



## Research Article

# Impact of *Plasmodium falciparum* Parasitaemia on Packed Cell Volume in Pregnant Women Attending Antenatal Clinic in Maiduguri, North-eastern Nigeria

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## ARTICLE INFO: ABSTRACT

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*Plasmodium falciparum* malaria remains a major cause of public health problems, such as maternal morbidity and anaemia, in Sub-Saharan Africa. However, trimester-specific relationships between parasite density and packed cell volume (PCV) in pregnancy remain underexplored in northeastern Nigeria. A cross-sectional study was conducted among 384 pregnant women attending antenatal care at the State specialist hospital, Maiduguri, between August and October 2024. Venous blood samples were collected using standard WHO protocols for malaria microscopy (thick and thin films) and PCV determination. Parasite density was quantified per  $\mu\text{L}$  of blood, and statistical analysis was performed in SPSS version 25 at a 95% confidence level. Overall, malaria prevalence was 79.2% (304/384). Infection was highest in the second trimester (44.8%), followed by the third (25%) and first (9.4%) trimester. A strong negative correlation was observed between parasite density and packed cell volume in the overall samples ( $r^2 = 0.7448$ ,  $P < 0.05$ ), and in the first ( $r^2 = 0.6718$ ,  $P < 0.05$ ), second ( $r^2 = 0.6720$ ,  $P < 0.05$ ), and third trimester ( $r^2 = 0.8662$ ,  $P < 0.05$ ). Pregnant women aged 25-34 years had the highest prevalence of parasite density  $>500$  parasite/ $\mu\text{L}$  (27.6), while those aged 18-24 years recorded the highest proportion with low PCV (39%). *Plasmodium falciparum* infection significantly reduces PCV in pregnant women, with the most substantial impact in the third trimester. Findings underscore the need for routine trimester-specific malaria screening and anaemia prevention strategies in antenatal clinics in Maiduguri. Regular and consistent screening of Malaria infection among pregnant women during each hospital visit should be considered.

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## INTRODUCTION

Malaria, caused by protozoan parasites of the genus *Plasmodium*, remains one of the most significant infectious diseases globally, with the highest burden in sub-Saharan Africa (WHO, 2023; Muhammad *et al.*, 2025). *Plasmodium*

*falciparum* is the most virulent species, responsible for over 90% of African malaria cases (Muhammad *et al.*, 2020; Inuwa *et al.*, 2021). In 2022, there were an estimated 249 million malaria cases worldwide, with 94% occurring in the African region (WHO, 2023; Muhammad *et al.*,

2025). Pregnant women are particularly susceptible due to pregnancy-induced immunosuppression, which increases their vulnerability to malaria infection and its complications (Desai *et al.*, 2021). In Nigeria, malaria transmission is intense and perennial, with more than 90% of the population at risk and an estimated 50% experiencing at least one episode annually (FMOH, 2021). Malaria in pregnancy is associated with maternal anaemia, spontaneous abortion, stillbirth, premature delivery, and low birth weight (Tay *et al.*, 2017; WHO, 2023). Anaemia in particular, often measured by packed cell volume (PCV) or haemoglobin concentration, is a significant consequence of *Plasmodium falciparum* infection due to destruction of parasitised red blood cells (RBC) and dyserythropoiesis (Kotepui *et al.*, 2020). Although several Nigerian studies have reported the prevalence of malaria and its association with anaemia in pregnancy (Akingbola *et al.*, 2018; Olukosi *et al.*, 2019; Timothy *et al.*, 2025), most have not examined trimester-specific patterns of parasite density in relation to PCV. However, physiological changes in blood volume and immunity during pregnancy vary by trimester, which may influence the severity of malaria-associated anaemia (Sullivan *et al.*, 2020). Understanding this relationship could improve targeted screening and intervention strategies in antenatal care. Malaria infection can lead to various haematological changes, including anaemia (low PCV), thrombocytopenia (low platelet count), lymphocytosis (high lymphocyte count), monocytosis (high monocyte count), and disseminated intravascular coagulation. Understanding these changes in blood parameters is crucial for clinicians to diagnose and treat malaria effectively (WHO, 2023; Maina *et al.*, 2010). In malaria-endemic areas, pregnant women attending routine antenatal care at the facility.

#### **ETHICAL CLEARANCE**

Ethical clearance was obtained from the State Specialist Hospital Maiduguri, Ethics Committee (Approval Number: SSH/ADM/621/VOL.1/127).

women and children are particularly susceptible to infection after 4-6 months, when maternal antibodies fade (Dobbs *et al.*, 2016). Despite a high malaria burden in Maiduguri, there is limited evidence on how *Plasmodium falciparum* parasite density correlates with PCV at different stages of pregnancy. Previous regional studies have focused on the overall prevalence or general haematological changes, without stratifying correlation strength.

Using a relatively large sample size and correlational statistics, this study provides a trimester-specific quantitative analysis of the relationship between parasite density and PCV among pregnant women in Maiduguri. The findings aim to guide targeted interventions in malaria prevention and anaemia management during pregnancy.

#### **MATERIALS AND METHOD**

##### **STUDY AREA**

This study was conducted at the State Specialist Hospital, Maiduguri, Borno State, Nigeria, in the northeastern geopolitical zone. Maiduguri is the capital city of Borno state, bordered by Yobe state to the west, Gombe to the southwest, and Adamawa to the south while its eastern border forms part of the national border with Cameroon, its northern border forms part of the national border with Niger, and its northeastern border with Chad, being the only state in Nigeria that is bordered with three (3) foreign countries (Muhammad *et al.*, 2020). Maiduguri is one of the largest cities in Nigeria, situated in the northeastern part of the country. The latitude of Maiduguri, Borno, Nigeria is 11.833333, and the longitude is 13.150000. The city is located in Nigeria in the Cities place category with the GPS coordinates of 11° 49' 59.9988" N and 13° 9' 0.0000" E (Muhammad *et al.*, 2025).

##### **Study Design and Period**

Written informed consents was obtained from each participant, confidentiality was maintained throughout the study period.

##### **Study Population and Eligibility Criteria**

##### **Inclusion Criteria**

Pregnant women attending antenatal care at the State Specialist Hospital Maiduguri during the study period.

**Exclusion Criteria**

Women with severe illness requiring urgent medical attention, and non-consenting participants.

**Sample Size Determination**

Sample size was calculated using the formula for single proportion (Inuwa *et al.*, 2023).

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

Where  $z$  = standard normal deviation and probability at 95% confidence level (1.96),  $p$  = prevalence or proportion of value to be estimated from previous studies

$q$  = proportion of failure (= 1-P)

$d$  = precision, tolerance limit

$$n = z^2pq/d^2 = 1.96^2 \times 0.5 \times 0.5/0.05^2 = 384$$

Thus, a total of 384 pregnant women were enrolled.

**Sampling Procedure**

Participants were selected consecutively as they attended antenatal clinics until the required sample size was reached.

**Blood Sample Collection**

Venous blood (2-3ml) was collected via aseptic venipuncture into EDTA anticoagulated tubes. Samples were labelled with unique participant ID's and processed within 2 hours of collection.

**Malaria Microscopy**

Both thick and thin blood smears were prepared following WHO guidelines (WHO, 2016). Thick smears were used for parasite detection and quantification, while thin smears were used for species identification. Slides were stained with 10% Giemsa for 15minutes, rinsed, air-dried, and examined under oil immersion (x100 objective). Parasite density (parasites/  $\mu L$ ) was calculated by counting asexual parasites against 200 white blood cells (WBCs) and multiplying by the participants WBC count, assuming 8,000 WBCs/  $\mu L$  if not available (WHO, 2016: Timothy *et al.*, 20205).

**PARKED CELL VOLUME (PCV) MEASUREMENTS**

PCV was determined using the microhaematocrit method (Cheesbrough, 2010). Capillary tubes were filled two-thirds with well-mixed EDTA blood, sealed with plasticine, and centrifuged at 12,000 rpm for 5 minutes in a Hawksley microhaematocrit centrifuge. The PCV was read using Hawksley hematocrit reader. The centrifuge was calibrated weekly using a tachometer, and PCV measurements were performed in duplicate for each sample to ensure precision.

**DATA ANALYSIS**

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistical version 25. Continuous variables were expressed as mean  $\pm$  standard deviation (SD), and categorical variables as frequencies and percentages. The prevalence of malaria was calculated, and parasite density categories were compared across all trimesters and age groups using chi-square

The relationship between parasites density and PCV was assessed using Pearson's correlation coefficient, stratified by trimester, a  $p$ -value  $<0.05$  was considered significant. The choice of Pearson's correlation was based on the continuous nature of normal distribution via the Shapiro-Wik test.

**RESULTS**

Participants Characteristics and Malaria Prevalence

A total of 384 pregnant women (aged 18-39 years) participated. The overall prevalence of *Plasmodium falciparum* infection was 79.2% (304/384; 95% CI; 74.9-82.9%). Infection prevalence was highest in the second trimester (44.8%, 172/384; 95%CI; 39.7-50.0), followed by the third trimester (25%, 96/384; 95% CI;20.7-29.8) and the first trimester (9.4%, 36/384, 95% CI;6.8-12.8) (Table 1).

**Table 1:** Characteristics of the study participants and *P. falciparum* prevalence by trimester.

Variables	Positive n(%)	Negative n(%)	Total n(%)	95% CI for Positive Prevalence
<b>N0. Enrolled</b>	304 (79.2%)	80 (20.8%)	384 (100%)	74.9-82.9
<b>1<sup>st</sup> Trimester</b>	36 (9.4%)	5 (1.3%)	41 (10.67%)	6.8-12.8
<b>2<sup>nd</sup> Trimester</b>	172 (44.8%)	48 (12.5%)	220 (57.3%)	39.7-50.0
<b>3<sup>rd</sup> Trimester</b>	96 (25.0%)	27 (7.0%)	123 (32.0%)	20.7-29.8

**Parasite Density and Age distribution**

Among the infected women, parasite density  $\leq 500$  parasite per  $\mu\text{L}$  (Mild parasitaemia) accounted for 49.7%, 500-1000 parasite per  $\mu\text{L}$  (Moderate) 47.4%, and  $>1000$  parasites per  $\mu\text{L}$

(high) for 2.9%. The highest proportion of high density infection was observed among women aged 25-34 years (27.6%,  $X^2=19.67$ ,  $P=0.001$ ) (Table 2).

**Table 2:** Age distribution of malaria parasite density among infected pregnant women

Parasitic density (parasite/ $\mu\text{L}$ )	18-24years n(%)	25-34 years n(%)	35-39 years n(%)	Total n(%)	$X^2$ – Value	P-Value
$\leq 500$	53(17.4%)	66(21.7%)	32(10.5%)	151(49.6%)		
500-1000	40(13.1%)	84(27.6%)	20(6.5%)	144(47.3%)		
1001-1500	8(2.6%)	1(0.3%)	0(0.00%)	9(2.9%)	19.67	0.001
<b>Total</b>	<b>101 (33.2%)</b>	<b>151(49.6%)</b>	<b>52(17.1%)</b>	<b>304(100%)</b>		

**Parasite Density by Trimester**

A significant association observed between parasite density and gestational trimester ( $X^2=11.02$ ,  $P=0.003$ ), women in their second trimester had highest proportion of moderate (27.9%) and high (3.9%) parasite density (Table 3).

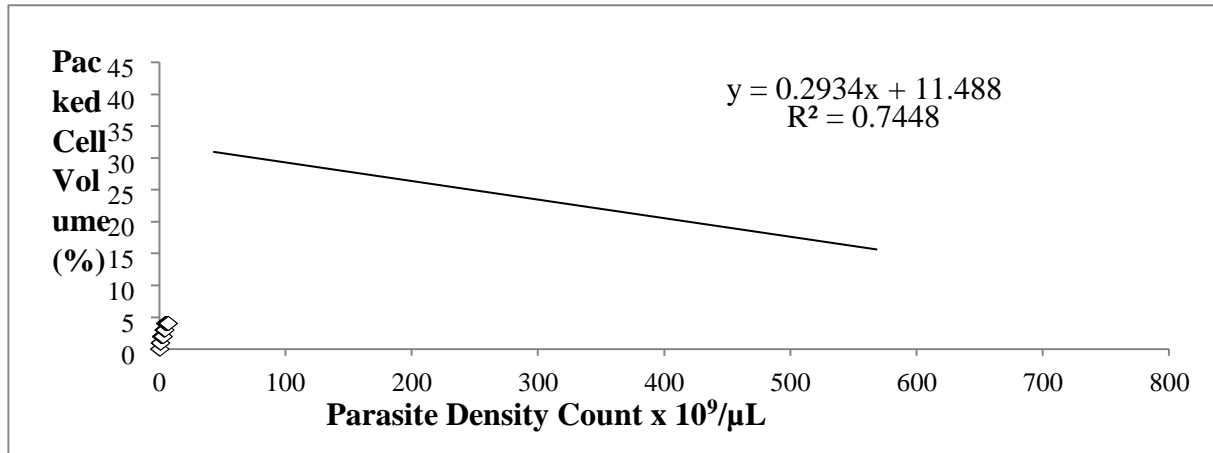
**Table 3:** Parasite Density distribution across trimester in infected women.

Parasitic density (parasite/ $\mu\text{L}$ )	First trimester (%)	Second trimester n(%)	Third trimester n(%)	Total n (%)	$X^2$ – Value	P-Value
$\leq 500$	26(8.5%)	84(27.%)	48(15.7%)	158(51.9%)		
500-1000	12(3.9%)	85(27.9%)	36(11.8%)	133(43.7)		
1000-1500	0(0.00%)	12(3.9%)	1(0.3%)	13(4.2%)	11.02	0.003
<b>Total</b>	<b>38 (12.5%)</b>	<b>181(59.5%)</b>	<b>85(27.9%)</b>	<b>304(100%)</b>		

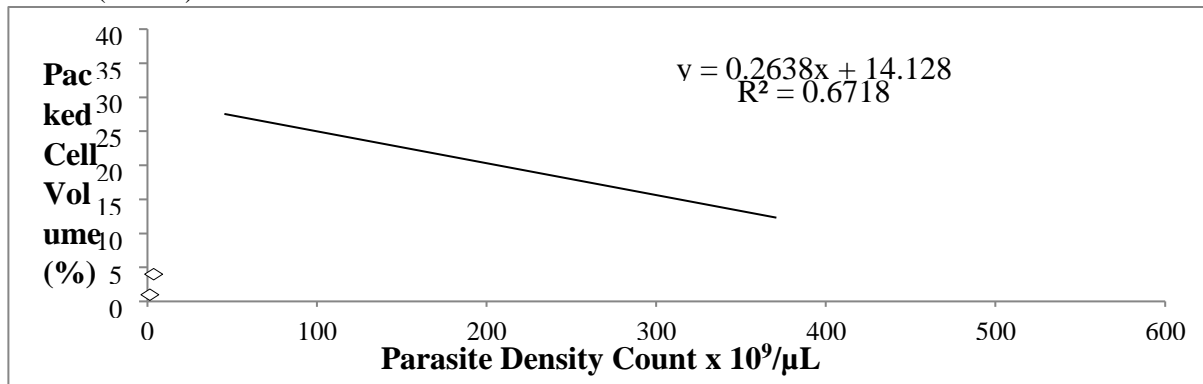
**Correlation between Parasite Density and Packed Cell Volume**

Overall, a strong negative correlation was found between parasite density and PCV ( $r^2= 0.7448$ ,  $p=0.05$ ). Stratified analysis showed: first trimester,  $r^2= 0.6718$ ,  $p= 0.05$ , second trimester,  $r^2= 0.672$ ,  $p= 0.05$  and third trimester,  $r^2= 0.8662$ ,  $p= 0.05$ .

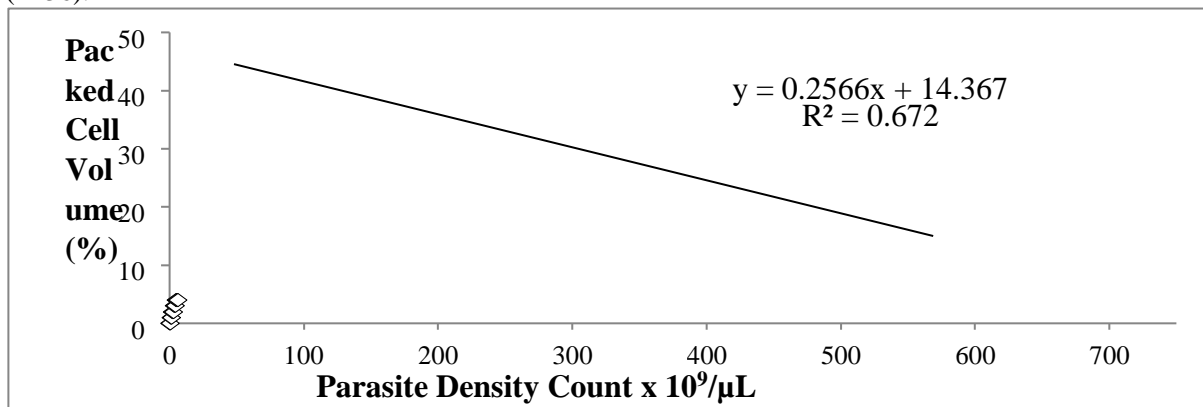
Figure 1 shows the overall correlation, while figures 2-4 present trimester specific relationships.



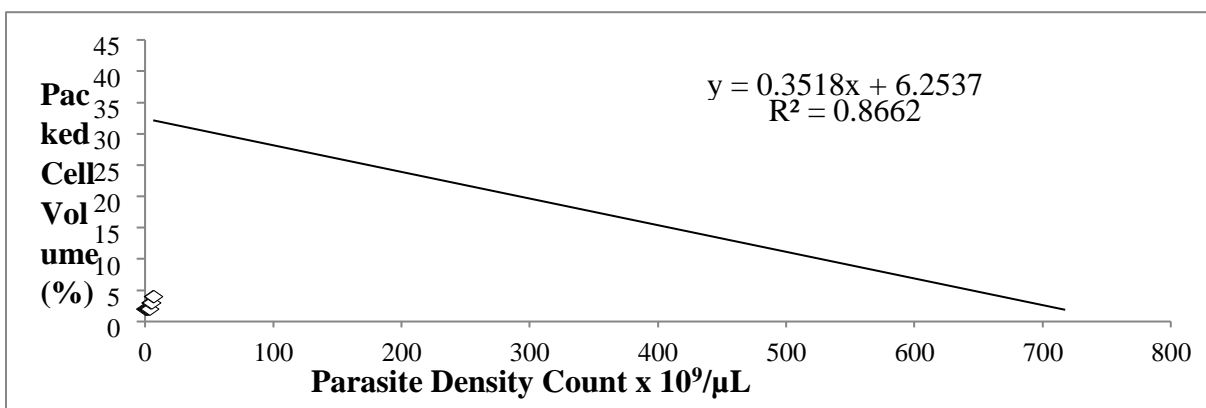
**Figure 1:** Scatter plot showing overall negative correlation between parasite density and parked cell volume (n= 304).



**Figure 2:** First (1<sup>st</sup>) trimester correlation of pregnant women infected with *P. falciparum* malaria. (n=36).



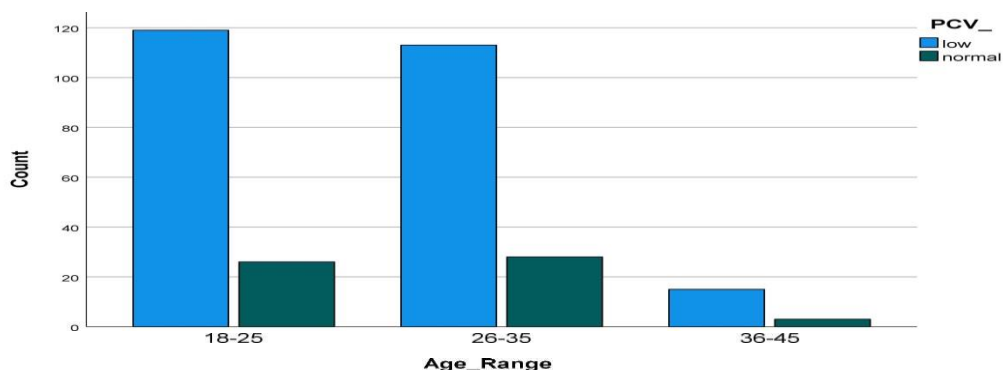
**Figure 3:** Second trimester correlation of pregnant women infected with *P. falciparum* malaria (n=172).



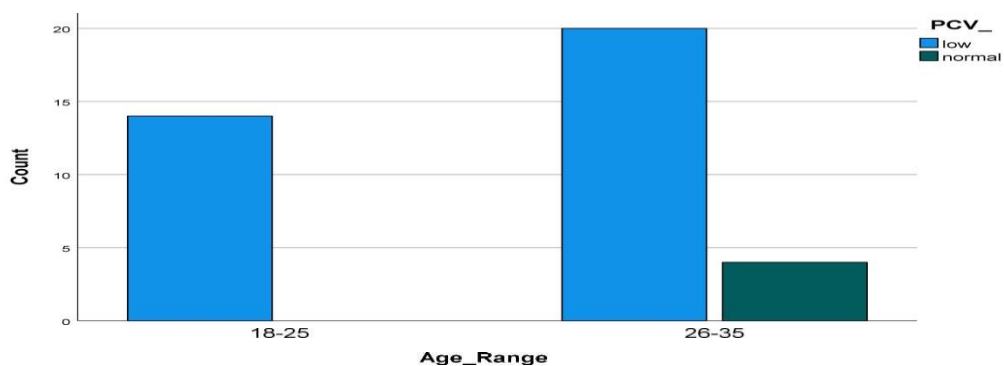
**Figure 4:** Third trimester correlation (n=96) of pregnant women infected with *P. falciparum* malaria.

#### PCV Distribution by Age and trimester

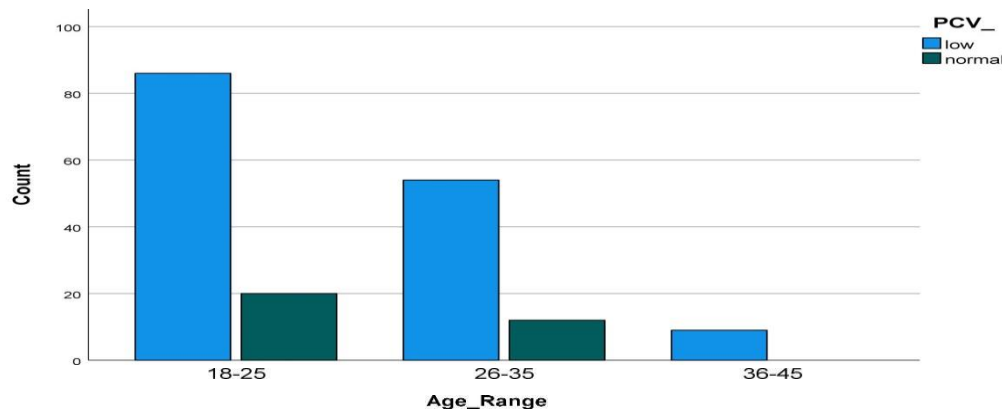
Low PCV (<33%) was most prevalent among aged women 18-24 years (39%), followed by those aged 26-35 years in the first trimester (52%), 18-25 years in the second trimester (48%), and 26-35 years in the third trimester (45%). Figure 5-8 illustrate PCV distribution by age groups across trimesters.



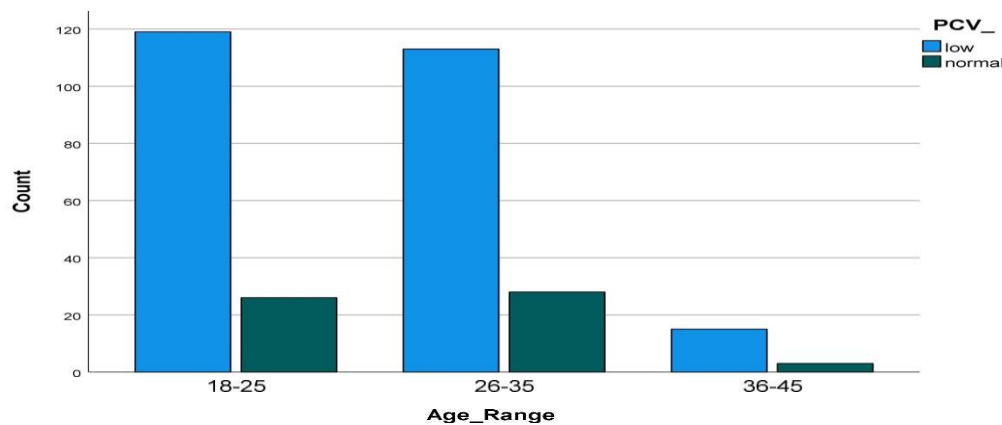
**Figure 5:** The distribution of PCV according to age range of the subject in the study area.



**Figure 6** The distribution of PCV according to age range of the subject in the study area in relation to first trimester.



**Figure 7** The distribution of PCV according to age range of the subject in the study area in relation to second trimester.



**Figure 8** The distribution of PCV according to age range of the subject in the study area in relation to third trimester.

## DISCUSSION

Malaria is a significant public health problem in sub-Saharan Africa, including Nigeria, where it accounts for more cases of infection and death than other country in the world, and the extent of utilisation of malaria preventive measures may impact the burden of malaria in pregnancy (Udomah *et al.*, 2015; Tango *et al.*, 2012). Being pregnant alone is a significant factor that compromises women's immune response, increasing their vulnerability to most infectious diseases (Sappenfield *et al.*, 2013; Tay *et al.*, 2017). Therefore, during pregnancy, the infection poses a high risk to the mother (Valente *et al.*, 2011). Risks associated with malaria during pregnancy include foetal death, premature

delivery, intrauterine growth retardation, low birth weight, maternal anaemia and mortality (Wini *et al.*, 2013).

This study found a high prevalence of *Plasmodium falciparum* parasitaemia (79.2%) among pregnant women attending antenatal at the State Specialist Hospital, Maiduguri, with the highest burden in the second trimester (44.8%). This prevalence exceeds recent reports from southern and Northern Nigeria (Akingbola *et al.*, 2018; 67.9%; Abigail *et al.*, 2021; 23.5%), and Ghana (Tay *et al.*, 2017; 62.5%), and is markedly higher than a 2023 Kenyan hospital-based survey (Desai *et al.*, 2023; 38.4%). The higher rates in our study may be due to Maiduguri's perennial malaria transmission, exacerbated by inadequate

vector control, poor drainage systems, and security-related displacement that increases exposure risk. This study corresponds with earlier findings of Jensen *et al.* (2017 and Timothy *et al.* (2025), who conducted a similar study in the Ebonyi and Borno states.

Our findings show that the second trimester recorded the highest prevalence and density of infection, aligning with reports from Ghana (Tay *et al.*, 2017), Borno and Sokoto, Nigeria (Udomah *et al.*, 2015; Muhammad *et al.*, 2025), where pregnancy was identified as a period of increased susceptibility. Physiologically, the second trimester is characterised by expanded plasma volume and reduced immunity due to hormonal modulation, which may facilitate higher parasite loads (Sullivan *et al.*, 2020). Interestingly, our strongest negative correlation between parasite density and PCV was observed in the third trimester ( $r^2 = 0.8662$ ), suggesting cumulative effects of prolonged infection or repeated exposure.

The strong inverse association between parasite density and PCV (overall  $r^2 = 0.7448$ ,  $p = 0.05$ ) is consistent with findings from recent multi-centre studies in Cameroon (Ngum *et al.*, 2021) and Ethiopia (Gebremichael *et al.*, 2022), both reporting significant reductions in hematocrit with increasing parasite loads. The pathology involves mechanical destruction of infected erythrocytes, immune-mediated clearance of uninfected cells, and bone marrow suppression (Kotepui *et al.*, 2020). Our data show that high parasite densities ( $>1000$  parasites per  $\mu\text{L}$ ) were (2.9%), yet again moderate parasitaemia significantly lowered PCV, indicating that anaemia risk is not limited to severe infections.

Younger pregnant women (18-24 years) showed higher rates of low PCV, consistent with Olukosi *et al.* (2019) and Panti *et al.* (2010), who reported that limited acquired immunity from fever malaria exposures contributes to poorer haematological outcomes in this age group. The highest prevalence of high-density parasitaemia in pregnant women aged 25-34 years (27.6%) may reflect both biological vulnerability and lifestyle exposure factors, such as outdoor evening activities and delayed use of preventive measures.

WHO recommends intermittent preventive treatment with sulfadoxine-pyrimethamine (IPT-SP) starting at 16 weeks of gestation (WHO, 2023). Our second-trimester peak prevalence suggests suboptimal uptake or late initiation of IPT-SP in this population. Similar patterns were reported in Maiduguri by Timothy *et al.* (2025), who found only 54% IPT-SP coverage among pregnant women.

The trimester-specific PCV decline observed here suggests that targeted anaemia prevention strategies should complement standard antenatal malaria screening, particularly in the third trimester. Integrating malaria rapid diagnostic testing with routine hematocrit monitoring could help identify women needing urgent intervention. Our findings support the WHO's Global Technical Strategy for Malaria (2021-2030) objectives of reducing malaria incidence and mortality by targeting high-risk populations, especially pregnant women. This study contributes actionable evidence to refine Nigeria's National Malaria Elimination Programmes' maternal health strategies by providing trimester-specific data.

#### **Limitations and Implications**

The study population comprised pregnant women attending a single tertiary hospital in Maiduguri, which may not fully represent women in the non-health-seeking population. The design captures parasite density and PCV simultaneously, limiting our ability to establish causality or track changes across trimesters in the same individuals. Other causes of anaemia, such as iron deficiency, HIV, and helminth infections, were not assessed in this study, which may have influenced PCV levels. While WHO-standard microscopy was used, PCR methods could have detected low-density infections missed by light microscopy. Data were collected between August and October, during peak malaria transmission; results may differ during the dry season.

Findings support integrating trimester-specific malaria and anaemia screening into routine antenatal care protocols in Nigeria. The substantial third-trimester PCV decline suggests a need for intensified prevention and monitoring towards the end of pregnancy. Longitudinal



cohort studies tracking women from early pregnancy to delivery could better establish temporal relationships between parasite density and PCV changes. The results of this study can guide targeted health education and IPT-SP delivery campaigns, particularly focusing on timely initiation in the second trimester and sustained preventive measures into the third trimester.

## CONCLUSION

This study demonstrated a high prevalence of *Plasmodium falciparum* (79.2%) among pregnant women in Maiduguri, with the most significant burden observed in the second trimester (44.8%) and the most severe impact on packed cell volume (PCV) occurring in the third trimester ( $r^2=0.8662$ ,  $p < 0.05$ ). Across all trimesters, parasite density was strongly and negatively correlated with PCV (overall  $r^2=0.7448$ ,  $p < 0.05$ ), indicating that even moderate parasitaemia substantially contributes to anaemia in pregnancy. Women aged 18-24 years were most likely to have low PCV, while high-density infections ( $< 1000$  parasites/ $\mu\text{L}$ ) were most prevalent in the 25-34-year age group.

## Recommendations

According to the findings of this study, it is recommended that;

- Implement routine trimester specific malaria and anemia screening in antenatal clinics.
- Strengthen uptake of intermittent preventive treatment with sulphadoxine-pyrimethamine (IPT-SP), particularly ensuring initiation in the second trimester and continuity into the third trimester.
- Integrate malaria rapid diagnostics testing with hematocrit or hemoglobin checks during all antenatal visits.
- Conduct community outreach to improve early antenatal attendance and preventive measure adoption, especially among younger women.

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