Malaria Parasitaemia and Household Mosquito Control Practices among Children in Uturu, a Resource-constrained Community in Abia State, Nigeria: A Community-based Cross-sectional Study

Victor Chidiebere Uzoma[1], Lorretta Chinyere Nwanesi[2], Blessing Uzoamaka Ejike[3], Ifeanyi Luke Okoro[4], Chidi Ole Ukwen[3], Nkiruka Regina Nwokporo[5], Amarachi Jennifer Amams[6] Jesse Onyemaechi Nwigwe[5] and Emmanuel Obioha Ahaotu[7]

[1]Department of Animal and Environmental Biology, Faculty of Biological Sciences, Abia State University, Uturu, Abia State, Nigeria.
[2]Department of Parasitology and Entomology, Faculty of Biosciences, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[3]Department of Biology/Microbiology, Ogbonnaya Onu Polytechnic, Aba, Abia State, Nigeria.
[4]Department of Public Health, Federal University of Technology, Owerri, Imo State, Nigeria.
[5]Department of Biology/Biotechnology, Faculty of Natural Science, David Umahi Federal University of Health Sciences Uburu, Ebonyi State, Nigeria.
[6]Department of Biology/Microbiology, School of Industrial and Applied Sciences, Federal Polytechnic Nekede, Owerri, Imo State, Nigeria.
[7]Department of Animal Science, University of Agriculture and Environmental Sciences Umuagwo, Imo State, Nigeria.
Corresponding Authors Email: uzoma.victor@abiastateuniversity.edu.ng

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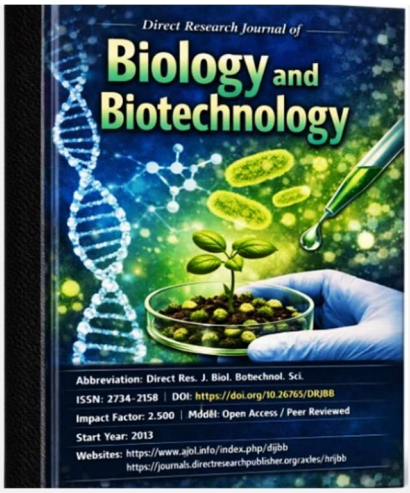
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ABSTRACT

Background: *Nigeria carries the largest share of the global malaria burden, yet community-level data on infection in children beyond the under-five age group, and on the protection afforded by the mosquito control measures households actually use, remain scarce in south-eastern Nigeria. This study determined the prevalence of malaria parasitaemia among children aged 0–12 years in Uturu, Abia State, and assessed its association with age, sex, community and household mosquito control practices.* ***Methods:*** *A community-based cross-sectional study was conducted from June to October 2022 among 400 children aged 0–12 years in three communities of Uturu (Ukwunwangwu, Hopeville and Achara). Venous blood was examined for malaria parasites by Giemsa-stained thick and thin film microscopy, and caregivers reported the mosquito control measures used in the household. Prevalence was estimated with Wilson 95% confidence intervals (CI), and associations were assessed with Pearson's chi-square test, the chi-square test for linear trend and prevalence ratios (PR).* ***Results:*** *Malaria parasites were detected in 311 of 400 children (77.8%; 95% CI: 73.4–81.6). Prevalence rose with age from 70.8% at 0–4 years to 81.6% at 9–12 years (trend p = 0.039) but did not differ by sex (78.6% versus 76.8%; p = 0.678) or community (76.8–78.4%; p = 0.951). Infection was almost universal among children from households that used no mosquito control measure (98.1%), compared with 70.5% among those that used at least one (PR = 0.72; 95% CI: 0.66–0.78). Protection depended on the measure: children whose households used a bed net had less than half the prevalence of those that did not (48.0% versus 88.9%; PR = 0.54; 95% CI: 0.44–0.66), and the lowest prevalence was among children whose households combined bed nets, window nets and insecticide (13.3%; PR = 0.14; 95% CI: 0.05–0.34). Window or door nets alone (84.0%) and insecticide alone (71.0%) offered much less protection.* ***Conclusion:*** *Malaria parasitaemia is highly prevalent among children of all ages in Uturu during the rainy season. Bed nets, particularly when combined with other measures, were associated with markedly lower infection, whereas window nets or insecticides alone were not sufficient. Universal net coverage that explicitly includes school-aged children, supported by house improvement and integrated vector management, is needed in this community.*

Keywords: *Malaria, Plasmodium, Parasitaemia, Children, Bed nets, Vector control, Abia State, Nigeria*



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INTRODUCTION

Malaria remains one of the leading causes of illness and death in sub-Saharan Africa. In 2023 there were an estimated 263 million malaria cases and 597,000 malaria deaths worldwide, about 95% of them in the World Health Organization (WHO) African Region (World Health Organization [WHO], 2024). Nigeria alone accounted for about 26% of global cases and 30.9% of global deaths, more than any other country (WHO, 2024). The disease is caused by protozoan parasites of the genus *Plasmodium* and is transmitted by female *Anopheles* mosquitoes; *Plasmodium falciparum*, the most virulent species, is responsible for nearly all infections in Nigeria (Bartoloni and Zammarchi, 2012).

The burden of malaria extends beyond acute illness. Repeated infection causes anaemia, impairs cognitive development and school performance, and leads to absenteeism among schoolchildren (Holding and Snow, 2001). At household level, malaria both results from and deepens poverty, because the poorest households have the least access to effective prevention and the most to lose from illness (Worrall *et al.*, 2005). These effects are greatest in rural farming communities, where agricultural activity and proximity to breeding sites coincide with the rainy season (Aribodor *et al.*, 2003).

Malaria surveillance and control in Nigeria have historically focused on children under five years of age, who carry the greatest risk of death. However, school-aged children constitute a large and often neglected reservoir of infection. In many African settings they have the highest prevalence of parasitaemia of any age group and are the least likely to sleep under insecticide-treated nets (ITNs) (Nankabirwa *et al.*, 2014). National surveys, which test only children aged 6–59 months, therefore describe only part of the burden. In the 2021 Nigeria Malaria Indicator Survey (NMIS), microscopy-confirmed prevalence among children aged 6–59 months was 19% in the South East zone and 15% in Abia State, and only 22% of children under five in Abia had slept under an ITN the night before the survey (National Malaria Elimination Programme [NMEP] *et al.*, 2022).

Insecticide-treated nets are the cornerstone of malaria prevention. They reduce child mortality by 17% and *P. falciparum* prevalence by 17% compared with no nets (Pryce *et al.*, 2018). House screening and modern housing also reduce exposure to mosquitoes (Kirby *et al.*, 2009; Tusting *et al.*, 2017). In practice, however, households in Nigeria rely on a mix of measures, including untreated window and door nets, aerosol insecticides and coils, whose effectiveness against infection is less well established, particularly where *Anopheles* populations are resistant to pyrethroids (Chukwuekezie *et al.*, 2020). Analysis of the 2021 NMIS identified age, net use, housing and region as determinants of malaria in Nigerian children under five, but did not include school-aged children or compare the different measures households use (Isiko *et al.*, 2024).

Uturu, a semi-urban farming community in Abia State that hosts Abia State University, lies close to the Ihiku and Atuma streams, which provide breeding sites for mosquitoes throughout the year. No published data exist on malaria parasitaemia among its children. This study therefore aimed to determine the prevalence of malaria parasitaemia among children aged 0–12 years in three communities of Uturu, to assess its variation by age, sex and community, and to compare infection among children according to the mosquito control measures used in their households.

MATERIALS AND METHODS

Study design and setting

A community-based, cross-sectional study was conducted from June to October 2022, during the rainy season, in Uturu, Isuikwuato Local Government Area, Abia State, south-eastern Nigeria. Uturu is a semi-urban community of predominantly Igbo, Christian inhabitants, about 70% of whom are engaged in subsistence agriculture, growing cassava, yam, cocoyam and maize as food crops and oil palm, rubber, cocoa and bananas as cash crops. The Ihiku and Atuma streams supply drinking water to the community throughout the year, and their margins, together with surrounding farmland, provide favourable breeding sites for *Anopheles* mosquitoes. Three communities were studied: Ukwunwangwu, which lies in the more developed part of Uturu; Hopeville; and Achara, which is more rural.

Study population and sampling

The study population comprised children aged 0–12 years who were resident in the three communities and whose mothers or caregivers consented to their participation. Children were randomly selected from households in each community. A total of 400 children were enrolled: 125 from Ukwunwangwu, 150 from Hopeville and 125 from Achara. This sample size allows the overall prevalence to be estimated with a precision of ± 4.1 percentage points at the 95% confidence level.

Data collection

Data and samples were collected in the children's homes. A structured questionnaire was administered to each child's mother or caregiver to record the child's age, sex and community, and the mosquito control measures used in the household. Mosquito control measures were classified as bed nets, window or door nets, and insecticides (sprays or coils), and households were grouped according to the combination of measures they reported using.

Blood collection and parasitological examination

Two millilitres of venous blood was collected from each child by a trained health practitioner into a labelled Ethylenediaminetetraacetic acid (EDTA) bottle and transported immediately to the laboratory. Thick and thin blood films were prepared, stained with Giemsa and examined under oil immersion with the ×100 objective, following standard procedures (Arora and Arora, 2001; WHO, 1991). Thick films were used to detect parasites and thin films to identify the *Plasmodium* species. A child was classified as positive when asexual malaria parasites were seen in the thick film.

Statistical analysis

The prevalence of malaria parasitaemia was calculated as the number of children with parasites divided by the number examined, overall and for each category of age, sex, community and mosquito control, with 95% confidence intervals calculated by the Wilson score method. Differences in prevalence between categories were tested with Pearson's chi-square test, and the chi-square test for linear trend was applied to age group. Because malaria parasitaemia was common, associations were expressed as prevalence ratios (PR) with 95% confidence intervals rather than odds ratios, which overstate the strength of association when an outcome is common. Each specific combination of control measures was compared with no control measure using Fisher's exact test. To identify which component measures were associated with lower prevalence, children were further grouped by any bed net use, and, among those using at least one measure, by whether the measures included a bed net, an insecticide or a window or door net. Analyses were performed in Python 3 (SciPy). A *p*-value below 0.05 was considered statistically significant.

RESULTS

Prevalence of malaria parasitaemia

Of the 400 children examined, 210 (52.5%) were male and 190 (47.5%) were female, and 158 (39.5%) were aged 9–12 years (Table 1). Malaria parasites were detected in 311 children, giving an overall prevalence of 77.8% (95% CI: 73.4–81.6).

Prevalence by age, sex and community

Prevalence increased with age, from 70.8% among children aged 0–4 years to 79.1% among those aged 5–8 years and 81.6% among those aged 9–12 years (Table 1). The overall difference between age groups was not significant ($\chi^2 = 4.67$, df = 2, $p = 0.097$), but the linear trend of increasing prevalence with age was ($\chi^2 = 4.27$, $p = 0.039$). Prevalence was similar in boys (78.6%) and girls (76.8%; PR = 1.02; 95% CI: 0.92–1.14; $p = 0.678$) and across the three communities, ranging from 76.8% in Ukwunwangwu to 78.4% in Achara ($p = 0.951$).

Mosquito control measures and malaria parasitaemia

A total of 295 children (73.8%) lived in households that used at least one mosquito control measure, and 105 (26.3%) lived in households that used none. Infection was almost universal among children from households without any control measure (98.1%; 95% CI: 93.3–99.5), compared with 70.5% (95% CI: 65.1–75.4) among those from households that used at least one measure (PR = 0.72; 95% CI: 0.66–0.78; $p < 0.001$; Table 1).

The specific combination of measures used was recorded for 363 children (Table 2, Figure 1). Prevalence differed markedly between combinations ($\chi^2 = 122.26$, df = 6, $p < 0.001$). It was lowest among children whose households combined bed nets, window nets and insecticide (13.3%; PR = 0.14; 95% CI: 0.05–0.34) and those that used bed nets only (40.0%; PR = 0.41; 95% CI: 0.25–0.66). In contrast, prevalence remained high where households used window or door nets only (84.0%), window nets with insecticide (88.6%) or insecticide only (71.0%). Children in households that used all three measures had a significantly lower prevalence than those using bed nets only (13.3% versus 40.0%; $p = 0.032$).

Bed net use was the component most strongly associated with lower infection. Children from households that used a bed net, alone or with other measures, had a prevalence of 48.0%, compared with 88.9% among those that did not (PR = 0.54; 95% CI: 0.44–0.66). This difference persisted when the comparison was restricted to households that used at least one measure (48.0% versus 82.7%; PR = 0.58; 95% CI: 0.47–0.72). Among these households, the inclusion of insecticide was associated with a modestly lower prevalence (61.9% versus 73.9%; PR = 0.84; 95% CI: 0.70–1.00), whereas the inclusion of window or door nets was associated with a higher prevalence (72.3% versus 57.1%; PR = 1.26; 95% CI: 0.99–1.61). Prevalence did not decline steadily with the number of measures used: it was 73.0% with one measure and 81.3% with two, falling to 13.3% only when all three were combined.

DISCUSSION

This study found that more than three-quarters of children aged 0–12 years in Uturu carried malaria parasites during the rainy season, that the burden was spread evenly across sexes and communities and increased with age, and that children from households using no mosquito control measure were almost all infected. Among the measures in use, bed nets were associated with substantially lower infection, whereas window or door nets

Table 1: Prevalence of malaria parasitaemia by age, sex, community and household mosquito control among children aged 0–12 years in Uturu, Abia State, Nigeria, June to October 2022 (*N* = 400).

Characteristic	No. examined (%)	No. infected	Prevalence, % (95% CI)	PR (95% CI)	*p*
Age group (years)					
0–4	113 (28.3)	80	70.8 (61.8–78.4)	Ref	0.097
5–8	129 (32.3)	102	79.1 (71.3–85.2)	1.12 (0.96–1.30)	
9–12	158 (39.5)	129	81.6 (74.9–86.9)	1.15 (1.00–1.33)	0.039†
Sex					
Male	210 (52.5)	165	78.6 (72.5–83.6)	1.02 (0.92–1.14)	0.678
Female	190 (47.5)	146	76.8 (70.3–82.3)	Ref	
Community					
Ukwunwangwu	125 (31.3)	96	76.8 (68.7–83.3)	Ref	0.951
Hopeville	150 (37.5)	117	78.0 (70.7–83.9)	1.02 (0.89–1.15)	
Achara	125 (31.3)	98	78.4 (70.4–84.7)	1.02 (0.89–1.17)	
Household mosquito control					
At least one measure used	295 (73.8)	208	70.5 (65.1–75.4)	0.72 (0.66–0.78)	< 0.001*
No measure used	105 (26.3)	103	98.1 (93.3–99.5)	Ref	
Total	400 (100.0)	311	77.8 (73.4–81.6)		

No., number; CI, confidence interval (Wilson method); PR, prevalence ratio; Ref, reference category. *p* from Pearson's chi-square test. †, chi-square test for linear trend across age groups. *, statistically significant ($p < 0.05$).

Table 2: Prevalence of malaria parasitaemia by household mosquito control measures among children aged 0–12 years in Uturu, Abia State, Nigeria.

Mosquito control measure	No. (%)	No. infected	Prevalence, % (95% CI)	PR (95% CI)	*p*
Specific combination used (*n* = 363; $\chi^2 = 122.26$, df = 6, $p < 0.001$)					
None	105 (28.9)	103	98.1 (93.3–99.5)	Ref	
Window net and insecticide	44 (12.1)	39	88.6 (76.0–95.0)	0.90 (0.81–1.01)	0.024*
Window/door net only	81 (22.3)	68	84.0 (74.5–90.4)	0.86 (0.78–0.94)	< 0.001*
Bed net and window net	47 (12.9)	35	74.5 (60.5–84.7)	0.76 (0.64–0.90)	< 0.001*
Insecticide only	31 (8.5)	22	71.0 (53.4–83.9)	0.72 (0.58–0.91)	< 0.001*
Bed net only	25 (6.9)	10	40.0 (23.4–59.3)	0.41 (0.25–0.66)	< 0.001*
Bed net, window net and insecticide	30 (8.3)	4	13.3 (5.3–29.7)	0.14 (0.05–0.34)	< 0.001*
Any bed net use (*n* = 363)					
Yes	102 (28.1)	49	48.0 (38.6–57.6)	0.54 (0.44–0.66)	< 0.001*
No	261 (71.9)	232	88.9 (84.5–92.2)	Ref	
Among users of at least one measure (*n* = 258)					
Measures included a bed net	102 (39.5)	49	48.0 (38.6–57.6)	0.58 (0.47–0.72)	< 0.001*
Measures did not include a bed net	156 (60.5)	129	82.7 (76.0–87.8)	Ref	
Measures included insecticide	105 (40.7)	65	61.9 (52.4–70.6)	0.84 (0.70–1.00)	0.041*
Measures did not include insecticide	153 (59.3)	113	73.9 (66.4–80.2)	Ref	
Measures included a window/door net	202 (78.3)	146	72.3 (65.7–78.0)	1.26 (0.99–1.61)	0.030*
Measures did not include a window/door net	56 (21.7)	32	57.1 (44.1–69.2)	Ref	
Number of measures used (*n* = 363)					
None	105 (28.9)	103	98.1 (93.3–99.5)	Ref	
One	137 (37.7)	100	73.0 (65.0–79.7)	0.74 (0.67–0.83)	
Two	91 (25.1)	74	81.3 (72.1–88.0)	0.83 (0.75–0.92)	
Three	30 (8.3)	4	13.3 (5.3–29.7)	0.14 (0.05–0.34)	

Percentages in the No. (%) column use the total for each panel as the denominator. CI, confidence interval (Wilson method); PR, prevalence ratio; Ref, reference category. In panel A, *p* from Fisher's exact test comparing each combination with no measure; in panels B and C, from Pearson's chi-square test. *, statistically significant ($p < 0.05$).

and insecticides used without bed nets were not. The prevalence of 77.8% confirms intense transmission in Uturu and is consistent with earlier community surveys in south-eastern Nigeria (Amadi *et al.*, 2017; Aribodor *et al.*, 2003). It is, however, far higher than the 15% recorded among children aged 6–59 months in Abia State by the 2021 NMIS (NMEP *et al.*, 2022), and even our youngest age group had a prevalence of 70.8%. Several factors may contribute to this difference. Sampling took place from June to October, at the peak of the rainy season, whereas the NMIS was conducted from October to December, as transmission declines (Isiko *et al.*, 2024). The study communities lie close to permanent streams and farmland, and the NMIS estimate averages over urban and rural areas of the whole state. Most infections in a highly endemic setting are also asymptomatic, low-density infections that persist for weeks. Finally, because microscopy was performed without reported external quality control, some over-reading of slides cannot be excluded. Confirmation with rapid diagnostic tests or molecular methods in future surveys would strengthen comparisons with national data. Prevalence increased with age and was highest among children aged 9–12 years. This pattern agrees with the findings of Aribodor *et al.* (2003), who recorded the highest prevalence among children aged 10–15 years in Anambra State, and with a review showing that school-aged children in Africa often have the highest prevalence of parasitaemia of any age group (Nankabirwa *et al.*, 2014). Older children spend more time outdoors in the evenings, accompany their

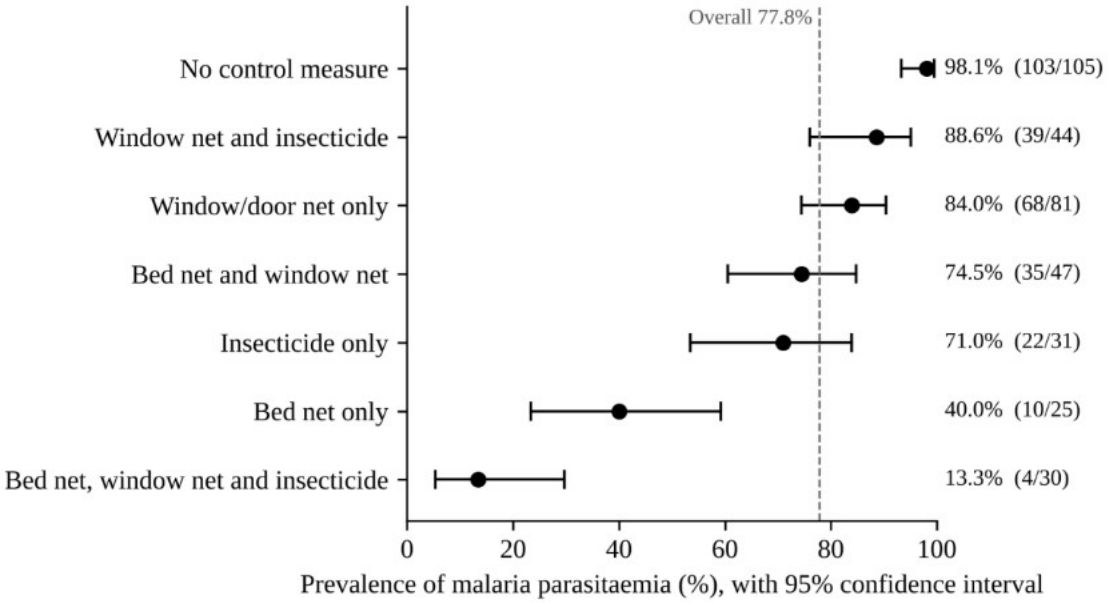


Figure 1: Prevalence of malaria parasitaemia, with 95% confidence intervals, by the combination of mosquito control measures used in the household (*n* = 363). The dashed line marks the overall prevalence (77.8%).

parents to farms near breeding sites, and are less likely than infants and young children to sleep under nets, which are usually prioritised for children under five and their mothers (Nankabirwa *et al.*, 2014). National surveys that test only children under five years therefore underestimate the reservoir of infection in communities such as Uturu. Among children under five in Nigeria, by contrast, the risk of malaria rises with age over the first years of life (Isiko *et al.*, 2024), which is consistent with the lower prevalence in our youngest group.

Prevalence did not differ between boys and girls. Some Nigerian studies have reported higher prevalence in males, attributed to greater outdoor exposure (Adekunle *et al.*, 2014; Etusim *et al.*, 2013), while others have reported higher prevalence in females (Oparaocha, 2003). In children of this age, who share sleeping arrangements and outdoor activities, exposure to infective bites is likely to be similar. The three communities also had nearly identical prevalence despite differences in their level of development, which suggests that transmission is driven by features common to all of Uturu, such as the streams and surrounding farmland, rather than by local differences in sanitation. *Anopheles* mosquitoes breed mainly in clean, sunlit water, so environmental sanitation exercises that clear refuse and drains are unlikely on their own to reduce malaria transmission.

The strongest finding of this study is the association between household mosquito control and infection. Almost every child from a household that used no measure was infected, and children from households that used a bed net had about half the prevalence of those that did not. The protective association of bed nets is consistent with the Cochrane review of randomised trials, in which ITNs reduced *P. falciparum* prevalence and child mortality (Pryce *et al.*, 2018), and with the protective association of ITN use in a multi-country analysis of African surveys (Tusting *et al.*, 2017). The very low prevalence among children whose households combined bed nets, window nets and insecticide suggests that layered protection, which reduces both indoor biting and mosquito entry, provides the greatest benefit. Households that adopt all three measures may also be more consistent in their use or better resourced, and this possibility cannot be excluded in a cross-sectional study.

Window or door nets used without bed nets offered little protection, and households whose measures included window nets had a higher prevalence than those whose measures did not. Screening can substantially reduce the number of mosquitoes entering houses. In a randomised trial in The Gambia, however, house screening reduced indoor mosquito density and anaemia but did not reduce the prevalence of parasitaemia (Kirby *et al.*, 2009). In Uturu, screens that are torn, poorly fitted or left open, and open eaves, may allow mosquitoes to enter freely. Households with window nets may also feel protected and be less likely to use bed nets. Insecticide sprays and coils used alone were associated with a prevalence of 71.0%. Their protection is short-lived, and *Anopheles gambiae* populations in south-eastern Nigeria show widespread resistance to pyrethroids, the class of insecticide used in

most household products and in standard nets, with knockdown resistance mutation frequencies of 0.6–0.9 (Chukwuekezie *et al.*, 2020). Pyrethroid resistance also threatens the effectiveness of standard ITNs, and WHO now recommends nets that combine pyrethroids with a second active ingredient or synergist in areas of resistance (WHO, 2023).

Prevalence did not decline steadily with the number of measures used: it was higher among households using two measures than among those using one, and fell sharply only when all three were combined. This pattern most likely reflects the type of measures combined rather than their number, because most two-measure households combined window nets with either insecticide or bed nets. It may also reflect reverse causation, in which households experiencing more mosquitoes and more malaria adopt additional measures. A similar paradox was observed in the 2021 NMIS, in which children from households with treated nets had higher odds of malaria (Isiko *et al.*, 2024). These findings show that the presence of a control measure in a household does not guarantee that it is used correctly and consistently.

These findings have practical implications for malaria control in Uturu and similar communities. Net distribution campaigns should aim for universal coverage of all household members, including school-aged children, rather than prioritising only children under five and pregnant women. Given pyrethroid resistance in the region, next-generation nets should be considered. Education for caregivers should stress that bed nets are the most important single measure and that window nets and insecticides are complements to, not substitutes for, nets. House improvements, such as well-fitted screens and closed eaves, and larval source management along the Ihiku and Atuma streams during the rainy season would further reduce exposure. Finally, the high prevalence of infection among school-aged children supports school-based malaria testing and treatment.

Strengths and limitations

This study is one of few to describe malaria parasitaemia across the full age range of childhood in a south-eastern Nigerian community, and it examined the protection associated with the combinations of control measures households actually use. It has several limitations. Its cross-sectional design cannot establish that control measures caused the differences in infection, and reverse causation is possible. Mosquito control measures were reported by caregivers and were not verified by observation; whether nets were insecticide-treated, their condition and whether the child slept under one the previous night were not recorded. The specific combination of measures was not available for 37 children. Analyses were unadjusted, so the associations may be confounded by household socio-economic status, housing quality and proximity to breeding sites, none of which were measured. Microscopy was performed without reported external quality control, and parasite density, species distribution and clinical status were not reported. Finally, data were collected only during the rainy season, so the results do not represent year-round transmission.

CONCLUSION

Malaria parasitaemia is highly prevalent among children of all ages in Uturu during the rainy season, affects boys and girls and all three communities equally, and is highest among school-aged children. Children from households that used no mosquito control measure were almost all infected. Bed nets were the measure most strongly associated with lower infection, especially when combined with window nets and insecticide, while window nets or insecticide alone offered little protection. Malaria control in Uturu should prioritise universal coverage with effective, preferably next-generation, insecticide-treated nets for all household members, including school-aged children, supported by education on correct and consistent net use, house improvement, larval source management and school-based testing and treatment. Longitudinal studies with verified net use, quality-assured diagnosis and adjustment for household factors are needed to confirm these associations.

Abbreviations

CI: Confidence interval; EDTA: Ethylenediaminetetraacetic acid; ITN: Insecticide-treated net; NMEP: National Malaria Elimination Programme; NMIS: Nigeria Malaria Indicator Survey; PR: Prevalence ratio; WHO: World Health Organization.

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Author contributions

UVC, EBU and NLC conceived and designed the study, collected the samples and data, performed the laboratory analysis and drafted the manuscript. OIL, UCO and NNR contributed to data collection and analysis. AAJ and NJO supervised the study and critically reviewed the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from [name of ethics committee] ([approval number]). Permission to conduct the study was also obtained from the heads of the Uturu community and town unions at a town-hall meeting organised to inform residents of the three communities about the research. The study procedures were explained to mothers and caregivers before blood collection, and informed consent was obtained from the mother or caregiver of each child.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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