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Red Blood Cell Indices of Children with Varying Degrees of Malaria Parasitemia in Jos, Plateau State-Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study aims to investigate the prevalence of haematological alterations and their diagnostic utility in malaria-infected children in Jos, Nigeria's Plateau state.
Study Design: This study is a cross-sectional study design to investigate the Red Blood Cell Indices of Children with Varying Degrees of Malaria Parasitemia in Jos, Plateau State-Nigeria.

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Place and Duration of the Study: The study was conducted in Jos University Teaching Hospital. Data collection covered a specific duration between August, 2022 to January, 2023.

Methods: From August 2022 to January 2023, the study was conducted as a cross-sectional study at Jos University Teaching Hospital in Plateau State. A total of 384 MP positive cases were collected and used in the study, which included children who met the inclusion criteria and were diagnosed throughout the study period. All patients had full blood counts taken as well as different red blood cell indices.

Results: The Comparison between children with mild malaria parasitemia to those with low malaria parasitemia, there was a significant rise in the red blood cell count (P<.05). Children with low, moderate, and high parasitemia levels of malaria do not significantly differ in red blood cell count (P>.05). The results of this study also revealed that there is no difference between children with low, mild, moderate, and high parasitemia levels in terms of their hematocrit (P>.05). Furthermore, when compared to children with mild malaria parasitemia, the haemoglobin level in the high parasitemia group of kids was considerably lower (P<.05). The children with low, mild, moderate, and high malaria parasitemia did not exhibit any discernible change in mean corpuscular volume according to the study's findings (P>.05). Contrarily, the mean corpuscular haemoglobin concentration was significantly higher (P<.05) in the children with high malaria parasitemia than in the children with mild malaria parasitemia, and it was significantly higher (P<.05) in the children with moderate malaria parasitemia than in the children with mild malaria parasitemia. Comparing the RDW-CV in moderate malaria parasitemia to mild malaria parasitemia, there was a substantial reduction (P<.05) in both cases.

Conclusion: This study's main finding is that children with various densities of malarial parasites display significant disparities in the indices of red blood cells during the infection.

Keywords: Malaria; red blood cell indices; children; Jos.

ABBREVIATIONS

WHO : World Health Organization
Hb : Hemoglobin
WBCs : White Blood Cells
RBCs : Red Blood Cells
RDW : Red Cell Distribution Width)
MCV : Mean Cell Volume
MCH : Mean Cell Hemoglobin
MCHC : Mean Cell Hemoglobin Concentration
RDW : Red Cell Distribution Width
K3 : EDTA-tripotassium ethylenediminetetraacetic acid

1. INTRODUCTION

The World Health Organization [WHO] estimates that malaria is a major public health issue in more than 100 countries, resulting in 200 million annual infections and more than 500 thousand fatalities [1]. In sub-Saharan Africa, where the illness is thought to claim one child every 30 seconds [2], more than 90% of these fatalities take place. Plasmodium species cause malaria, which is then disseminated by female *Anopheles* mosquitoes. The five Plasmodium species that are known to infect people are *Plasmodium falciparum, Plasmodium vivax, Plasmodium malariae, Plasmodium ovale,* and *Plasmodium knowlesi*. They are eukaryotic, unicellular protozoa that can infect a wide range of vertebrates, including reptiles, mammals, and birds. Malaria transmission was once widespread throughout the globe, but currently it is largely endemic to tropical and subtropical regions [3], as a result of some outstanding efforts. According to the World Health Organization's 2019 malaria report, there were 228 million cases and 405,000 fatalities from the disease in 2018[4], with 93% of all cases occurring in the African region. Nigerian anti-malaria campaigns concentrate on youngsters and expectant mothers.

Children's submicroscopic infections, asymptomatic parasitaemia, and detectable parasitaemia, however, are still unappreciated and require improvement [5]. Any disease condition, including endemic illnesses like malaria that can have an impact on human health and manifest in a variety of clinical ways, is likely to have an impact on changes in haematological parameters [6]. Changes in blood cell counts are a well-known sign of malaria infections. One of the most typical malarial consequences is hemorrhaging, and this plays a

significant part in the pathogenesis of malaria.[6]. Hematological abnormalities such anemia, thrombocytopenia, and leukocytosis or leucopoenia are widely documented to occur after a malaria infection. Patients with malaria typically had significantly lower levels of platelets, WBCs, lymphocytes, eosinophils, RBCs, and Hb, although their neutrophil and monocyte counts were significantly greater than those of patients without malaria [7]. Additionally, the degree of malaria endemicity, the presence of underlying hemoglobinopathy, demographic variables, and malaria immunity can all affect the hematological changes brought on by a malaria infection. The pathophysiological mechanisms underlying the hematological alterations brought on by malaria are intricate, numerous, and yet poorly understood [8]. RDW (Red Cell Distribution Width), MCV (Mean Cell Volume), MCH (Mean Cell Hemoglobin), and MCHC (Mean Cell Hemoglobin Concentration) are the erythrocyte indices taken into account in this study. Red Cell Distribution Width (RDW) is an automated measure of variation in red blood cell sizes, and RDW is typically calculated by dividing the standard deviation (a measure of variation) of RBC volume by MCV and multiplying by 100. MCV is a measure of the average size of a red blood cell, and MCH is a calculation of the average amount of hemoglobin inside a red blood cell. The current study aims to investigate the prevalence of haematological alterations and their effects in malaria-infected children in Jos, Nigeria's Plateau state.

2. METHODOLOGY

2.1 Study Area

This present study was carried out at the Hematology Department of the Jos University Teaching Hospital, Jos Plateau state.

2.2 Research Design

This study was designed as a cross-sectional study.

2.3 Study Population

2.3.1 Inclusion criteria

Malaria-infected children ranging from zero age (0) to seventeen (17) years who presented with both clinical symptoms and laboratory-confirmed malaria parasite infection (cases) that applied to the outpatient clinics or were hospitalized at the Jos University Teaching Hospital are included in this study.

2.3.2 Exclusion criteria

Adults above seventeen (17) years of age, and children with hemoglobinopathies and other severe medical conditions are excluded from this study.

2.4 Sample Size Determination

A total of 384 subjects, with appropriate clinical findings and laboratory confirmation were used. The sample size was calculated using the formula;

$n=Z^2pq/ d^2$

Where, n= sample size,

Z is to be 1.96 (for 95% confidence level),
d is the desired level of accuracy (taken as 0.05),
p is the estimate of the satisfaction rate among our target population (which was assumed to be 50% in the absence of a pre-existing estimate)
$n=Z^2pq/ d^2$
$(1.96)^2 \times 0.5\times 0.5 / (0.05)^2 = 384.$

Therefore, 384 participants were used for this study.

2.5 Data Collection Methods

2.5.1 Collection of blood sample

Children's handy peripheral veins were used to extract 5ml of blood into K3-EDTA vacutainer tubes. The child's number, sex, weight, and age were additionally written on the vacuum tubes. Within two hours of collection, the samples were utilized to create thick and thin blood smears for malaria parasite microscopy. While parasites were isolated using a microscope method and their density was measured against infected red blood cells, other clinical information was gleaned from the participants' medical records. The values of red cell indices were collected using the automated complete blood count.

2.5.2 Determination of malaria density

Parasites density was calculated using a microscopic technique. The microscopic method was employed to determine malaria parasite density as thus; the film was examined

microscopically with high power objective lens, with a total of 200 fields examined microscopically for each film, positive findings were graded on the thin smear using the 'plus' system scale. These scores were used to estimate the parasite densities: + = 10 to 90 parasites /µl; ++ = 100 to 1,000 parasites /µl; +++ = 1,000 to 10,000 parasites /µl; ++++ = > they were graded as thus; + = low, ++ = mild, +++ = moderate, and ++++ = high.

2.5.3 Determination of red blood cells indices

The following steps were taken in order to determine the erythrocyte indices and leucocyte counts using the Sysmex XN550 haematology analyzer: After three minutes in a blood mixer with EDTA samples, the blood cells were automatically counted using a probe attached to a Sysmex system. The blood cell count result was shown on the machine's coloured LCD screen and printed using the appropriate printer after one minute.

2.6 Statistical Analysis

Statistical analyses were conducted using SPSS (version 23) software, and results was expressed in simple percentages, mean ± standard deviation. The hypothesis was tested using the student t-test. Results were presented in tables.

3. RESULTS

The following results were obtained from this study, analyzed and presented in tables and figures.

Table 1. Demographic Distributions of the study participants

Characteristics		Frequency (N)	Percentage (%)
Age (years)	Less than a year (infant)	23	6.0
	1-3 years (Toddler)	69	18.0
	4-9 years (School age)	184	47.9
	10-18 years (Adolescent)	108	28.1
Sex	Female	197	51.3
	Male	187	48.7
Ethnicity	Beron	46	12.0
	Fulani	34	8.9
	Hausa	85	22.1
	Igbo	20	5.2
	Ngas	43	11.2
	Yoruba	26	6.8
	Others	130	33.8

Table 2. Hematological parameters of subjects infected expressed in Mean ± SEM

Variables	Low	Mild	Moderate	High	F-value	P-value
RBC (10^6/µL)	4.04 ± 0.17	4.47 ± 0.06	3.97 ± 0.15	4.06 ± 0.18	4.987	0.002
HCT (%)	31.5 ± 1.12	34.1 ± 0.46	31.8 ± 1.12	31.8 ± 1.24	2.841	0.058
HGB (g/dL)	10.5 ± 0.37	11.3 ± 0.15	10.5 ± 0.39	10.3 ± 0.42	3.197	0.023
MCV (fL)	79.1 ± 1.67	77.9 ± 0.65	80.6 ± 0.99	78.5 ± 1.19	0.998	0.394
MCH (pg)	26.2 ± 0.69	25.1 ± 0.26	27.0 ± 0.51	25.4 ± 0.43	3.327	0.020
MCHC (g/dL)	32.8 ± 0.27	32.2 ± 0.16	33.1 ± 0.34	33.5 ± 1.12	2.631	0.050
RDW-CV (%)	16.4 ± 0.68	16.7 ± 0.23	14.4 ± 0.37	15.2 ± 0.37	7.244	0.000

Key; RBC= red blood cells, HCT= hematocrit, HGB= hemoglobin, MCV= mean corpuscular volume, MCH= mean corpuscular hemoglobin, MCHC= mean corpuscular hemoglobin concentration, RDW-CV= red cell distribution width

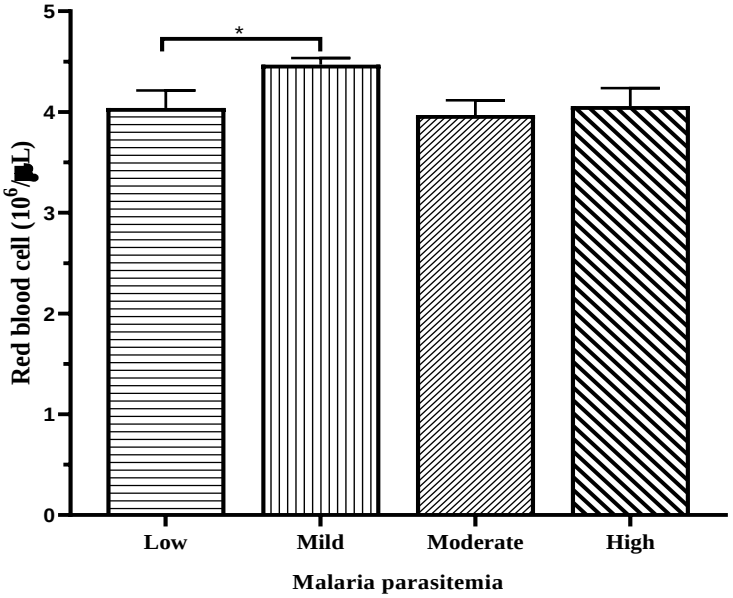

Fig. 1. The red blood cell counts in the children with malaria parasitemia
*Bars represent Mean±SEM, *significant difference P <.05.*

The red blood cell count was significantly increased (*P*<.05) in the children with mild malaria parasitemia when compared with the children with low malaria parasitemia. There is no significant difference (*P* >.05) in the red blood cell count of children with low, moderate and high malaria parasitemia.

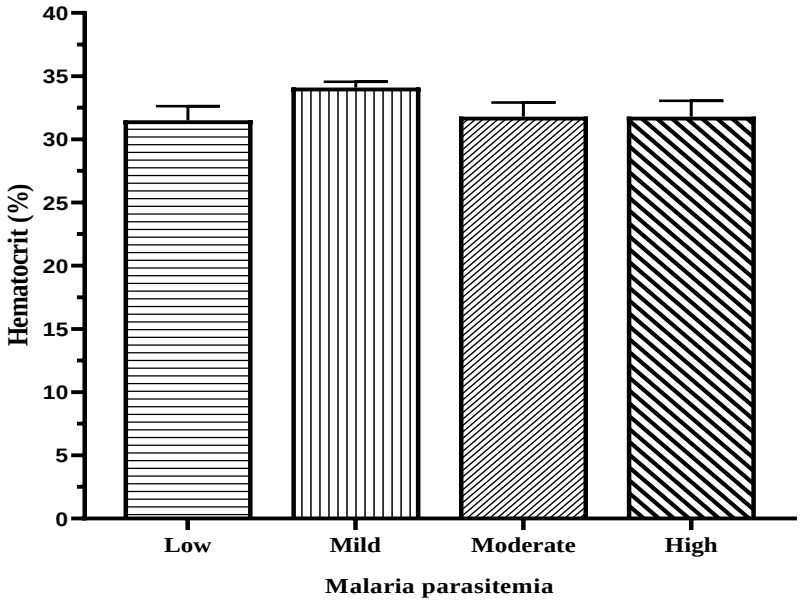

Fig. 2. Hematocrit in the children with malaria parasitemia
Bars represent Mean±SEM

There is no significant difference (*P*>.05) in the hematocrit of the children with low, mild, moderate, and high malaria parasitemia.

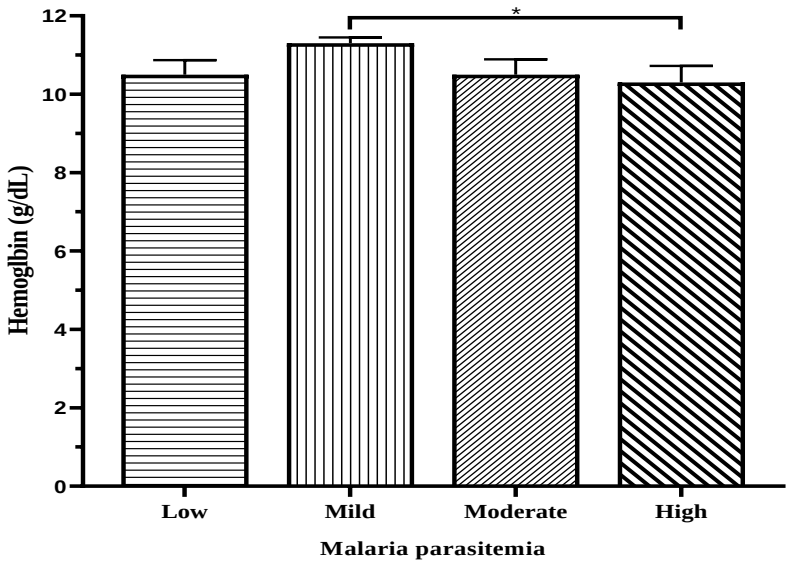

Fig. 3. Hemoglobin in the children with malaria parasitemia
*Bars represent Mean±SEM, *significant difference P <.05*

The hemoglobin level was significantly reduced (*P* <.05) in the children with high malaria parasitemia when compared with the children with mild malaria parasitemia.

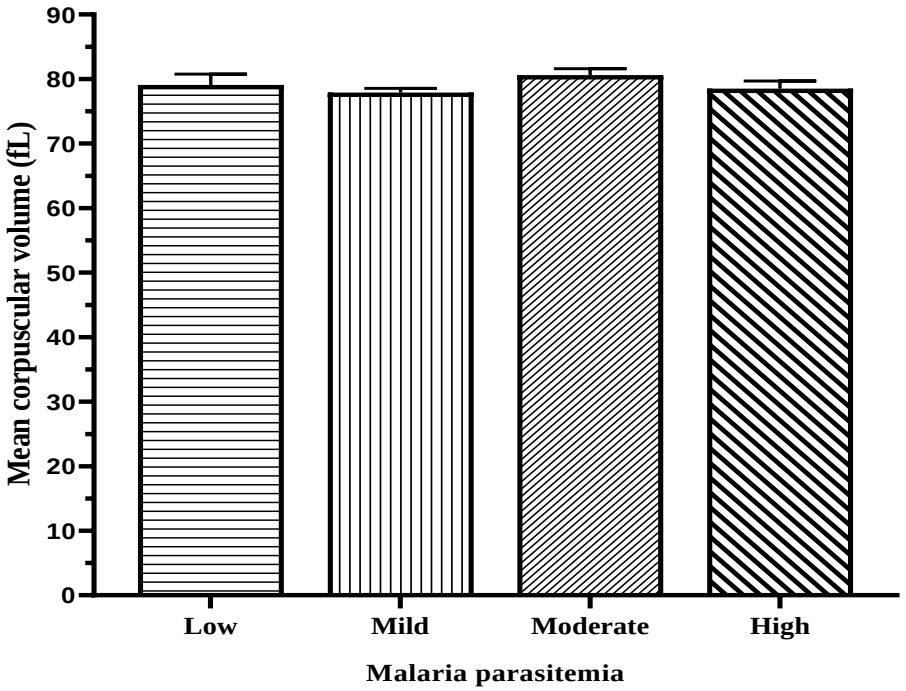

Fig. 4. Mean corpuscular volume in the children with malaria parasitemia
Bars represent Mean±SEM,

There is no significant difference (*P* >.05) in the mean corpuscular volume of the children with low, mild, moderate, and high malaria parasitemia.

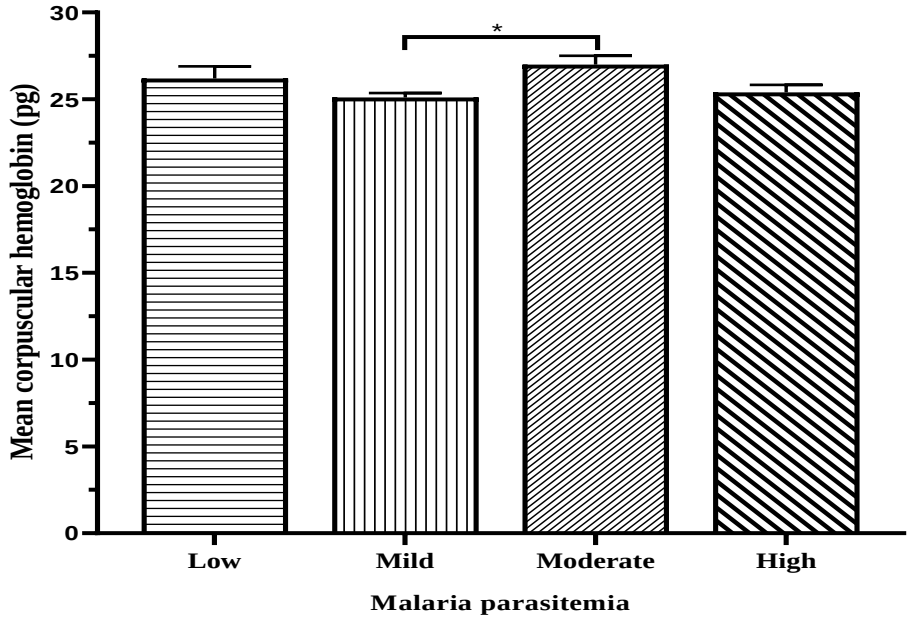

Fig. 5. Mean corpuscular hemoglobin in the children with malaria parasitemia
*Bars represent Mean±SEM, *significant difference P <.05.*

The mean corpuscular hemoglobin was significantly increased (*P* <.05) in the children with moderate malaria parasitemia when compared with the children with mild malaria parasitemia.

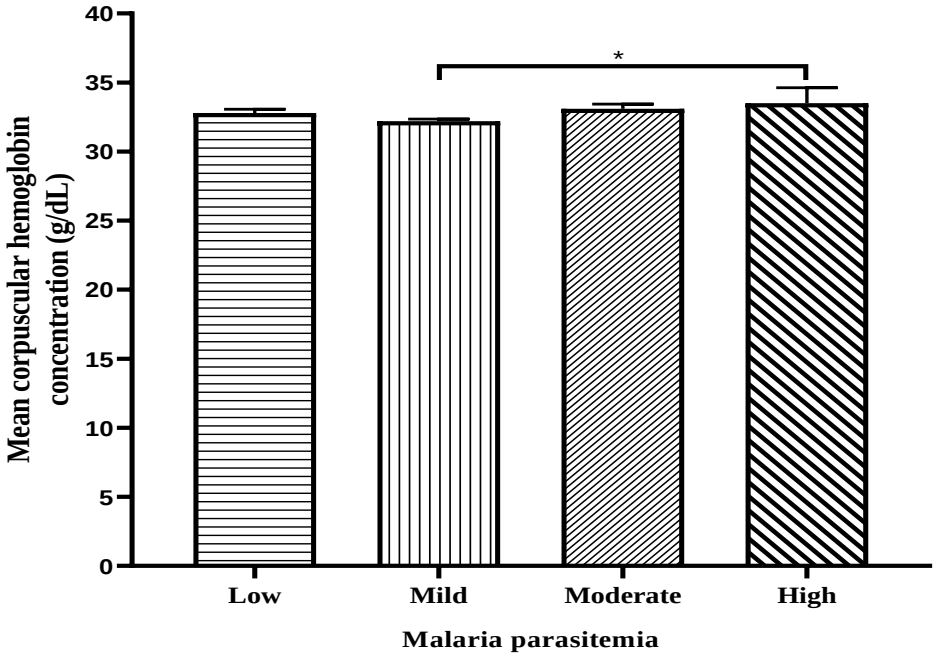

Fig. 6. Mean corpuscular hemoglobin concentration in the children with malaria parasitemia
*Bars represent Mean±SEM, *significant difference P <.05.*

The mean corpuscular hemoglobin concentration was significantly increased (*P* <.05) in the children with high malaria parasitemia when compared with the children with mild malaria parasitemia.

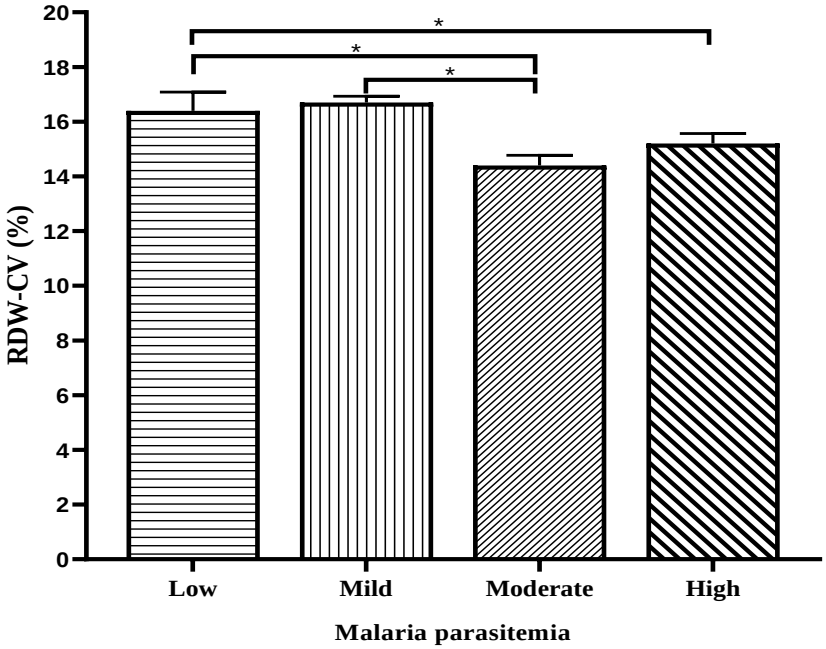

Fig. 7. RDW-CV in the children with malaria parasitemia
*Bars represent Mean±SEM, *significant difference P <.05.*

The RDW-CV was significantly reduced (*P* <.05) in the moderate and high malaria parasitemia when compared with the low malaria parasitemia. The RDW-CV was also significantly reduced (*P* <.05) in moderate malaria parasitemia when compared with the mild malaria parasitemia.

4. DISCUSSION

The findings of the gender distributions of the study group revealed that 197 (51.3%) of the children were females while 187 (48.7%) were males, indicating the predominance of female children over boys infected with malaria in this study. Erythrocyte indices of children in Jos with varying degrees of malaria parasitemia have been analysed. When compared to children with low malaria parasitemia, children with mild malaria parasitemia had a significantly higher red blood cell count (*P*> .05). Because anaemia has been noted as a side effect of malaria infection, there is no significant difference (*P* > .05) in the red blood cell count of children with low, moderate, or high malaria parasitemia. Children with malaria have been observed to have lower hematocrit levels, which may indicate the presence of asymptomatic anaemia caused by an imbalance between the creation and destruction of red blood cells in these children [9]. The results of this study, however, indicate that there is no significant difference (*P*> .05) between the hematocrits of the kids with low, mild, moderate, and high parasitemia levels of malaria. Our results support a report that the severity of malarial anaemia, whose hematocrit level may approach 15% or less and is frequently much higher than what can be accounted for by the loss of infected red blood cells, does not correlate with the degree of parasitemia [10,11]. Additionally, as compared to children with mild malaria parasitemia, the haemoglobin level in the children with severe malaria parasitemia was considerably lower (*P*>.05). This result is consistent with a study that mathematically modelled hematological data from experimental human P. falciparum infections and found that up to 12 non-iRBCs can be destroyed for every iRBC, suggesting that non-iRBC destruction may be the primary cause of the decline in haemoglobin as parasite density rises [12].

According to Ajugwo and Adias [13], people with malaria had a higher mean cell volume than those without the infection. According to the study's findings, the children with low, mild, moderate, and high malaria parasitemia did not differ significantly (*P*>.05) in the mean corpuscular volume. This may imply that, despite the known difference in mean cell volume

between children with and without malaria, density has no bearing on the magnitude of the difference in mean cell volume.

In contrast, the mean corpuscular haemoglobin concentration was significantly higher (*P*> 0.05) in the children with high malaria parasitemia than in the children with mild malaria parasitemia, and it was significantly higher (*P*> 0.05) in the children with moderate malaria parasitemia than in the children with mild malaria parasitemia. The results of a study that revealed an increase in mean corpuscular haemoglobin and mean corpuscular haemoglobin concentration [14], are consistent with the findings of this study. These alterations occur as a result of the sequestration and rosetting of infected and uninfected erythrocytes, which clog the capillary and postcapillary venules of numerous organs. Malaria-related anaemia is also exacerbated by the increased breakdown of uninfected erythrocytes and a decrease in erythrocyte synthesis [15]. This could be the cause of how quickly RBCs are produced, which releases immature RBCs into the bloodstream and could raise MCH and MCHC values [16]. It appears that parasite density affects these alterations. When compared to children without the infection, plasmodium falciparum infection, which is the most common cause of malaria infection in Nigeria, causes a significant increase in red cell distribution width, which suggests apparent anisocytosis [17]. This study demonstrates that, as compared to low malaria parasitemia, the RDW-CV was considerably lower in moderate and high malaria parasitemia (*P*<.05). When compared to mild malaria parasitemia, the RDW-CV was similarly considerably lower (*P*<.05) in moderate malaria parasitemia. The observed variance demonstrates that, in contrast to those with moderate and high parasitemia, the degree of variation in the size of red blood cells is greater during low parasitemia. As a result, the variance that was found in this study suggests that RBCs have different sizes (i.e., anisocytosis) when the parasite density fluctuates. This could be the body's attempt to make up for the anaemia that develops as the infection worsens.

5. CONCLUSION

This study's main finding is that children with various densities of malarial parasites display significant disparities in the indices of red blood cells during the infection. Patients with various malaria parasite densities also experience considerable changes in their red blood cell count, haemoglobin concentration, mean cell haemoglobin, mean corpuscular volume, and red blood cell dispersion width. In contrast, the mean corpuscular volume and hematocrit of infected children with various parasitemia densities did not vary in any discernible way. The goal of malarial parasite density reduction or clearance should be the focus of malaria control policy. It is anticipated that the findings from this study will help in understanding erythrocyte status and enhance clinical care for kids who have malaria in this area.

CONSENT

All authors unanimously declare that written informed consent was obtained from the participants for publication of this study finding.

ETHICAL APPROVAL

Ethical approval was obtained from the ethics committee of the University of Jos Teaching Hospital.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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