCR were identical to those for the primary PCR primers. A total of 50µl was used for all PCR reactions, which included 0.2 Mm dNTPs, 2 Mm Mgcl2, 1 µM of each primer, and 1 unit of AmpliTaq polymerase (Perkin Elmer, England). Positive and Negative controls were included in each reaction.

3. Results

A total of 331 probable malaria patients were screened for malaria parasite and out of these, 103 (31.1%) were positive. *Plasmodium falciparum* was the parasite discovered in all cases.

Table 1 distribution of parasitaemia in relation to study sites

Hospital	No Reported	No Examined	No Positive	%	P value
UITH	5100	87	39	38%	
CSC	4680	80	25	24 %	
SSH	4164	72	19	18 %	0.355
KWASUTH	2700	46	8	8 %	
OCHC	2700	46	12	12 %	
Total	19,344	331	103	100	

The table above shows that UITH had the highest prevalence (38%), followed by CSC (24%), and KWASUTH (8%). P≤0.05 indicates that the difference is not statistically significant.

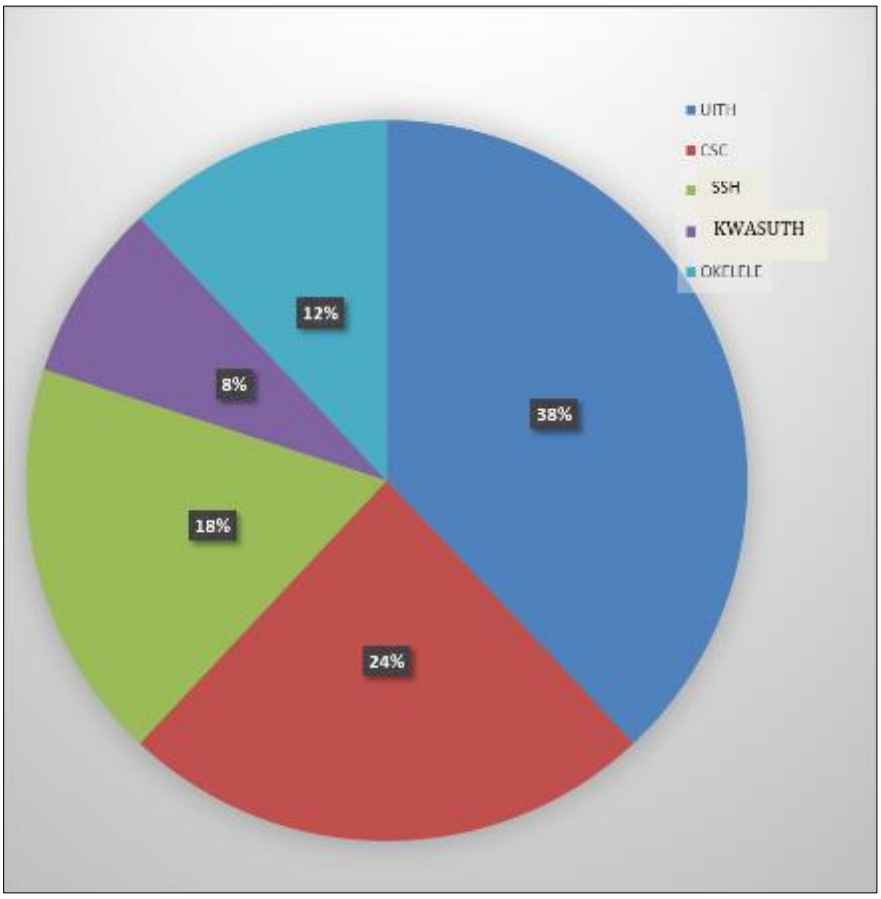

Figure 2 Pie-chart illustrating parasitemia distribution according to research sites

- UITH: University of Ilorin Teaching Hospital
- CSC: Civil Service Clinics
- SOBI: Sobi Specialist Hospital
- KWASUTH: Kwara State University Teaching Hospital
- CHCO: Comprehensive Health Centre Okelele

Table 2 distribution of parasitemia in relation to age

Age (years)	No Examined	No Positive	% Positivity	P value
1-5	108	33	32	
6-20	113	37	36	
21-40	74	22	21	0.004
>40	36	11	11	
Total	331	103	100	

Table showed that age group (6-20) years had the highest prevalence (36 %), which was followed closely by the age group (1-5) years with (32 %) and the least prevalence was recorded in the age groups >40years (11 %). Difference is statistically significant (P≤0.05).

Table 3 distribution of parasitemia in relation to gender

Gender	No examined	No Positive	% Positivity	P value
Male	131	40	39	
Female	200	63	61	0.713
Total	993	103	100	

The table shows that females were commonly infected (61 %) than male (39 %). The difference is not significant (P≤0.05).

Table 4 Distribution of parasitaemia in relation to occupation

Occupation	No. Examined	No. Positive	% Positivity	P value
Civil Servant	60	17	18	
Business	40	11	11	
Students	146	50	49	0.005
Artisan	60	17	18	
No Occupation	25	8	8	
Total	331	103	100	

The table showed that students had the highest prevalence (49 %) followed by both the civil servant and the artisan (18 %) each, while those without occupation recorded the least prevalence (8%) and the difference is statistically significant (P≤0.05).

Table 5 Distribution of Parasitaemia in relation to Haematological Parameters (n=103)

Parameter	Normal Range	Low	Percentage %	Normal	Percentage %	High	Percentage %
WBC	4.0-10.00	15	14.5	85	82	3	2.9
RBC	2.00-7.00	61	59	32	31	10	10.0
Hb	11.0-16.0	63	61	40	39	-	-
HCT	37.0-54.0	71	69	30	29	2	2.0
MCV	80-100	27	26	64	62	12	12.0

RDW	35.0-56.0	50	48.5	48	47	3	3.0
Platelet	100-300	90	87	13	13	1	1.0
Neutrophil	50.0-70.0	10	9.7	92	89	1	1.0
Lymphocyte	20.0-40.0	25	24	77	75	1	1.0
Monocyte	3.0-12.0	20	19.4	63	61	20	19.0
Eosinophil	0.5-5.0	-	-	94	91	9	9.0
Basophil	0.0-1.0	2	1.9	53	51	48	47.0

Abbreviations: WBC, white blood cell; RBC, red blood cell; MCV, mean corpuscular volume; RDW, red cell distribution width.

Table 6 Comparison of Haematological Parameters between Malaria infected and non-infected

Parameters	**MP infected n**	**Non-MP infected**	**P-value**
WBC (x 10^9/L)	6.01 ± 1.73	7.93 ± 1.	0.002*
Lymphocytes (%)	33.48 ± 9.53	21.76 ± 8.25	0.005*
Neutrophil (%)	68.60 ± 4.72	43.50 ± 8.15	0.000*
Monocytes (%)	10.07 ± 3.69	7.73 ± 2.15	0.013*
Eosinophil (x 10^{12}/L)	2.09 ± 1.25	3.81 ± 0.43	0.010*
Basophil (%)	1.58 ± 0.78	0.85 ± 0.19	0.000*
RBC (x 10^{12}/L)	3.63 ± 0.73	3.90 ± 0.32	0.009*
HBG (g/dL)	10.86 ±0.99	13.59 ± 2.17	0.000*
HCT (%)	37.11 ± 4.32	39.68 ± 1.34	0.029*
MCV (fL)	104.8 ± 19.02	90.43 ± 2.50	0.000*
MCH (Pg)	40.83 ± 7.23	31.71 ± 1.53	0.000*
RDW ()	48.94 ± 7.15	48.07 ± 4.33	0.596
PLT (x 10^9/L)	137.37 ± 72.33	262.89 ± 33.75	0.000*
Parasite (x 10^4/mL)	4.76 ± 9,73	0.00	--
NLR	1.55 ± 1.06	3.61 ± 1.37	0.002*
PLR	4.90 ± 4.67	13.36 ± 4.15	0.000*
MLR	0.37 ± 0.25	0.39 ± 0.13	0.420

The Table above showed comparison between haematological parameters among malaria infected and non-infected control. The outcome revealed significantly differences in the values of almost all the parameters, with the exception of MLR

4. Discussion

Assessing molecular markers in endemic areas is crucial for managing resistance and for monitoring and implementing evidence-based management actions. The reemergence of the chloroquine susceptible allele and the selection and propagation of ACT resistance have been linked to an over-reliance on ACT treatment [16]. Out of the 331 samples that were evaluated for malaria parasitaemia, 103 tested positives for the disease at all of the five sites. The parasite density varied from 986 to 127,000 parasites/µl, with an average of 11,256 parasites/µl (SD=21,125). All of the Plasmodia involved were *P. falciparum*.

According to the findings, UITH had the highest prevalence, followed by CSC, while KWASUTH had the lowest frequency. However, the infection varied from one site to another because of a number of circumstances, such as housing, poverty, ignorance, socioeconomic status, geographic location, and environmental settings.

The prevalence in relation to age showed that the highest prevalence was observed among individuals aged 6–20 years, followed closely by those aged 1–5 years, while the lowest prevalence was recorded in individuals older than 40 years. These findings are largely consistent with those of Faga *et al*. (2020), [17] who reported the highest prevalence in the 1–10-year age group. This pattern may be attributed to the underdeveloped immune systems characteristic of younger age groups, which tend to strengthen with age. Factors such as repeated exposure to the parasite, proper nutrition, and effective illness management play critical roles in enhancing immunity [19] Prevalence of malaria in relation to gender indicated notable variations between genders, influenced by a combination of biological, social, and behavioral factors. Several studies have investigated these differences, yielding diverse findings. Here, females were more frequently infected than males which is synonymous with the finding of the study conducted in Uganda that found that females disproportionately contribute to the burden of malaria diagnosed at public health facilities, especially once they reach childbearing age [18] but contravened research in Ethiopia that reported a higher prevalence of malaria among males compared to females.

In terms of occupation, majority of students were infected, which is consistent with the findings of the [14]. This could be because they were exposed to mosquito bites from their outdoor activities at school and at home, which goes against the widely held belief that socioeconomic status, illiteracy, and disregard for mosquito control measures would make people more vulnerable to contracting malaria.

4.1. White Blood Cells (WBC)

The majority of patients (82%) had normal WBC counts, while 14.5% had low WBC levels, and only 2.9% had high counts. Leukopenia (low WBC count) can be associated with malaria due to the destruction of white blood cells or their sequestration in the spleen [9]. Mild leukocytosis (high WBC) can sometimes occur due to secondary infections.

4.2. Red Blood Cells (RBC)

A significant proportion of patients (59%) had low RBC counts, which suggests anaemia, a common consequence of malaria. The destruction of RBCs by Plasmodium species and the suppression of erythropoiesis contribute to this [19]. About 10% had high RBC counts, which might indicate compensatory erythropoiesis in response to anaemia.

4.3. Haemoglobin (Hb) and Haematocrit (HCT)

A majority of the patients (61%) had low Hb levels, and 69% had reduced haematocrit. This finding aligns with malaria-induced haemolysis and bone marrow suppression. Low Hb is a primary indicator of anaemia, which is a major complication of malaria [20]. The absence of elevated Hb levels further supports the disease's impact on erythropoiesis.

4.4. Mean Corpuscular Volume (MCV)

A majority (62%) had normal MCV values, but 26% had low values, suggesting microcytosis, which is often linked to iron deficiency anaemia or chronic disease. The 12% with high MCV might indicate macrocytosis due to increased erythropoiesis in response to haemolysis.

4.5. Red Cell Distribution Width (RDW)

Approximately 48.5% had low RDW, while 47% were normal, and 3% had elevated values. Increased RDW indicates anisocytosis, which is expected in malaria due to varying RBC sizes caused by haemolysis and reticulocytosis [21].

4.6. Platelets

A significant proportion (87%) had low platelet counts, which is consistent with thrombocytopenia, a common finding in malaria patients due to increased platelet destruction and consumption [20].

4.7. Neutrophils

Most patients (89%) had normal neutrophil counts, while 9.7% had lower counts. Neutropenia is sometimes associated with malaria due to immune-mediated destruction.

4.8. Lymphocytes and Monocytes

A majority of patients (75%) had normal lymphocyte counts, while 24% had low counts, which may be due to sequestration in the spleen. Monocytosis (19%) is commonly seen in malaria, reflecting the immune response to the parasite.

4.9. Eosinophils and Basophils

Most patients (91%) had normal eosinophil levels, while 9% had elevated values. Eosinophilia can occur post-malaria as the immune system recovers [21]. A striking 47% had high basophil counts, which might indicate a significant immune response or allergic-type reactions during malaria infection.

The haematological profile of malaria-infected individuals shows significant alterations compared to non-infected controls. These changes reflect the complex interactions between the malaria parasite and the host's immune and haematopoietic systems.

4.10. White Blood Cells (WBC) and Differential Counts

The mean WBC count is significantly lower in malaria-infected individuals ($6.01 \pm 1.73 \times 10^9$/L) than in non-infected controls ($7.93 \pm 1.00 \times 10^9$/L, $p = 0.002$). Leukopenia in malaria is likely due to sequestration of WBCs in the spleen and bone marrow suppression [21].

- **Lymphocytes (%)** are significantly higher in infected individuals (33.48 ± 9.53) compared to controls (21.76 ± 8.25, $p = 0.005$). This lymphocytosis could be due to immune activation in response to parasitic infection [22]
- **Neutrophil (%)** is significantly elevated in malaria patients (68.60 ± 4.72) compared to non-infected individuals (43.50 ± 8.15, $p < 0.001$). This increase may be due to an acute immune response to infection.
- **Monocytes (%)** are also significantly higher in malaria cases (10.07 ± 3.69) compared to controls (7.73 ± 2.15, $p = 0.013$). Monocytes play a role in phagocytosis of infected erythrocytes and parasite clearance [19].
- **Eosinophils ($\times 10^{12}$/L)** are lower in malaria-infected individuals (2.09 ± 1.25) than in controls (3.81 ± 0.43, $p = 0.010$). This suppression could be due to immune modulation by the malaria parasite [21].
- **Basophils (%)** are significantly elevated in malaria patients (1.58 ± 0.78) compared to controls (0.85 ± 0.19, $p < 0.001$). Basophils may contribute to the inflammatory response and cytokine release during malaria infection.

4.11. Red Blood Cell Parameters and Anaemia Indicators

Malaria-induced haemolysis and bone marrow suppression contribute to the significant reductions in red blood cell (RBC) indices.

- **RBC count ($\times 10^{12}$/L)** is significantly lower in malaria-infected patients (3.63 ± 0.73) compared to controls (3.90 ± 0.32, $p = 0.009$). RBC destruction by Plasmodium and ineffective erythropoiesis contribute to this decline [22].

- **Haemoglobin (Hb, g/dL)** is significantly reduced in malaria cases (10.86 ± 0.99) compared to controls (13.59 ± 2.17, $p < 0.001$), confirming malaria-associated anaemia.

- **Haematocrit (HCT, %)** is also lower in infected individuals (37.11 ± 4.32) compared to controls (39.68 ± 1.34, $p = 0.029$), further supporting anaemia as a primary consequence of malaria infection.

4.12. Red Blood Cell Morphology and Variability

- Mean Corpuscular Volume (MCV, fL) is significantly elevated in malaria patients (104.8 ± 19.02) compared to controls (90.43 ± 2.50, $p < 0.001$). Macrocytosis in malaria may be due to the presence of young reticulocytes compensating for RBC destruction.
- Mean Corpuscular Haemoglobin (MCH, pg) is also significantly higher in malaria cases (40.83 ± 7.23) versus controls (31.71 ± 1.53, $p < 0.001$). Increased MCH might be due to haemolysis-induced compensatory erythropoiesis.
- Red Cell Distribution Width (RDW, %) shows no significant difference between groups ($p = 0.596$), suggesting that RBC size variability remains comparable.

4.13. Platelet Count and Malaria-Induced Thrombocytopenia

Malaria-infected individuals exhibit significantly lower platelet counts ($137.37 \pm 72.33 \times 10^9$/L) compared to controls ($262.89 \pm 33.75 \times 10^9$/L, $p < 0.001$). Thrombocytopenia in malaria is attributed to platelet destruction, splenic sequestration, and immune-mediated mechanisms [21]

4.14. Inflammatory and Immune Response Ratios

- Neutrophil-to-Lymphocyte Ratio (NLR) is significantly lower in malaria-infected patients (1.55 ± 1.06) compared to controls (3.61 ± 1.37, $p = 0.002$). NLR has been proposed as a marker for infection severity, with lower values indicating a heightened lymphocyte response in malaria [22].
- Platelet-to-Lymphocyte Ratio (PLR) is also significantly reduced in malaria cases (4.90 ± 4.67) compared to controls (13.36 ± 4.15, $p < 0.001$). PLR has been explored as a potential marker of systemic inflammation and disease severity.

Monocyte-to-Lymphocyte Ratio (MLR) shows no significant difference between malaria-infected and non-infected individuals ($p = 0.420$), suggesting that monocyte activation levels remain relatively stable.

5. Conclusion

The haematological changes observed provide critical insights into the pathogenesis of malaria and its impact on the host's haematopoietic and immune systems. These findings underscore the importance of routine haematological assessments for

- Early diagnosis and monitoring disease progression,
- Assessing severity and guiding therapeutic interventions,
- Evaluating immune response and potential complications in malaria patients.
- Anaemia and Thrombocytopenia were major haematological abnormalities observed in all cases of malaria. Therefore, patients presenting with febrile illness that also have thrombocytopenia should alert the clinician about the possibility of malaria infection.

Recommendation

The study reinforces the value of haematological parameters as diagnostic and prognostic markers in malaria management. Future research should focus on exploring the molecular mechanisms underlying these haematological alterations to develop targeted therapeutic strategies.

Authors contributions

Oluwasogo, O, conceived and designed the study, Abdulraheem, J performed the field work and laboratory aspect of the work, while Awe, S did the intellectual manuscript review. All authors reviewed and approved it.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declared that this research was conducted without any financial benefit that can influenced the results / outcome of the work. There is no conflict of interest by the authors.

Statement of ethical approval

Ethical clearances were obtained from ethical review committees of both the Kwara State Ethical Committee, Ministry of Health, Fate Ilorin (**MOH/KS/EU/777/493**) and The University of Ilorin Teaching Hospital Ilorin, Kwara State, Nigeria (**UITH PAN/2022/12/0223)**. The study followed Helsinki ethical code of conduct 2019

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] World Health Organization. World malaria report (2015). Geneva: World Health Organization; https://apps.who.int/iris/bitstream/handle/10665/200018/9789241565158_eng.pdf;jsessionid=A63034A5EF79C858F9DE80D3349C82AD?sequence=1. Accessed 15 July 2020.

[2] Mangusho, C., Mwebesa, E., Izudi, J., Aleni, M., Dricile, R., Ayiasi, R. M., & Legason, I. D. (2023). High prevalence of malaria in pregnancy among women attending antenatal care at a large referral hospital in northwestern Uganda: A cross-sectional study. PloS One, 18(4), e0283755. https://doi.org/10.1371/journal.pone.0283755

[3] Muwonge H, Kikomeko S, Sembajjwe LF, Seguya A, Namugwanya C. (2013). How reliable are hematological parameters in predicting uncomplicated Plasmodium falciparum malaria in an endemic region? ISRN Trop Med. 1–9. doi: 10.1155/2013/673798. [DOI] [PMC free article] [PubMed] [Google Scholar]

[4] Bakhubaira S. (2013). Hematological parameters in severe complicated Plasmodium falciparum malaria among adults in Aden. Turk J Haematol. 30:394–9. doi: 10.4274/Tjh.2012.0086. [DOI] [PMC free article] [PubMed] [Google Scholar]

[5] Latif I, Jamal A. Hematological changes in complete blood picture in paedriatric patients of malaria caused by Plasmodium vivax and falciparum. J Ayub Med Coll Abbottabad. 2015;27:351–5. [PubMed] [Google Scholar]

[6] Ménard, D., Khim, N., Beghain, J., Adegnika, A. A., Shafiul-Alam, M., Amodu, O., Rahim-Awab, G., Barnadas, C., Berry, A., Boum, Y., Bustos, M. D., Cao, J., Chen, J.-H., Collet, L., Cui, L., Thakur, G.-D., Dieye, A., Djallé, D., Dorkenoo, M. A., … Mercereau-Puijalon, O. (2016). A worldwide map of Plasmodium falciparumK13-propeller polymorphisms. The New England Journal of Medicine, 374(25), 2453–2464. https://doi.org/10.1056/nejmoa1513137

[7] Mahmood A, Mahmood R, Iqbal MI (2020). Evaluation of haematological parameters in malaria infection and its association with different species of malarial parasite. Pak Armed Forces Med J.70:1576–80. [Google Scholar]

[8] D'acremont V, Landry P, Mueller I, Pécoud A, Genton B. (2002). Clinical and laboratory predictors of imported malaria in an outpatient setting: an aid to medical decision making in returning travelers with fever. Am J Trop Med Hyg. 66:481–4. doi: 10.4269/ajtmh.2002.66.481. [DOI] [PubMed] Google Scholar

[9] Maina R.N, Walsh D, Gaddy C (2022). Impact of Plasmodium falciparum infection on haematological parameters in children living in western Kenya. Malaria Journal. Suppl 9 (3).

[10] Bidaki Z, Dalimi A (2023). Biochemical and hematological alteration in vivax malaria in Kahnouj city. J Rafsanjan Univ Med Sci. 17–24.

[11] Author field survey, 2022

[12] Njunda AL, Ngouadjeu DTE, Nsagha DS, Nyanjoh EM, Kwenti TD, Assob NJC (2016). Haematological profile of children with malaria in Kumba Health District, South West Region Cameroon. Afr J Integ Health. 6:23–9.

[13] Oluwasogo, O A., Ismail, H.O., Pelumi, D.A (2020). Molecular Epidemiology of Plasmodium falciparum Transporter Genes among School Children in Kwara State, Southwestern Nigeria. International Journal of Tropical Disease and Health. 41 (2) : 1-12

[14] Cheesebrough, M. (2010). District Laboratory Practice in Tropical Countries; Second edition update (Part1). Cambridge University press.

[15] Kolawole, M. O., Mokolu, A. O., Olukosi, A. Y., & Oleyede, A. T. (2016). Population genomic diversity of Plasmodium falciparum in malaria patients attending Okelele Health Centre. African Health, 16(3).

[16] Abdulraheem, J.O., Oluwasogo, O., Sunday, A. (2024). Distribution of Plasmodium falciparum Resistance Transporter (Pfcrt) and Plasmodium falciparum (Pfmdr-1) genes in Ilorin, North Central Nigeria. FUDMA Journal of Sciences.8(5) pp 201-209. Doi:https://doi.org/10.33003/fjs-2024-0805-2661

[17] Mohammed, R. H., Nock, H. I., Ndams, S. I., George, B. J., & Deeni, Y. (2017). Distribution of Pfmdr1 and Pfcrt chloroquine drug resistance alleles in north-western Nigeria. Malaria World Journal, 8.

[18] Faga, D.C., Obisike, V.U., Onah, I.M., Amuta, E.U (2020). Assessment of Malaria Parasitaemia and Genotype of Patients Attending two Hospitals in Benue State, Nigeria. Animal Research International. 17(2): 3640 – 3648

[19] Okiringi J., Epstein A., Namuganga F., Kamya E V., Nabenda I., et al (2022). Gender difference in the incidence of malaria diagnosed at public health facilities in Uganda. Malaria Journal 21(1):22 doi 10.1186/s12936-022-04046-4

[20] Erhabor, O., Ivo, I., & Isaac, Z. (2022). Haematological changes associated with malaria: A review. Tropical Medicine and Infectious Disease, 7(1), 14. https://www.mdpi.com/2414-6366/7/1/14

[21] Lathia, T. B., & Joshi, R. (2004). Can haematological parameters differentiate malaria from other acute febrile illnesses in the tropics? Indian Journal of Medical Sciences.

[22] Kotepui, M., Kotepui, K. U., Milanez, G. D., & Masangkay, F. R. (2020). Effects of malaria infection on haematological parameters in humans: A systematic review and meta-analysis. Malaria Journal 19 (1), https://malariajournal.biomedcentral.com/articles/10.1186/s12936-020-03201-5

[23] Chua, C. L., Brown, G., Hamilton, J. A., Rogerson, S., & Boeuf, P. (2021). Monocyte and macrophage dysfunction in malaria. Pathogens, 10(9), 1203.https://www.mdpi.com/2076-0817/10/9/1203