

Vitamin A and Zinc Profile of *Plasmodium falciparum* Malaria in Selected Communities in Delta Central Senatorial District, Delta State, Nigeria

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Abstract

Malaria remains a major public health concern in sub-Saharan Africa, where micronutrient deficiencies may complicate infection. This study assessed malaria parasitemia intensity and serum vitamin A and zinc concentrations in Delta Central Senatorial District, Delta State, Nigeria. Thick blood film microscopy was used to examine 566 participants for malaria parasitemia. Serum vitamin A and zinc concentrations were measured in a subset of 50 parasitemic volunteers using the Carr–Price colorimetric method and flame atomic absorption spectrophotometry, respectively. Analysis of variance was used to compare micronutrient concentrations between parasitemic participants and uninfected controls. Moderate parasitemia (1,000–9,999 parasites/ μ L) predominated (75.8%), followed by mild parasitemia (24.2%). No parasite densities of $\geq 10,000$ parasites/ μ L were observed. Serum vitamin A and zinc concentrations were numerically higher in parasitemic participants than in uninfected controls, but neither difference was statistically significant ($p > .05$). The findings document a predominance of moderate parasitemia without statistically significant differences in the measured micronutrient concentrations between infected participants and controls. This study provides local evidence to inform malaria control strategies that consider both infection and nutritional status in endemic populations.

Keywords: Malaria; Parasitemia; Vitamin A; Zinc; Micronutrient Status

INTRODUCTION

Malaria is endemic in Nigeria and constitutes a major public health problem (Akande *et al.*, 2022). Globally in 2024, there were an estimated 282 million malaria cases and 610 000 malaria deaths in 80 countries. African Region carries a disproportionately high share of the global malaria burden. In 2024, the WHO reported that Africa was home to 95% of malaria cases (265 million) and 95% (579 000) of malaria deaths. Children under 5 accounted for about 75% of all malaria deaths in the Region (WHO, 2025).

Currently, about 109 countries and territories are considered malarious, with roughly 47 of them located in sub-Saharan Africa (~43%) (WHO, 2025). The manifestation of the disease in different populations varies across the continent. In many parts of Africa, young children and pregnant women are most affected while in Asia adults as well as children are equally affected. In Nigeria, malaria is significantly more prevalent in rural than in urban areas, although both environments support mosquito breeding due to the presence of swamps, grassy areas, and stagnant water in drains, wells, and storage tanks (Isiko, *et al.*, 2024).

Among several complications of malaria includes severe anaemia, circulatory collapse and complications, hypoglycemia and respiratory distress. Among these, is the development of respiratory distress, which occurs in up to 25% of adults and 40% of children with severe malaria is associated with high mortality (Taylor, *et al.*, 2012). Possible causes include respiratory decompensation of metabolic acidosis, noncardiogenic pulmonary oedema, concomitant pneumonia, and severe anaemia. Although rare in young children with severe malaria, acute respiratory distress syndrome occurs in 5–25% of adults and up to 29% of pregnant women (Rijken *et al.*, 2012). Life-threatening malaria complications can affect patients of all ages, but disease presentation and mortality are intimately related to transmission intensity and age of the patient. Research indicates that severe malaria occurs in young children in areas of intense malaria transmission and in persons of all ages in areas where transmission intensity is low and that mortality differs according to the different forms of severe malaria and to the age of the patients. The underlying general principle is that when the intensity of transmission is higher, more persons are exposed to infection, exposure to infection occurs earlier, partial immunity develops earlier, and the risk of severe malaria decreases. Among the five *Plasmodium*

species known to infect humans, *Plasmodium falciparum* is considered the most virulent and life-threatening (WHO, 2019).

Malaria caused by *Plasmodium falciparum* remains a major cause of morbidity and mortality among African children (Cohee *et al.*, 2020). Between 300 to 500 million new cases of malaria, primarily due to *P. falciparum*, are annually observed in the world, with 90% in sub-Saharan Africa, and these account for an estimated one million children deaths. Furthermore, resistance to drugs and insecticides used to fight this disease has hampered malaria control efforts (Benelli and Beier, 2017). Children and adults living in malaria-endemic areas often have a high prevalence of malnutrition and deficiencies of micronutrients such as vitamin A and zinc; this situation creates a complexity of interactions with serious health consequences (Bhutta, 2019; Ahmed, 2020). Vitamin A is essential for normal immune function, suggesting that it could play a role in protection against malaria. Zinc is essential for many biological functions such as protein synthesis, growth and immunity. Vitamin A metabolism requires normal zinc status, explaining the frequent association of their deficiency. The beneficial protective effects of vitamin A and zinc supplementation on malaria-related morbidity have been demonstrated in studies conducted in Papua New Guinea, Peru, and Zanzibar (Zeba, 2008). Two randomized, placebo-controlled trials conducted in Ghana did not find an overall significant effect of vitamin A on malaria parasitemia rates or parasite densities although the studies showed a reduction of 23% and 32% of probable malaria illness in supplemented children (Gera *et al.*, 2020; Das *et al.*, 2018).

There are several studies regarding the correlation of the level of micronutrients and different diseases. Despite these studies and their relevance in management of malaria, little or none of such documentation exist within Delta Central of Delta State. This study will therefore provide information to baseline information on vitamin A and zinc profile in malarious volunteers in our study area.

MATERIALS AND METHODS

Description of Study Area

The study was conducted in Delta Central Senatorial District in Abraka, Eku, Okpara, Ovu, Salubi town, in Ethiope East and Ugheli North Local Government Area, Delta State, Nigeria. This area is characterized by tropical climate conditions that support

the breeding of mosquitoes, the vector for *Plasmodium* sp., the causative agent of malaria. Delta Central Senatorial District lies between latitudes 50 09¹ and 60 03¹ North of the Equator and Longitudes 50 30¹ and 60 12¹ East of the Greenwich Meridian. The size of the region is about 3,700km². The population is estimated to be 2,032,707 people (Nigeria Population Census, 2007) and has eight (8) Local Government areas.

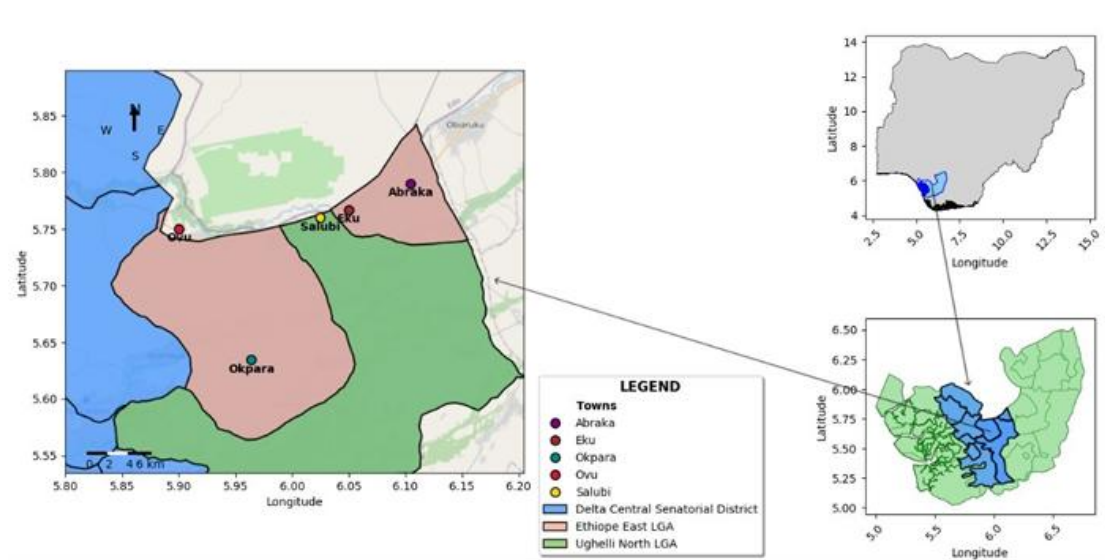


Figure 1. Map of Delta State Showing the Study Area

Source: Developed using QGIS Version 3.36.0

Research Design

A cross-sectional analytical study design was employed to assess the serum vitamin A and zinc profiles of individuals infected with *Plasmodium* species in the Delta Central Senatorial District of Delta State, Nigeria. The study was conducted over a 12-month period. A total of 566 participants were screened for malaria infection, of which 50 malaria-positive samples were further recruited for vitamin A and zinc analysis.

Ethical Consideration

Ethical clearance was obtained from the Research and Ethical Committee Delta State University, Abraka, and informed consent were obtained from all participants or their guardians, before collection of samples.

Sample Size

Krejcie and Morgan's Formula was used to determine the sample size of this study Krejcie & Morgan (1970).

Krejcie and Morgan's Formula; $n = (N * x^2) / (1 + (N - 1) * x^2)$.

Where:

N = population size (2,032,707)

x = Z-score (1.96)

$n = (2,032,707 \times 1.96^2) / (1 + (2,032,707 - 1) \times 1.96^2)$

$n = 566.45$

The estimated sample size consists of 566 male and female volunteers aged between 19 and 65 years from Abraka, Eku, Salubi, and Ovu.

Sample Collection

5 ml of venous blood samples through venipuncture was collected from each participant using sterile techniques. Blood samples will be divided into two parts: one for malaria diagnosis and one for vitamin A and zinc analysis.

Sample Preservation/Preparation

After collection of samples, blood samples for malaria microscopy were stored in EDTA anticoagulant bottles as well as that of Vitamin and Zinc. To prevent the effect of light on vitamin, the sample was further wrapped with a foil paper and then stored cold in ice and transported to the Advance Research Center laboratory Delta State University, Abraka for laboratory determination of malaria, Vitamin A and Zinc respectively.

Diagnosis of *Plasmodium* Infection

Malaria diagnosis was performed using thick and thin blood smears prepared and stained with Giemsa stain, followed by examination under oil immersion microscopy for confirmation of *Plasmodium* parasites (Cheesbrough, 2012).

Parasite density was determined by counting the number of asexual *Plasmodium* parasites per 200 white blood cells (WBCs) and converting the result to parasites per microliter (μL) of blood, assuming a standard WBC count of 8,000 WBCs/ μL . Parasite density was classified as mild (0–999 parasites/ μL), moderate (1,000–9,999 parasites/ μL), and severe ($\geq 10,000$ parasites/ μL) (WHO, 2024).

Determination of Vitamin A and Zinc in Blood Samples

Vitamin A was determined using the standard photoelectric colorimetric method based on the Carr–Price reaction. Zinc concentration was determined using Flame Atomic

Absorption Spectrophotometry (FAAS) at a wavelength of 213.9 nm following standard analytical procedures (AOAC, 2019).

RESULTS

Prevalence of malaria by age category and gender as seen in table 1. The study indicates the distribution of malaria parasitemia severity (mild, moderate, and severe) across various age categories and by gender among 566 participants. The results revealed that moderate parasitemia (1,000–9,999 parasites/ μ L) was the most prevalent form across all age groups and in both sexes. No cases of severe parasitemia ($\geq 10,000$ parasites/ μ L) were recorded in any age or gender subgroup. Highest burden of parasitemia was recorded in the 30–34 and 35–39 age groups, with 94 and 96 individuals respectively. Moderate parasitemia was most common across all age categories, consistently accounting for more than 70% of the infections in both males and females. For example, among females aged 25–29, 80.5% had moderate parasitemia compared to 71.7% in males of the same age group. In males, the 30–34 age group recorded the highest percentage (84.6%) of moderate infections. Males consistently had slightly higher proportions of mild parasitemia in most age categories (e.g., 38.5% in age 50–54 and 31.8% in 45–49), while females showed a more uniform distribution with moderate parasitemia being predominant. Further analysis using two-way ANOVA demonstrated that neither gender ($F(1, 550) = 1.543$, $p > 0.05$), age group ($F(7, 550) = 0.827$, $p > 0.05$), nor their interaction ($F(7, 550) = 0.623$, $p > 0.05$) had a significant effect on infection status.

Table 1: Prevalence of Malaria by Age Category and Sex in Delta Central Senatorial District, Delta State, Nigeria

Age Category	Female			Male			Total
	Mild	Moderate	Severe	Mild	Moderate	Severe	
19–24	14(28.6)	35(71.4)	(0)	19(31.7)	40(66.7)	0	108
25–29	8(19.5)	33(80.5)	(0)	13(28.3)	33(71.7)	0	87
30–34	10(23.8)	32(76.2)	0	8(15.4)	84.6	0	94
35–39	13(24.5)	40(75.5)	0	10(32.8)	32(76.2)	0	95
40–44	5(21.7)	26(78.3)	0	6(18.2)	27(81.8)	0	64
45–49	6(18.2)	27(81.8)	0	7(31.8)	15(68.2)	0	55
50–54	5(21.7)	18(78.3)	0	10(38.5)	16(61.5)	0	49
55–59	2(20)	8(80)	0	1(33.3)	2(66.7)	0	13
Total	63	219	0	74	209	0	566

Table 2 presents the relationship between Plasmodium infection intensity and the micronutrient status (Vitamin A and Zinc) of affected individuals. Vitamin A levels are substantially higher in infected individuals (both mild and moderate) compared to controls. With mild infection: 3.79 $\mu\text{mol/L}$, moderate infection: 3.71 $\mu\text{mol/L}$, Control group: 0.27 $\mu\text{mol/L}$. Zinc levels appear highest in mildly infected individuals (21.18 $\mu\text{mol/L}$) and decline with increasing infection intensity (18.64 $\mu\text{mol/L}$ in moderate cases). Control group's zinc levels (17.93 $\mu\text{mol/L}$) are close to the moderate group, indicating that Zinc may decline with infection severity. The absence of severe infection ($\geq 10,000$ parasites/ μL) was recorded. ANOVA revealed that there were no statistically significant ($p > 0.05$)

Table 2: Vitamin A and Zinc Profile/Levels According to Level of Parasitemia.in Delta Central Senatorial District, Delta State, Nigeria

Infection Intensity	N	Vitamin A ($\mu\text{mol/L}$) (Mean $\pm$ SD)	Zinc ($\mu\text{mol/L}$) (Mean $\pm$ SD)
Mild (0–999)	10	3.79 $\pm$ 1.07	21.18 $\pm$ 11.68
Moderate (1,000–9,999)	40	3.71 $\pm$ 2.24	18.64 $\pm$ 10.58
Severe ($\geq 10,000$)	0	0	0
Control (Uninfected)	5	0.27 $\pm$ 0.03	17.93 $\pm$ 4.30

Table 3: Intensity of Parasitemia Levels Among Malaria Patients Categorized by Severity in Delta Central Senatorial District, Delta State, Nigeria.

Parasitemia Range (parasites/ μL)	Male (%)	Female (%)	Total
Mild 0-999	74(54.0)	63(45.9)	137
Moderate 1,000-9999	210(48.9)	219(51.0)	429
Severe $\geq 10,000$	0	0	0
Total	284(50.2)	282(49.8)	566

Intensity of parasitemia levels among malaria Patients categorized by severity in Delta Central Senatorial District, Delta State, Nigeria shown in table 3. Of these, females comprised 51.0%, while males 48.9%, indicating a slightly higher burden of moderate infection among females. Mild Parasitemia constituted 24.2% of cases, with a male dominance (54.0%) compared to females (45.9%). No cases of severe Parasitemia were recorded among the participants. Overall, the gender distribution was nearly equal (males: 50.2%; females: 49.8%), suggesting minimal gender bias in the occurrence of malaria within this population. A Pearson chi-square test was conducted to assess the association between gender, and Parasitemia level. The results were not statistically significant for females (χ^2 (7)

= 2.539, $p = .924$), males ($\chi^2 (14) = 11.794$, $p = .623$), or the combined population ($\chi^2 (14) = 10.699$, $p = .710$).

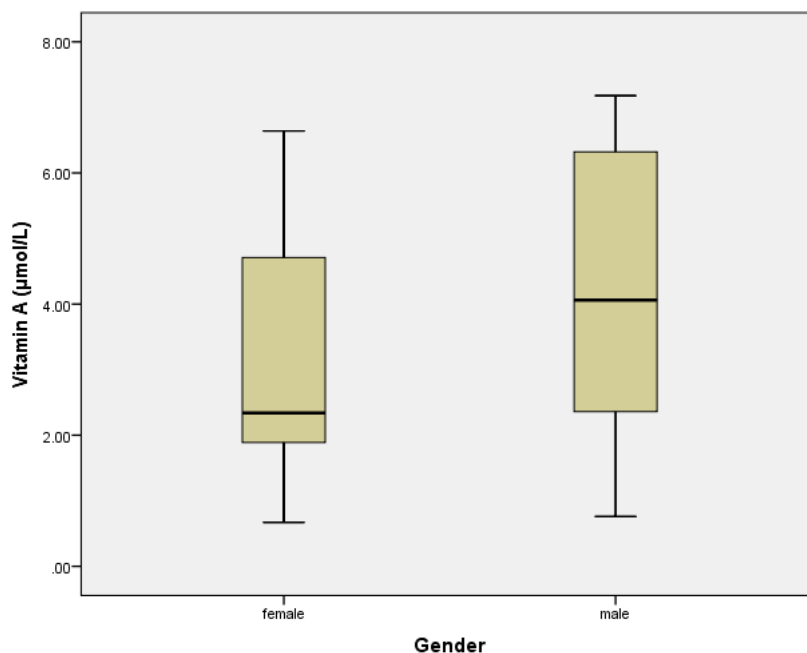


Figure 2: Vitamin A Level and The Male and Female Volunteers.

Vitamin A level and the male and female volunteers as seen in Figure 3. Vitamin A in males recorded a higher mean concentration ($4.05 \pm 2.10 \mu\text{mol/L}$) compared to females ($3.24 \pm 1.93 \mu\text{mol/L}$). The male distribution was nearly symmetric, whereas the female distribution showed a slight right skew. ANOVA revealed no statistically significant difference or in vitamin A levels ($F (1,48) = 3.279$, $p > 0.05$).

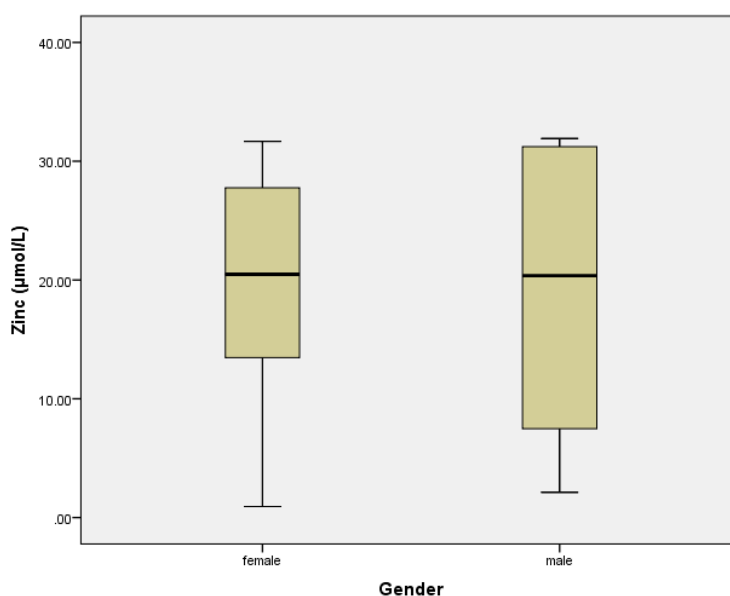


Figure 3 Vitamin A Level and The Male and Female Volunteers

Vitamin A level and the male and female volunteers as seen in Figure 3. Zinc levels were similar across both sexes, with females showing a mean of $19.33 \pm 9.43 \mu\text{mol/L}$ and males $19.03 \pm 11.68 \mu\text{mol/L}$. These trends are also reflected in the stem-and-leaf plots, where male vitamin A values are more symmetrically distributed and extend to higher levels, while zinc plots show wide variability for both sexes. ANOVA revealed no statistically significant difference in zinc levels between male and female $F(1,48) = 0.649$, $p > 0.05$).

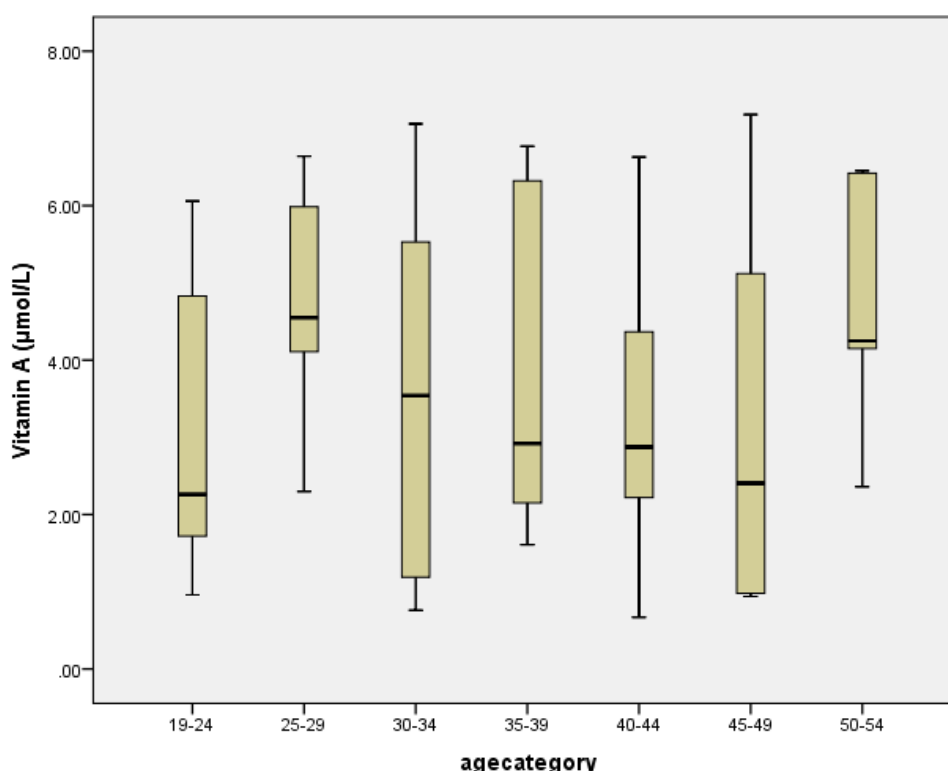


Figure 4: Vitamin A Level by Age Group

Vitamin A level by age group as seen in Figure 4. The highest mean vitamin A levels were observed in age groups 25–29 ($4.81 \mu\text{mol/L}$) and 50–54 ($4.73 \mu\text{mol/L}$), while the lowest were seen in age groups 19–24 ($3.08 \mu\text{mol/L}$) and 45–49 ($3.17 \mu\text{mol/L}$). One-way ANOVA indicated no significant difference in vitamin A levels by age $F(6,43) = 0.784$, $p > 0.05$).

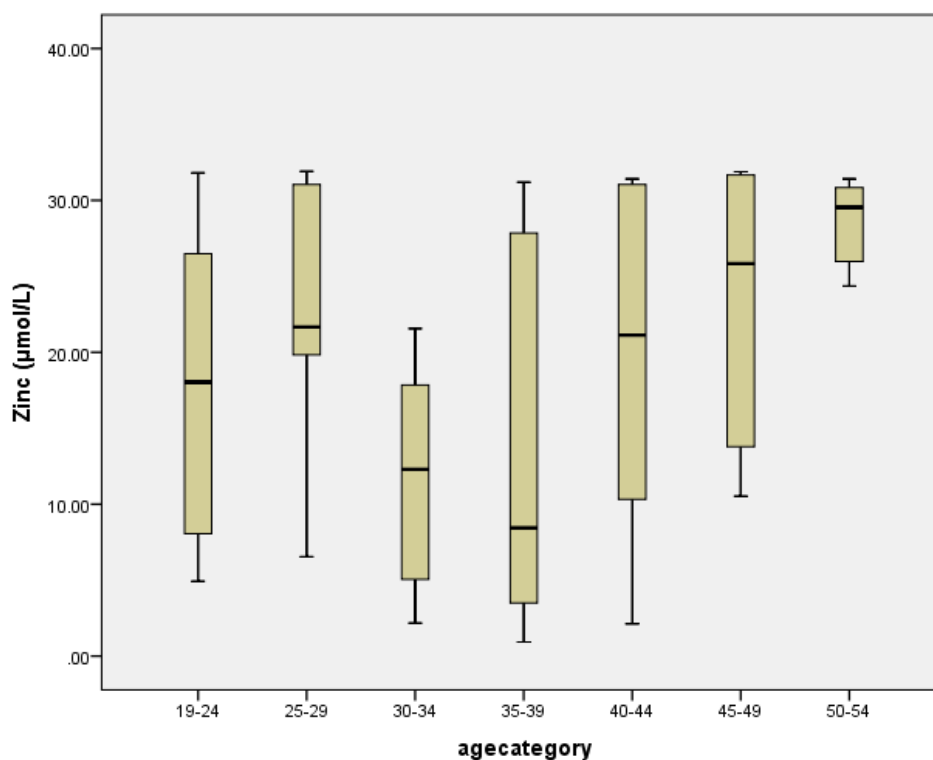


Figure 5: Zinc Level According to The Age Group.

Zinc level according to the age group as seen in Figure 5. Zinc concentrations generally increased with age, with the lowest mean observed in the 30–34 age group (11.69 $\mu\text{mol/L}$) and the highest in the 50–54 group (28.43 $\mu\text{mol/L}$). Stem-and-leaf plots and boxplots further support these patterns, showing lower vitamin A values and wider variability in younger age groups, while older groups display more consistent and higher zinc values. One-way ANOVA indicated no significant difference in zinc levels $F(6,43) = 2.010$, $p > 0.05$).

Table 4: Age Group vs. Vitamin A and Zinc Levels

Age Group	n	Vitamin A ($\mu\text{mol/L}$)	Zinc ($\mu\text{mol/L}$)
19–24	8	3.08 ± 1.88	17.74 ± 10.41
25–29	7	4.81 ± 1.54	23.12 ± 9.16
30–34	7	3.54 ± 2.67	11.68 ± 7.83
35–39	9	3.82 ± 2.14	14.61 ± 12.58
40–44	8	3.28 ± 1.84	19.81 ± 11.97
45–49	6	3.17 ± 2.52	23.25 ± 9.68
50–54	5	4.73 ± 1.73	28.42 ± 3.10

Table 4 shows the age group vs. vitamin A and zinc levels. Vitamin A Levels were generally stable across age groups, ranging between ~ 3.1 and ~ 4.8 $\mu\text{mol/L}$. The highest

mean vitamin A concentration is in 25–29 years (4.81 $\mu\text{mol/L}$). The lowest mean vitamin A was found in 19–24 years (3.08 $\mu\text{mol/L}$). The levels of vitamin A was not significantly influenced by age group ($F = 1.070$, $p = 0.398$).

DISCUSSION

In this present study, the distribution of parasitemia between males (50.2%) and females (49.8%) was nearly identical, indicating that sex did not substantially influence parasite density in the study population. This observation agrees with Oyibo *et al.* (2023), who found no significant differences in malaria parasite densities between male and female children during a nationwide analysis of malaria epidemiology in Nigeria. The authors concluded that environmental exposure and transmission intensity exert greater influence on parasite density than biological sex.

The absence of severe parasitemia in the present study contrasts with the findings of Nmorsi *et al.* (2007), who reported severe *Plasmodium falciparum* malaria among Nigerian children and demonstrated that high parasite density was associated with severe clinical manifestations. The difference may be due to variations in the study population, age group, healthcare access, and early treatment practices.

This study investigated the vitamin A and zinc profile of *Plasmodium*-infected volunteers in selected communities in Delta Central Senatorial District, Delta State, Nigeria. The present study shows disparity in vitamin A status when compared with findings from Bayelsa State. Ebisintei *et al.* (2024) reported that children infected with *Plasmodium* had significantly lower vitamin A levels than healthy individuals ($p = 0.0388$), suggesting that malaria infection may reduce vitamin A levels. However, in the current study, infected participants actually showed higher vitamin A levels than uninfected controls, even though levels were quite similar between mild and moderate infections. This difference may be due to variations in diet, nutritional status, immune response, infection patterns, or the use of supplements across different study areas.

For zinc, however, the findings are more similar. Both this study and Ebisintei *et al.* (2024) found no strong or statistically significant difference in zinc levels between infected and uninfected individuals. Although zinc levels in the present study showed a slight decrease as infection intensity increased, the differences were not large enough to suggest a clear pattern. This suggests that zinc levels may remain relatively stable during malaria

infection, or that changes are too small to be clearly detected without larger or more detailed studies.

The lower vitamin A levels seen in some malaria studies have been linked to several possible reasons. These include the body using up more vitamin A during inflammation, reduced absorption due to malaria-related gut disturbances, and increased breakdown of vitamin A during infection-related immune responses (Menéndez *et al.*, 2000; Ebisintei *et al.*, 2024). On the other hand, the lack of clear differences in zinc levels may suggest that the body is able to maintain zinc balance during infection. However, zinc levels can still be influenced by poor diet, increased demand during illness, or absorption problems, especially in malaria-endemic areas (Shankar, 2000; Ebisintei *et al.*, 2024).

Looking at a broader perspective, these findings are in line with the review by Kotepui *et al.* (2023), which showed that zinc supplementation, whether given alone or with other nutrients, does not significantly reduce malaria infection risk. This supports the idea that zinc is important for immune function, but may not directly determine whether someone becomes infected with malaria or not. However, this is in disparity with a 2024 study in Ekpoma, Edo State, where there was a significant reduction in serum zinc among malaria-positive subjects ($p < .05$), confirming lower zinc levels are commonly associated with malaria infection (Dic-Ijiewere, 2017). National-level nutritional trials such as a 6-month beverage intervention among Nigerian school children recorded $1.0 \mu\text{mol/L}$ improvements in serum zinc ($p = 0.031$), alongside $0.10 \mu\text{mol/L}$ increases in retinol ($p = 0.016$), reinforcing the potential for school-based micronutrient intervention (Aaron *et al.*, 2011).

Also, a study on antenatal vitamin A supplementation in Ebonyi State deduced that maternal vitamin A supplementation delayed first infant parasitemia and decreased parasite loads (Elom *et al.*, 2021). Similarly, in Tanzania, prenatal zinc reduced the risk of placental malaria by 36% (risk ratio = 0.64) compared to controls (Darling *et al.*, 2017). Together, these findings strengthen the case for community-wide supplementation programs.

National surveys also indicate vitamin A deficiency remains high among Nigerian adolescents (24 %) and zinc deficiency in young children (35 %) (Jimoh, *et al.*, 2022). These population-wide deficiencies may partly explain the low baseline vitamin A ($0.27 \mu\text{mol/L}$) in our controls.

Jimoh *et al.* (2022) reported that zinc levels were significantly lower in malaria-infected children compared with uninfected controls, and that zinc decreased further with increasing parasite density. This suggests that malaria infection may be associated with reduced serum zinc, likely reflecting inflammatory processes and increased metabolic demand during infection. This is a reflection of a general lack of access to micronutrient-rich diets in the population. Since the control group in our study did not receive supplementation, it is likely that they were similarly affected by these population-level deficiencies. As a result, the low baseline vitamin A level (0.27 $\mu\text{mol/L}$) observed in the control group can be reasonably attributed to the pre-existing poor nutritional status that is prevalent in the community.

REFERENCES

- Aaron, G. J., Kariger, P., Aliyu, R., Flach, M., Iya, D., Obadiah, M., & Baker, S. K. (2011). A multi-micronutrient beverage enhances the vitamin A and zinc status of Nigerian primary schoolchildren. *The Journal of Nutrition*, 141(8), 1565–1572. <https://doi.org/10.3945/jn.110.136770>
- Ahmed, S. (2020). Micronutrient deficiencies and malaria: A review of the evidence. *Malaria Journal*, 19(1), 1–15.
- Akande, F. A., Ejilude, O., Adelakun, O. D., & Idowu, A. O. (2022). Hunting: A risk factor associated with malaria infection in Ogun State, Southwest Nigeria. *Nigerian Journal of Parasitology*, 43(1). <https://www.njpar.com.ng/index.php/home/article/view/253>
- AOAC INTERNATIONAL. (2019). *Official methods of analysis of AOAC INTERNATIONAL* (21st ed.). https://members.aoac.org/AOAC/AOAC/Item_Detail.aspx?Category=OMA&iProductCode=1121
- Benelli, G., & Beier, J. C. (2017). Current vector control challenges in the fight against malaria. *Acta Tropica*, 174, 91–96. <https://doi.org/10.1016/j.actatropica.2017.06.028>
- Bhutta, Z. A. (2019). The burden of malnutrition and micronutrient deficiencies in malaria-endemic countries. *BMC Public Health*, 19(1), 1–12.
- Cheesbrough, M. (2010). *District laboratory practice in tropical countries* (2nd ed.). Cambridge University Press.
- Cheesbrough, M. (2012). *District laboratory practice in tropical countries* (2nd ed.). Cambridge University Press.
- Cohee, L. M., Opondo, C., Clarke, S. E., Halliday, K. E., Cano, J., Shipper, A. G., Barger-Kamate, B., Djimde, A., Diarra, S., Dokras, A., Kamya, M. R., Lutumba, P., Ly, A. B., Nankabirwa, J. I., Njagi, J. K., Maiga, H., Maiteki-Sebuguzi, C., Matangila, J., Okello, G., ... Chico, R. M. (2020). Preventive malaria treatment among school-aged children in sub-Saharan Africa: A systematic review and meta-analyses. *The Lancet Global Health*, 8(12), e1499–e1511. [https://doi.org/10.1016/S2214-109X\(20\)30325-9](https://doi.org/10.1016/S2214-109X(20)30325-9)

- Darling, A. M., Mugusi, F. M., Etheredge, A. J., Gunaratna, N. S., Abioye, A. I., Aboud, S., Duggan, C., Mongi, R., Spiegelman, D., Roberts, D., Hamer, D. H., Kain, K. C., & Fawzi, W. W. (2017). Vitamin A and zinc supplementation among pregnant women to prevent placental malaria: A randomized, double-blind, placebo-controlled trial in Tanzania. *The American Journal of Tropical Medicine and Hygiene*, 96(4), 826–834. <https://doi.org/10.4269/ajtmh.16-0599>
- Das, D., Grais, R. F., Okiro, E. A., Stepniewska, K., Mansoor, R., van der Kam, S., Terlouw, D. J., Tarning, J., Barnes, K. I., & Guérin, P. J. (2018). Complex interactions between malaria and malnutrition: A systematic literature review. *BMC Medicine*, 16(1), Article 186. <https://doi.org/10.1186/s12916-018-1177-5>
- Dic-Ijiewere, O. E., Elekhebor, J. E., Airhomwanbor, K. O., Ehimare, R. I., Idehen, I. C., Osarobo, E., & Okparaku, S. O. (2017). Assessment of some serum micronutrient levels in malaria parasite infected subjects in Ekpoma and environs, Nigeria. *International Journal of Community Research*, 6(3), 81–92.
- Ebisintei, P., Ebikonbowei, A. O., & Idam, B. U. (2024). The impact of malaria infection on serum vitamin A and zinc levels in children in malaria-endemic regions. *Greener Journal of Medical Sciences*, 14(2), 89–93. <https://www.gjournals.org/2024/07/03/060824078-ebisintei/>
- Elom, M. O., Okafor, F. C., Eyo, J. E., Usanga, V. U., & Umoh, N. O. (2019). Maternal vitamin A supplementation delays time to first episode of parasitaemia and reduces malaria parasite densities among infants in rural communities in Ebonyi State, Nigeria. *Tropical Biomedicine*, 36(1), 194–200.
- Gera, T. (2020). The intersection of malaria and malnutrition: A review of the evidence and implications for policy and practice. *International Health*, 12(3), 1–14.
- Isiko, I., Nyegenye, S., Bett, D. K., Asingwire, J. M., Okoro, L. N., Emeribe, N. A., Koech, C. C., Ahgu, O., Bulus, N. G., Taremwa, K., & Mwesigwa, A. (2024). Factors associated with the risk of malaria among children: Analysis of 2021 Nigeria Malaria Indicator Survey. *Malaria Journal*, 23(1), Article 109. <https://doi.org/10.1186/s12936-024-04939-6>
- Jimoh, B. O., Fadipe, M. T., & Emokpae, M. A. (2022). Serum copper, zinc, and copper–zinc ratio in children with malaria. *Saudi Journal for Health Sciences*, 11(2), 119–124.
- Kotepui, M., Wilairatana, P., Mala, W., Kotepui, K. U., Masangkay, F. R., & Wangdi, K. (2023). Effects of daily zinc alone or in combination with other nutrient supplements on the risk of malaria parasitaemia: A systematic review and meta-analysis of randomised controlled trials. *Nutrients*, 15(13), Article 2855. <https://doi.org/10.3390/nu15132855>
- Mbacham, W. F., Ayong, L., Guewo-Fokeng, M., & Makoge, V. (2019). Current situation of malaria in Africa. In F. Arie, F. Gay, & R. Ménard (Eds.), *Malaria control and elimination* (pp. 29–44). Humana. https://doi.org/10.1007/978-1-4939-9550-9_2
- Menéndez, C., Fleming, A. F., & Alonso, P. L. (2000). Malaria-related anaemia. *Parasitology Today*, 16(11), 469–476. [https://doi.org/10.1016/S0169-4758\(00\)01774-9](https://doi.org/10.1016/S0169-4758(00)01774-9)
- Nmorsi, O. P. G., Ukwandu, N. C. D., Oladokun, I. A., & Elozino, S. E. (2007). Severe *Plasmodium falciparum* malaria in some Nigerian children. *Journal of Pediatric Infectious Diseases*, 2(4), 205–210. <https://doi.org/10.1055/s-0035-1557049>
- Oyibo, W., Latham, V., Oladipo, O., Ntadom, G., Uhomoibhi, P., Ogbulafor, N., Okoronkwo, C., Okoh, F., Mahmoud, A., Shekarau, E., Oresanya, O., Cherima, Y. J., Jalingo, I., Abba, B., Audu, M., & Conway, D. J. (2023). Malaria parasite density

- and detailed qualitative microscopy enhances large-scale profiling of infection endemicity in Nigeria. *Scientific Reports*, 13, Article 1599. <https://doi.org/10.1038/s41598-023-27535-1>
- Rijken, M. J., McGready, R., Boel, M. E., Poespoprodjo, R., Singh, N., Syafruddin, D., Rogerson, S., & Nosten, F. (2012). Malaria in pregnancy in the Asia-Pacific region. *The Lancet Infectious Diseases*, 12(1), 75–88. [https://doi.org/10.1016/S1473-3099\(11\)70315-2](https://doi.org/10.1016/S1473-3099(11)70315-2)
- Shankar, A. H. (2000). Zinc and immune function. *Nutrition Research Reviews*, 13(1), 1–15.
- Taylor, W. R. J., Hanson, J., Turner, G. D. H., White, N. J., & Dondorp, A. M. (2012). Respiratory manifestations of malaria. *Chest*, 142(2), 492–505. <https://doi.org/10.1378/chest.11-2655>
- World Health Organization. (2019). *Vitamin A*. WHO Guidelines on Nutrition.
- World Health Organization. (2024). *World malaria report 2024: Addressing inequity in the global malaria response*. <https://www.who.int/publications/i/item/9789240104440>
- World Health Organization. (2025, December 4). *Malaria*. <https://www.who.int/news-room/fact-sheets/detail/malaria>
- World Health Organization. (2026). *Malaria*.
- Zeba, A. N., Sorgho, H., Rouamba, N., Zongo, I., Rouamba, J., Guiguemä, R. T., Hamer, D. H., Mokhtar, N., & Ouedraogo, J.-B. (2008). Major reduction of malaria morbidity with combined vitamin A and zinc supplementation in young children in Burkina Faso: A randomized double blind trial. *Nutrition Journal*, 7, Article 7. <https://doi.org/10.1186/1475-2891-7-7>