



Research Article

Effect of *Plasmodium falciparum* Infection on Eosinophil among Semi-Arid Zone Under-five Children: A Hospital Based Cross-sectional Study in Maiduguri, Northeastern Nigeria

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ABSTRACT

Malaria is a public health issue in Nigeria, especially in under five children. This study aims to determine the effect of *Plasmodium falciparum* parasitaemia on eosinophil counts in semi-arid zone children (6-59 months old) that attended State Specialist Hospital, Maiduguri, Borno State, Nigeria. The study employed cross sectional study design and included 138 children. Ethical approval for the study was granted by the State Specialist Hospital Ethical Committee. Blood samples were collected, prepared and examined microscopically for malaria parasites using Giemsa stain. The World Health Organization's established protocols (2008) and Sysmex Haematology Auto-analyser were used to count parasite density and determined eosinophil level. Simple linear regression were used as the statistical test to find out the relationship between parasite density and eosinophils. The results revealed the malaria prevalence of 43% (47/110) and were higher in males (23.6%) as compared to females (19.1%). A strong relationship was found between parasite density and eosinophil counts ($R^2 = 0.583$, $p = 0.021$) in aged children (41-59 months). Findings from the study shows that *P. falciparum* infection induces eosinophilia, which contribute to immune responses, but also pathology. It is necessary to monitor the haematological changes in malaria cases. Routine haematological monitoring in paediatric malaria is important for the detection of eosinophilia-related complications in State Specialist Hospital, Maiduguri, Borno State.

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INTRODUCTION

Malaria is a deadly parasitic disease that poses a global intimidation, mostly among under five children, despite myriad sustained struggles by government and non-governmental agencies (Awine *et al.*, 2017; Bohli *et al.*, 2025). This age group is disproportionately affected, accounting for the high of deaths in the region (World Health Organization, 2023). Malaria is prevalent in 83 countries with an estimated 263 million cases globally (WHO., 2022). The African region bear the highest burden of all malaria cases (94%) and death (95%), with Nigeria bearing the highest death burden of 31% in Africa, (WHO, 2023). Almost 97% of Nigeria's population (173 million) at risk (Omojuyigbe *et al.*, 2023). The disease is majorly caused by *Plasmodium falciparum*, the most virulent species in Africa (WHO., 2022). Infected female *Anopheles* mosquitoes, particularly *Anopheles gambiae* s.s transmit the infection (Hamza *et al.*, 2024) in northern Nigeria where the study was conducted.

The Arid zones of West Africa, especially Nigeria's Borno State, have distinct environmental factors that influence malaria epidemiology (Villena *et al.*, 2024). In these semi-arid regions, the relationship between environmental conditions and malaria transmission is complicated. While aridity (lower rainfall or moisture than normal, where water deficits dominate the landscape, vegetation, and human activity) may reduce *Anopheles* mosquito breeding sites due to limited water sources (Brown, 2014), seasonal rains can cause the formation of temporary water bodies, creating favourable conditions for mosquito breeding (Ryan *et al.*, 2014). This periodic change in mosquito numbers can lead to increased malaria transmission, especially during and after the rainy season (Brown, 2014). Malaria mortality (65%) occurred among children, and can be associated with their low level of immunity and its acquisition with repeated exposures (Bohli *et al.*, 2025). In Nigeria, malaria is responsible for 60% of hospital visits, 30% of under-5 hospitalisations and 11% of maternal deaths. (Nwoye *et al.*, 2025). Malaria prevalence of 43.23% was reported in Maiduguri (Inuwa *et al.*, 2023a), indicating ongoing transmission of the infection. For the detection of *Plasmodium falciparum*,

microscopy remain the gold standard in endemic areas despite recent advances (Fitri *et al.*, 2022).

Haematological parameters provide protection and serve as indicators of parasite infection (Kita *et al.*, 2011) Changes in haematological indices in malaria are expected as a result of parasite invasion into blood cells and subsequent reactions, which are driven by immunity and endemicity (Roy *et al.*, 2024). Eosinophils provide parasite defence, but their response in malaria is complex, with suppression during the acute phase followed by eosinophilia after treatment (Kita *et al.*, 2011). Knowledge about changes in eosinophil counts in children under the age of five is not well characterised (Chen *et al.*, 2023), despite the fact that it is critical in North-eastern Nigeria, where malaria is highly prevalent. There is insufficient data on the effect of *Plasmodium falciparum* parasitaemia on eosinophils in children under the age of five in Maiduguri, Nigeria. This study was designed to evaluate the prevalence and the effect of *Plasmodium falciparum* malaria on eosinophil among Under-five Children in State Specialist Hospital, Maiduguri, North Eastern Nigeria.

MATERIALS AND METHODS

STUDY AREA

The study was conducted in State Specialist Hospital in Maiduguri, Borno State, Nigeria (latitude 11°40'N, longitude 13°5'E) (Inuwa *et al.*, 2023a). The state has a population of 4,151,193 and an area of 71,210 square kilometres (NPC, 2009). The people are primarily farmers, traders, fishers, and herders. The major tribes include Kanuri, Shuwa, Marghi, Bura, and Fulani (Abubakar 2017). Borno State borders the Niger Republic to the north, Chad to the northeast, Cameroon to the east, Adamawa State to the south, and Gombe and Yobe States to the west and northeast (Inuwa *et al.*, 2023a). Maiduguri is in the Sahel savannah region, with an average annual rainfall of 650 mm and a temperature of 32°C. The hottest months are March and April (30-40°C), while November to January are cold and dry due (Ajileye *et al.*, 2018).

ETHICAL APPROVAL

Ethical approval was granted by the Ethic committee of the Specialist Hospital, Maiduguri, Borno State

(SGH/GEN/641/VOL.1). Verbal informed permission were obtained from the parents/guardian of the study participants.

STUDY DESIGN

This research adopted cross-sectional design (Inuwa *et al.*, 2023a), which enrolled under five children attending State Specialist Hospital, Maiduguri, from July to November, 2022.

SAMPLE SIZE DETERMINATION

The sample size was estimated using the Naing *et al.* (2006) protocol:

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

Where,

Z is the standard deviation of the needed confidence, P is a simple proportion, d2 is the alpha margin of error, and for the normal distribution, accuracy is 0.05. Previous studies (2.21%) (0.1) David *et al.* (2016).

$$(1.96)^2 (0.1) (0.9) / (0.05)^2 = 3.8416 * 0.09 / 0.0025$$

$$0.345744 \div 0.0025 = 138$$

$$n=138$$

STUDY PARTICIPANTS AND SAMPLING PROCEDURE

The study included 138 children under the age of five (between 6 to 59 months), who were both hospitalised and in the General Outpatients Department (GOPD). Among the 138 youngsters, parental consent were obtained from the parent of only 110 children. Simple random sampling were employed in selecting the sample size from the hospital's inpatient and outpatient populations.

INCLUSION CRITERIA

Children aged 6-59 months who presented to the hospital with a history of febrile illness and whose parents/guardians gave informed consent were included in the study.

EXCLUSION CRITERIA

Children under 6 months or over 59 months, or those without parental consent were not eligible for the study. All non-febrile children were also excluded from the study. Due to lack of parental consent, blood sample were collected from 110 children, twenty eight (28) were excluded.

BLOOD SAMPLE COLLECTION AND LABORATORY ANALYSIS

BLOOD COLLECTION, FILM PREPARATION AND EXAMINATION

As per the reports of Cheesbrough (2006), three millilitres of venous blood was collected

by venepuncture, using hypodermic needle and five millilitres syringe, and transferred into a well-label sterile EDTA tube and prepared. For thick films, a blood drop was placed in the center of a slide, spread in a circular motion to coin size using the corner of another slide, air dried for 30 -60 minutes, and marked. For thin films, a drop was placed near one end, spread at a 45° angle, air dried, and marked. Films were stained with 10% Giemsa and flood for 10 minutes before washing and air dry vertically (Inuwa *et al.*, 2023a). Blood films were examined using an Olympus CX21 Microscope with an x100 objective to detect the presence of sporozoite of *Plasmodium falciparum*. Blood films were viewed with a x100 oil immersion lens for at least 100 ocular fields before the slides were certified negative (Inuwa *et al.*, 2023a).

DETERMINATION OF PARASITE DENSITY

After staining with Giemsa, asexual sporozoites were calculated against 200 leukocytes (or 500 if <100 parasites). If the parasite count was less than 10 parasites/200 leucocytes; the count is continued per 500 leucocytes (Inuwa *et al.*, 2023a). The parasite density was expressed as the number of asexual parasites per ml of blood by assuming a mean normal leukocyte count of 8000/ μ L of blood. The Density was determined as: (number of parasites \times 8000) / number of leukocytes, assuming 8000 leukocytes/ μ L (WHO, 2008). Parasitaemia (per μ L) is calculated as = number of parasites \times 8000 / number of leucocytes. Parasitaemia was expressed per μ L (Grabias *et al.*, 2019)

PROCEDURE FOR EOSINOPHIL ESTIMATION

Eosinophils were assessed using a Sysmex Haematology Auto Analyser (2011). Venous blood sample were collected into EDTA anticoagulant tubes. Some blood samples were transferred to the laboratory for eosinophil estimate, and 2 ml of blood was placed into the machine for estimation, with the results recorded according to standard operating procedure (2011). The analyser was calibrated according to the manufacturer guides and internal quality control was done daily using commercial low and high level control materials prior to sample analysis. Age specific reference ranges for eosinophils

county in children under five year ($0.05 - 0.7 \times 10^9/L$) were applied. Briefly:

The machine was turned on and waits for the VDU to display “ready” for 5 minutes. The blood sample was mixed in a mixer for approximately 5 minutes. After opening the well, the blood was mixed with EDTA and primed with a probe. The sysmex auto-analyser automatically analyses the sample and makes a bit sound. The sample was then removed and the blood parameters such as eosinophil count and percentage were recorded. The results were validated by quality officer and finally documented in result sheets (SOP, 2011, Inuwa *et al.*, 2023).

METHOD OF DATA ANALYSIS

Data were entered and cleaned using Microsoft Statistics version 8.0 (2013) while all statistical analyses were performed using SPSS version 20.0 (Armonk & Peck, 2011). Descriptive statistics (means, SD, percentages)

Table 1: Individualities Baseline for the Enrollment of the study participant and Sex-specific prevalence of malaria among children attending State Specialist Hospital Maiduguri, Borno State, Nigeria.

Variables	Tested positive	Tested negative	Total
No. of enrolled	47 (43%)	63 (57%)	110 (100)
Mean \pm SD	7.10 \pm 2.0	9.45 \pm 4.21	16.55 \pm 6.21
Range	6-59 (months)	6-59 (months)	6-59 (months)
Male	26 (39.39%)	40 (60.61%)	66
Female	21 (47.73%)	23 (52.27%)	44

Figure 1: shows the relationship between eosinophils and parasites density in malaria infected under five children based on age. Higher parasite density was observed in 41-59 months age groups (Figure 4). Aged group 41 – 59 months recorded the highest percentage of both the eosinophils (12%) and the parasite density (30) each.

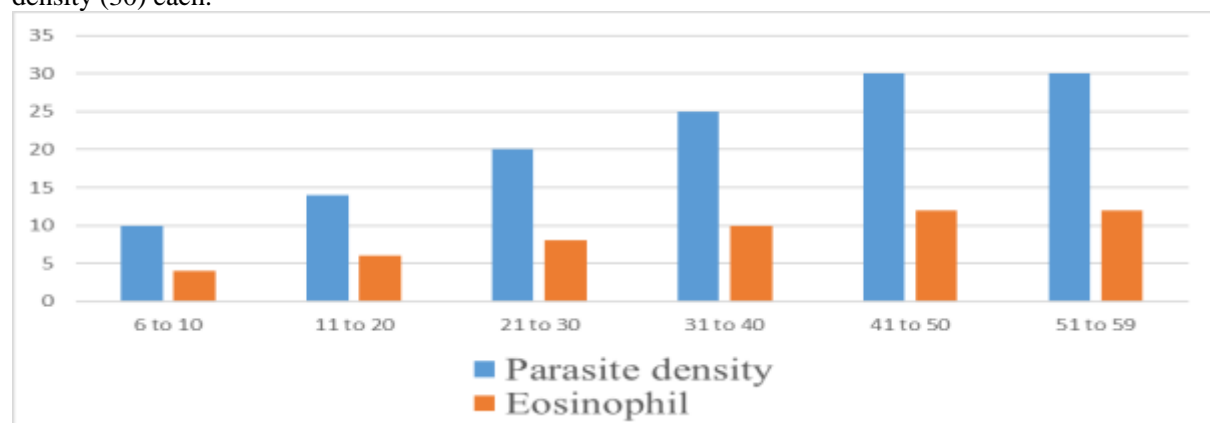


Figure 1: Relationships between Eosinophils and Parasite Density among Children attending State Specialist Hospital, Maiduguri, Borno State, Nigeria.

were also used. Correlations Coefficient (r) and Coefficient of Determination (R²) (Linear regression) were used to determine the relationship between the variables and to determine variance in the correlation analysis. Statistical significance of the correlation was assessed using the p-value, with $p < 0.05$ considered statistically significant.

RESULTS

Table 1 shows the results for children under the age of five who attend the State Specialist Hospital in Maiduguri, Borno State. A total of 110 children were involved in this study; 47 (43%) tested positive, while 63 (57%) tested negative. The overall malaria prevalence was 43%. The average age \pm SD for positives was 7.10 ± 2.00 months, while negatives were 9.45 ± 4.21 months (Table 1). The table shows that plasmodium falciparum infection is more common in men (23.64%) than in women (19.09%).

Figure 2; 3 and 4: shows the influence of mean parasite densities (*P. falciparum*) on eosinophils in under five children (6-59 months) infected with malaria based on gender. A significant positive correlation were found between parasite density and eosinophils ($R^2 = 0.583$, $p = 0.021$; Figure 2). For males: $R^2 = 0.571$, $p = 0.008$ (Figure 3); females: $R^2 = 0.541$, $p = 0.005$ (Figure 3). The correlation coefficient (r) between parasite density and eosinophil count is 0.671 (Figure 5), which indicates a moderate positive correlation between the two variables. This means as parasite density increases, eosinophil

count also tends to increase. The regression model gives a slope of 0.782 and an intercept of -41.27 (figure 5). Linear regression analysis indicated that parasite density accounts for the variability in eosinophils count. The R^2 value (coefficient of determination) is approximately 54 -58%, meaning that more than 55% of the variability in eosinophil count can be explained by parasite density. The p-value of 0.017 (Figure 5) indicates that the correlation and regression model are statistically significant, as the p-value is less than the common threshold of 0.05.

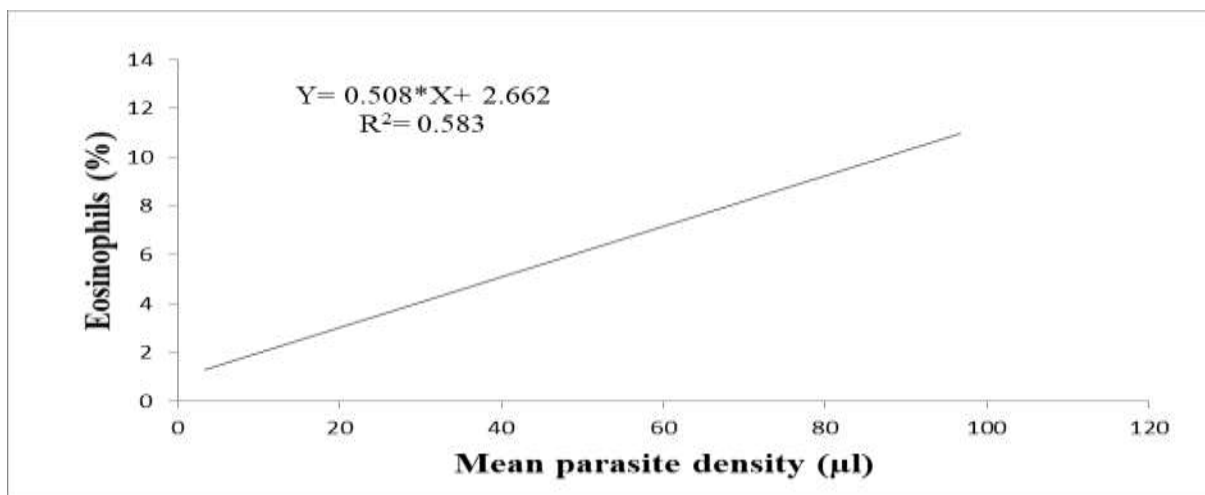


Figure 2: The influence of mean parasite densities (*P. falciparum*) on eosinophils in male under five children (6-59 months) infected with malaria.

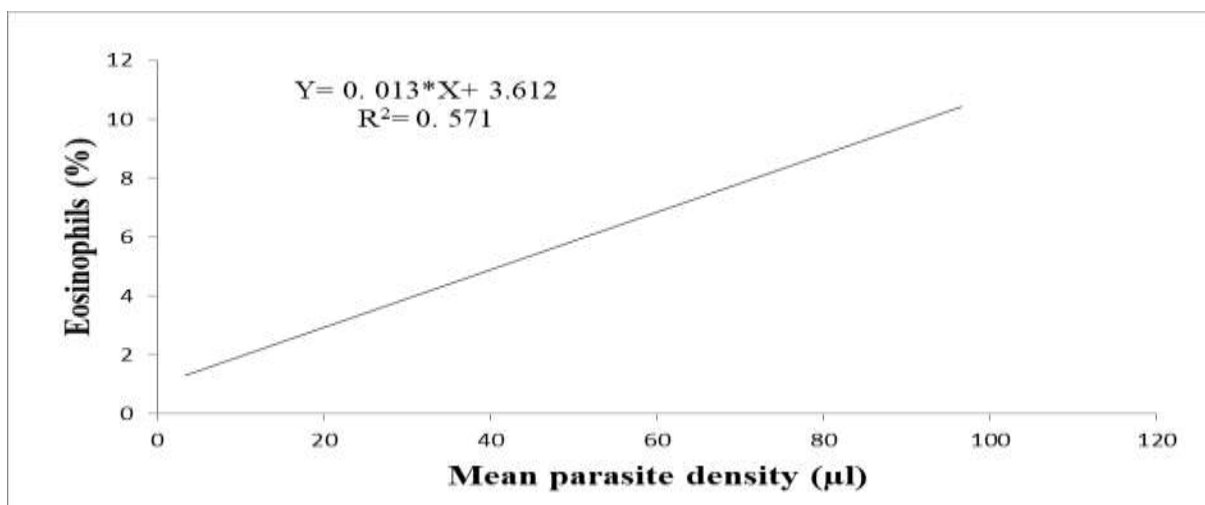


Figure 3: The influence of mean parasite densities (*P. falciparum*) on eosinophils in female children (6-59 months) infected with malaria.

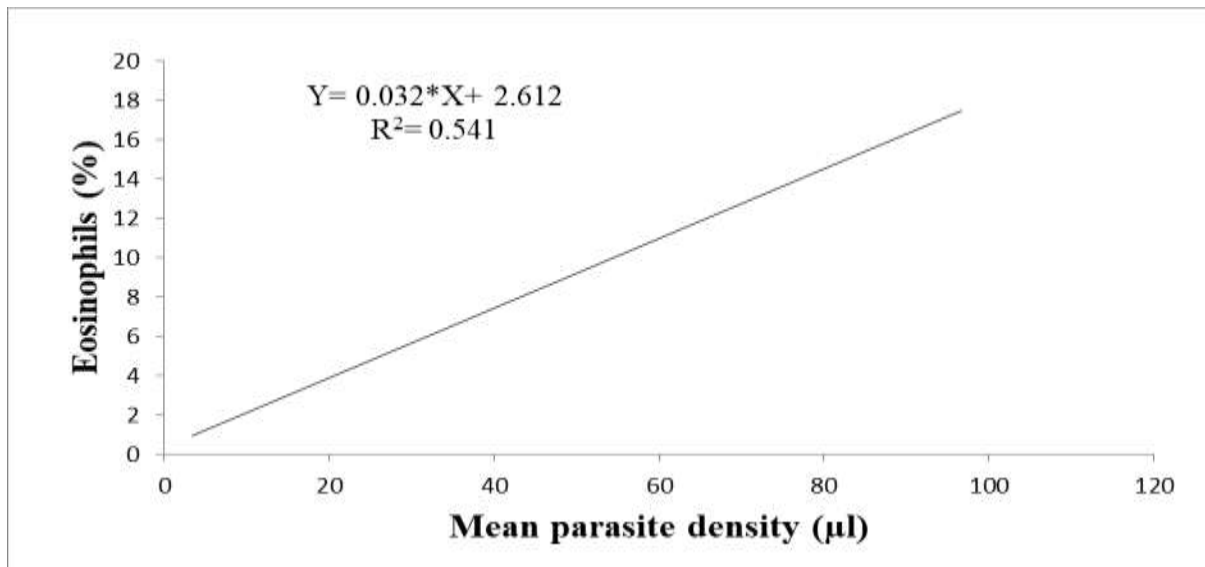


Figure 4: The influence of mean parasite densities (*P. falciparum*) on eosinophils in both male and female children (6-59 months) infected with malaria.

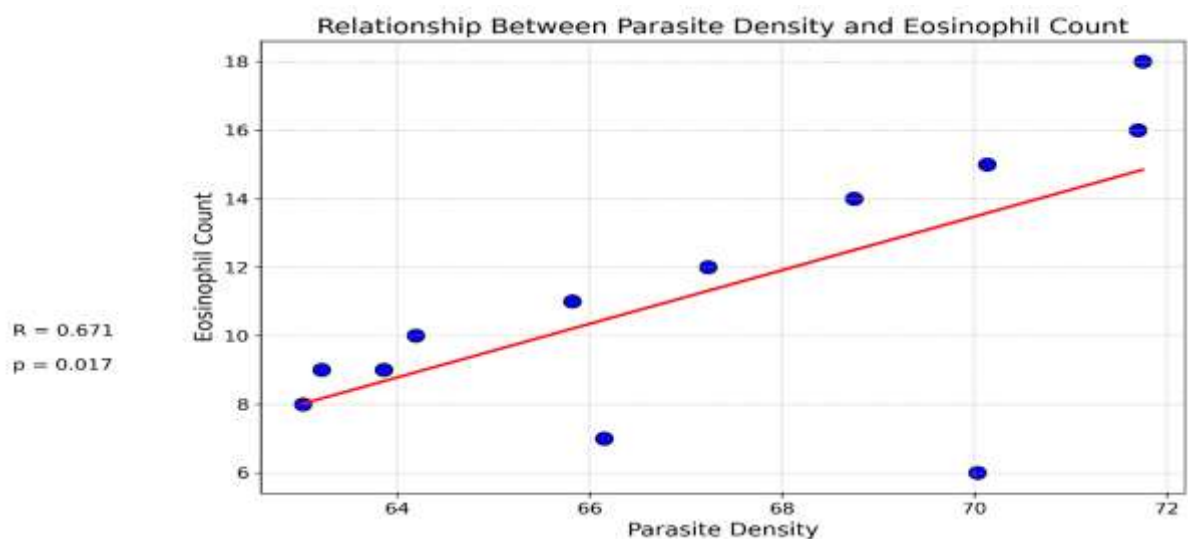


Figure 5: Correlation Coefficient relationship between parasite densities (*P. falciparum*) and eosinophils counts in children (6-59 months) infected with malaria.

DISCUSSION

Derangements for haematological indices due to malaria are apparent complications and are very principal parameters for the determination of the level of some infection such as malaria. The magnitude of these changes vary due to some factors such as the endemicity of malaria, environment, degree of immunity and nutritional status of an individual (Ogbonna *et al.*, 2021). Among the principal types of leucocytes that protect the body against infections from various pathogens is eosinophils. Eosinophils depend

the body against parasitic infections through biochemical processes that resulted in the release of substances that damage or kill parasitic germs. They act by attaching to the surface of parasites coated with antibodies and subsequently secrete toxic proteins. These proteins damage the parasites outer membrane, and in effect kill the parasites (Wen and Rothenberg, 2016). Eosinophils values are critical parameters in malaria pathology as low values signify malaria infection and post malaria treatment causes rebound of

eosinophilia because of the immune recovery and bone marrow regeneration (D'souza *et al.*, 2017).

This study recorded malaria prevalence of 43% children attending State Specialist Hospital Maiduguri, Borno State. This prevalence is relatively high and can be attributed to the weak immunity of the study participants whose protection is building up due to their age factor (Roberts and Matthews, 2016). Furthermore, it can also be link with the rainy season which is associated with profuse breeding sites preferred by malaria vector, *Anopheles* mosquitoes. The rainy season provide many temporary breeding sites such as gutter, puddles, tyre track and many more wet areas that *Anopheles* mosquitoes can breed and increasingly proliferate, hence increasing the relative abundance of mosquitoes and the high chances of increasing the rate of malaria infection (Hamza *et al.*, 2024). This findings aligns with the earlier study of Osaro *et al.* (2014) who revealed 52.5% of the children attending State Specialist Hospital emergency unit at Sokoto State were found with malaria. This study also corroborate with the earlier studies such as Ebadan *et al.* (2017); Mohammed *et al.* (2020); Inuwa *et al.* (2023b) and Abdulkadir *et al.* (2025) who reported similar prevalence in Edo, Kaduna, Borno and Nasarawa State, Nigeria. Many studies have reported high prevalence far above the one recorded in this study. These include the report of Olasehinde *et al.* (2010) in Edo State, Nwaorgu and Orajaka, (2011) in Anambra State and Oyerogba *et al.* (2023) in Ibadan State, Nigeria.

The study further revealed that the parasite density is higher than the eosinophil across all age groups. As the parasite density increases then the eosinophils also increases. Maina *et al.* (2010) found that children with malaria exhibit some derangement in blood parameters with low count of blood indices, which are principally used as an important predictors of malaria. When parasites density increases then eosinophils also increases, this is a direct indication that the body is mounting a strong immune response to the malarial attack, the body is responding proportionally and the infection is active or ongoing. The result of this research is likely an indication that the

malarial attack is at chronic stage, because in the case of acute attack the eosinophils usually decreases as pinpointed by Chukwuanukwu *et al.* (2025) who indicated that decreases in eosinophils directly indicates acute malarial attack, because during acute *Plasmodium falciparum* infection, eosinophil counts typically reduced, leading to a condition called eosinopenia. This condition is triggered by the release of cortisol and cytokine (Davoine and Lacy, 2014), which suppress eosinophil production in the bone marrow, the elevation of interleukin, which directly inhibit eosinophil proliferation and dysregulation of the bone marrow which retard the production of eosinophil (Kovalszki and Weller, 2019). Higher densities of eosinophils potentially indicate a more robust immune response (Gansane *et al.*, 2013).

This study revealed high parasite density in children aged 41 – 59 months. This findings is consistent with a study in Ethiopia where 81% of children aged 48–59 months were malaria-positive, compared to lower prevalence rates in younger age groups (Aliyo *et al.*, 2024). Similarly, research in Guinea, Benin, and The Gambia indicated that malaria prevalence increased with age, with infants having lower parasite densities than older children (CDC, 2015). The observed higher parasite density in older children may be attributed to waning maternal immunity and the acquisition of partial immunity through repeated exposures (Mwaiswelo *et al.*, 2021).

The study further reveals that the parasite density is high among males than female children. This can be attributed to the variances in immune responses between male and female children. Females tend to have a stronger immune response to infections, including malaria, compared to males. This stronger immune response in females could result in faster clearance of *Plasmodium* parasites from the bloodstream, leading to lower parasitemia in females. Males, on the other hand, may have slower immune responses, resulting in higher parasite densities. This findings tally with the study of Awosolu *et al.* (2021) who reported male children exhibited higher malaria prevalence and mean parasite density than females. This also aligns with the findings of Kepha *et al.* (2016), which also observed higher malaria

prevalence among males compared to females. In contrast, a study by Oluwafemi *et al.* (2024) reported discrepancy. Oluwafemi *et al.* (2024) reported female children with higher parasite density than males, though the difference was not statistically significant. This highlights the complexity of gender differences in malaria parasitemia and suggests that factors such as age and gender influences malaria burden in children. In hyperendemic areas like Maiduguri, there is need for could targeted interventions, such as integrating eosinophil assessments in malaria control programs.

CONCLUSION

This study evaluated the effect of *Plasmodium falciparum* infection on eosinophil among under-five children. The findings reveals a significant positive correlation between *P. falciparum* parasitaemia and eosinophil counts in children aged 6-59 months, with implications for immune pathology and protection. Future research shall conduct longitudinal studies to monitor eosinophil counts over time in children with *P. falciparum* infection.

CONFLICT OF INTEREST

The authors do hereby declare that there are no conflicts of interest on this study.

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