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Impact of Integrated Malaria Control Interventions: A Comparative Analysis of Pre- Intervention, Post-Intervention, and Combined Intervention Approaches in Rural and Urban settlement Southeastern Nigeria

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Research Article

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Abstract

Background

Malaria remains an important public health challenge in Nigeria, particularly in rural and urban communities where environmental and socioeconomic conditions favours malaria transmission. This study evaluated malaria prevalence and compared the effectiveness of single and combined malaria control interventions in selected rural and urban communities of southeastern Nigeria.

Methods

A comparative intervention-based study was conducted among 1,600 participants from eight communities in Obowo and Owerri-North Local Government Areas, southeastern Nigeria. Malaria prevalence was assessed before and after implementation of selected interventions, including insecticide-treated nets (ITNs), antimalarial drugs, indoor residual spraying (IRS), sanitation, and health education. Descriptive statistics were used to determine malaria prevalence, while Pearson's chi-square test was used to determine the association between malaria infection status and selected demographic and intervention-related categories. Statistical significance was considered at a threshold of **$p < 0.05$.**

Results

Overall malaria prevalence was 26.12%. Prevalence was significantly higher in Obowo (36.38%) than in Owerri-North (15.88%) ($\chi^2 = 87.10$, $p < 0.001$). Males had significantly higher prevalence (36.23%) than females (18.46%) ($\chi^2 = 64.21$, $p < 0.001$), while prevalence differed significantly across age groups ($\chi^2 = 25.53$, $p < 0.001$). Following implementation of single interventions, malaria prevalence declined to 9.52% (70/735), with the lowest prevalence recorded in the ITN group (4.59%) and the highest in the control group (17.14%). The difference among intervention categories was significant ($\chi^2 = 25.41$, $p < 0.001$). Combined interventions produced a further reduction to 4.62%, with infection prevalence of approximately 2.55%, 2.14%, and 3.89% among the ITN + sanitation, drug + education, and IRS + ITN groups, respectively. The combined intervention categories differed significantly ($\chi^2 = 11.00$, $p = 0.012$).

Conclusion

Malaria prevalence was significantly associated with geographical location, sex, age, and intervention strategy. Both single and combined malaria control interventions were associated with substantial reductions in malaria prevalence, with combined interventions demonstrating a stronger overall reduction. Integrated malaria control incorporating vector control, appropriate treatment, sanitation, and health education may therefore provide a more effective strategy for reducing malaria transmission in rural and urban communities of southeastern Nigeria.

Introduction

Malaria remains one of the most devastating vector-borne infectious diseases in sub-Saharan Africa, with Nigeria accounting for a disproportionate share of the regional and global disease burden (1–6). In 2022, Nigeria alone contributed approximately 27% of global malaria cases and 31% of malaria-related deaths, underscoring its central role in the global malaria epidemic (7–9). Since 2000, global malaria control programmes have prevented an estimated 2.2 billion malaria cases and 12.7 million deaths, with nearly 70% of these gains attributed to large-scale implementation of vector control interventions, particularly insecticide-treated nets (ITNs) and indoor residual spraying (IRS) (10, 11). Nevertheless, progress has plateaued in many endemic countries, and malaria transmission has resurged in several parts of sub-Saharan Africa (10). A major contributor to this stagnation is the widespread emergence of insecticide resistance, especially resistance to pyrethroids, the principal insecticide class used for ITNs and IRS. The extensive use of pyrethroids in both agriculture and public health has accelerated the development and spread of resistance among malaria vectors, threatening the long-term effectiveness of these interventions (10, 12). Current malaria control relies on a combination of interventions targeting both the mosquito vector and the parasite. Core vector control measures include insecticide-treated nets, long-lasting insecticidal nets (LLINs), and indoor residual spraying, while complementary approaches such as larval source management, biological control, environmental management, and improved housing seek to reduce vector abundance and human-vector contact (13, 14). In addition, parasite-targeted interventions including prompt diagnosis and treatment with Artemisinin-based combination therapies (ACTs), intermittent preventive treatment, mass drug administration in selected settings, and the recent introduction of malaria vaccines have expanded the available tools for malaria prevention and elimination (15). Increasingly, malaria programmes advocate integrated vector management (IVM), which promotes the coordinated use of multiple evidence-based interventions to maximize disease control while minimizing environmental impacts, insecticide selection pressure, and risks to human health (16). Malaria control efforts in resource-limited settings have traditionally relied on vector control interventions, particularly the widespread deployment of insecticide-treated nets (ITNs) and indoor residual spraying (IRS), both of which have demonstrated substantial effectiveness in reducing malaria transmission (17). Despite these achievements, the global malaria burden has shown only modest declines in recent years, underscoring the need for more comprehensive and sustainable control strategies (17). Consequently, integrated malaria prevention, which combines multiple complementary interventions, has emerged as a promising approach to enhance malaria control (18). In addition to ITNs and IRS, this strategy incorporates larval source management, improved housing to reduce mosquito entry, and the use of topical repellents (19). Evidence indicates that the concurrent implementation of these interventions provides greater protection against malaria transmission and results in more substantial reductions in malaria incidence and prevalence than single-intervention strategies alone (19). Effective malaria control requires strong community engagement, with local populations playing a central role in adopting preventive practices and utilizing timely treatment services (20). Consequently, insufficient community participation may limit the effectiveness and sustainability of malaria control interventions, regardless of their design or implementation quality. Studies have demonstrated that expanding access to Artemisinin-based combination therapies can substantially decrease malaria incidence and interrupt transmission,

particularly when integrated with vector control measures such as ITNs and IRS (21, 22). Countries including Kenya and Zambia have reported marked reductions in malaria burden following the combined implementation of effective treatment and vector control interventions (23–25). Despite the availability of multiple malaria prevention strategies, evidence comparing the effectiveness of individual and combined interventions at the community level remains limited in southeastern Nigeria, where adoption and utilization of preventive measures vary considerably. Understanding the relative contribution of different intervention combinations is essential for optimizing malaria control programmes in endemic settings. Therefore, this study evaluated the effectiveness of individual and combined malaria prevention interventions including insecticide-treated nets, indoor residual spraying, and prophylactic antimalarial drug use in relation to malaria transmission in two contrasting communities in Imo State, Southeastern Nigeria. The findings provide evidence to inform integrated malaria control strategies and strengthen implementation of the Roll Back Malaria programme in Nigeria.

Materials and Methods

Study Area

The study was conducted between July 2023 and May 2024 in eight selected communities drawn from two Local Government Areas (LGAs) of Imo State, southeastern Nigeria (Fig. 1). Four rural communities were selected from Obowo LGA, while four urban communities were selected from Owerri North LGA. The rural communities comprised Avutu, Umuariam, Ehume, and Amuzi, whereas the urban communities comprised Orji, Akwakuma, Amakohia, and Works Layout. Obowo LGA lies approximately between latitudes 5°10'N and 5°51'N and longitudes 6°35'E and 7°28'E, while Owerri North LGA lies approximately between latitudes 5°15'N and 5°34'N and longitudes 7°15'E and 7°30'E. Detailed descriptions of the study areas have been reported (26–28). The selected communities are characterized by varying environmental and socioeconomic conditions. Poor solid-waste disposal is common, with refuse frequently accumulated around residential areas, schools, roadsides, and market environments. Inadequate waste disposal and blocked drainage channels contribute to poor environmental sanitation and environmental degradation. During the rainy season, stagnant water associated with blocked drainage systems and improperly discarded containers may provide suitable breeding habitats for mosquitoes and consequently increase the risk of malaria transmission.

Source: (29)

Study Population

The study population consisted of rural and urban residents aged 5 years and above living in the selected communities of Obowo and Owerri North LGAs. The communities were selected to provide a comparison between rural and urban ecological settings with potentially different environmental and malaria transmission characteristics.

A total of 1,600 participants were enrolled in the study. Eight communities were included, with 200 participants recruited from each community. Thus, 800 participants were recruited from the four rural communities in Obowo LGA and another 800 participants from the four urban communities in Owerri North LGA.

Sample Size Determination

The minimum sample size was estimated using the formula described by Lemeshow et al. (30):

$$n = \frac{Z^2 p(1 - p)}{d^2}$$

Where:

n = required minimum sample size;

Z = standard normal deviate corresponding to a 95% confidence level (1.96);

p = estimated prevalence/proportion of the factor under investigation (0.187 or 18.7%)

d = acceptable margin of error (0.05 or 5%).

Based on the parameters above, the minimum sample size was estimated to be approximately 200 participants. To facilitate comparison across intervention groups and communities, a total of 1,600 participants were recruited, comprising 200 participants from each of the eight selected communities.

Blood Collection and Malaria Diagnosis

Peripheral blood samples were collected from consenting participants using a sterile finger-prick technique as described by Ukaga and Nwoke (31). Blood collection in the rural communities was conducted at designated community meeting halls following routine community meetings, whereas samples from participants in the urban communities were collected at churches following services and, where necessary, at participants' residences. Malaria infection was determined using the CareStart™ Malaria Pf (HRP2) antigen rapid diagnostic test (RDT). The test kits were obtained from a pharmacy outlet and used

according to the manufacturer's instructions. For each participant, the thumb was cleaned with an alcohol-based swab and allowed to dry before being punctured with a sterile lancet. A sufficient quantity of capillary blood was collected using the supplied capillary tube and transferred into the sample well of the RDT cassette. The manufacturer's recommended quantity of buffer solution was subsequently added. The test cassette was allowed to stand for approximately 15 minutes before the result was interpreted.

Interpretation of Malaria RDT Results

The test was considered **invalid** when the control line (C) failed to appear, irrespective of whether a test line was visible. Invalid tests were repeated using a new test cassette. A result was considered negative when only the control line (C) appeared. A result was considered positive when both the control line and the test line appeared in the test window. The results obtained before and after implementation of the intervention measures were documented for subsequent statistical analysis.

Experimental Design and Allocation of Intervention Measures

The eight study communities were organized into four intervention groups, with each group comprising one rural and one urban community. The intervention groups were structured to permit comparison of different malaria control strategies. The communities and their respective intervention groupings were as follows:

Group 1

Avutu (rural) and Orji (urban)

Group 2

Umuariam (rural) and Akwakuma (urban)

Group 3

Ehume (rural) and Amakohia (urban)

Group 4

Amuzi (rural) and Works Layout (urban)

The study initially evaluated the effects of selected single malaria intervention measures. Subsequently, combined intervention strategies were implemented based on the outcomes of the single-intervention phase and information obtained through focus group discussions.

Single Intervention Measures

Three intervention measures were evaluated individually, while one group served as the control.

Participants in Group 1 received long-lasting insecticide-treated nets (ITNs). Group 2 received antimalarial drugs, while Group 3 received indoor residual spraying (IRS). Participants in Group 4 did not receive a study intervention and served as the control group. A total of 196 ITNs were distributed to Group 1 participants. Of these, 113 nets were distributed in Avutu, including nets installed on doors/windows and beds, while 83 nets were distributed in Orji, with similar household installation arrangements.

For Group 2, 140 units of antimalarial medication were distributed monthly, comprising participants from Umuariam and Akwakuma. A total of 83 units were allocated to Umuariam and 57 to Akwakuma.

For Group 3, IRS was implemented among 154 participants, comprising 93 participants from Ehume and 61 from Amakohia. Participants in Amuzi and Works Layout constituted the control group and received no intervention during the intervention period.

Combined Intervention Measures

Following the single-intervention phase, combined intervention strategies were implemented to strengthen malaria prevention and control.

Group 1: ITN and Environmental Sanitation

Participants who received ITNs were additionally encouraged to participate in environmental sanitation activities. These activities included community clean-up exercises, removal of stagnant water and mosquito larvae habitats around homes, clearing of overgrown vegetation, covering of open drains, and proper management of artificial water-holding containers.

Group 2: Antimalarial Drugs and Health Education

Participants who received antimalarial drugs were also provided with health education on malaria transmission, prevention, and vector control. Education focused on mosquito biology and transmission, environmentally appropriate vector-control practices, personal protection, and household-level measures for reducing mosquito exposure.

Group 3: IRS and ITNs

Participants who received IRS were additionally provided with ITNs. This combination was designed to provide complementary protection through reduction of indoor mosquito populations and prevention of mosquito bites during sleeping hours.

Group 4: Control

Participants in the control communities, Amuzi and Works Layout, did not receive any of the study intervention measures during the intervention period.

Intervention Materials and Sources

Two types of antimalarial drugs, Combisunate and Loatherm, were used in the study and obtained from a licensed pharmacy. The long-lasting insecticide-treated nets consisted of white and blue-coloured nets of different shapes and sizes and were obtained from suppliers. The insecticide used for indoor residual spraying was locally available Sniper insecticide obtained from the market.

Compliance and Monitoring

To promote adherence to the intervention measures, community monitoring committees were established in both intervention and control communities. The committees consisted of youth representatives and other recognized community opinion leaders. Their responsibilities included monitoring the appropriate use of intervention materials, encouraging community participation, and reporting challenges relating to intervention implementation. The research team periodically supervised and monitored the activities of the community committees to assess compliance and ensure that the intervention measures were implemented as planned.

Assessment of the Impact of Intervention Measures on Malaria

The impact of the various malaria intervention measures was assessed by comparing malaria prevalence among participants before and after implementation of the interventions. Blood samples were collected and tested using the same malaria diagnostic procedure throughout the study period. The malaria infection status obtained after implementation of the intervention measures was compared with baseline findings. Changes in malaria prevalence within and between intervention groups were assessed to determine the relative effects of the different malaria-control strategies.

Comparison of Intervention Efficacy

The efficacy of the different intervention strategies was evaluated by comparing malaria infection status among participants exposed to the different intervention measures. Comparisons were made between the single-intervention and combined-intervention phases, as well as between intervention and control groups. The effects of the intervention measures were also compared across the rural and urban communities to determine whether differences in ecological setting were associated with variations in malaria-control outcomes.

Data Analysis

Data generated from the study were coded, entered, and subjected to statistical analysis. Descriptive statistics were used to summarize the study variables, while Pearson's chi-square (χ^2) test was used to assess associations between categorical variables and malaria infection status across intervention groups and study locations. Statistical significance was assessed at a 5% level of significance ($p < 0.05$).

Results

Table 1: Prevalence of Malaria Parasitaemia in the Study Area

Of the 1,600 individuals examined, 418 were infected, giving an overall malaria prevalence of 26.12%. Prevalence was considerably higher in Obowo LGA (291/800; 36.38%) than in Owerri-North (127/800; 15.88%). The findings revealed a **significant difference**($\chi^2 = 87.10$, df = 1, $p < 0.001$). Among the communities, Ehume recorded the highest number of infections (100), followed by Umuariam (75), Orji (61), Avutu (60), Amuzi (56), Workslayout (24), Amakohia (23), and Akwakuma (19). The original table reports these community-specific contributions to the overall infected population. The table is also illustrated in Figure 2.

Table 2: Distribution of Malaria Prevalence by Age and Gender

Males had a higher malaria burden than females, with 250/690 (36.23%) males infected compared with 168/910 (18.46%) females. The findings revealed a **significant difference**($\chi^2 = 64.21$, df = 1, $p < 0.001$). Malaria prevalence also varied significantly across age groups ($\chi^2 = 25.53$, df = 5, $p < 0.001$). Based on the actual numbers examined and infected, the highest prevalence occurred among individuals aged 21–30 years (118/363; 32.51%), followed by 31–40 years (101/363; 27.82%), 41–50 years (73/367; 19.89%), >51 years (54/161; 33.54%), 11–20 years (56/260; 21.54%), and 0–10 years (16/86; 18.60%).

Table 3: Pre and intervention results of malaria prevalence

Following intervention, 70 infections were recorded among 735 individuals examined (9.52%), compared with the pre-intervention total of 418/1,600 (26.12%). The intervention groups showed lower infection levels than the control group. Among the intervention groups, infection prevalence based on the reported counts was approximately 4.59% for ITN, 5.71% for drug intervention, 7.14% for IRS, and 17.14% for the control group. The findings revealed a **significant difference among the groups** ($\chi^2 = 25.41$, df = 3, $p < 0.001$), indicating that malaria prevalence was associated with the intervention strategy.

Table 4: Malaria Prevalence and Uptake of Preventive Interventions by Age and Gender

The age- and sex-stratified results showed that malaria infection remained concentrated in the older age categories, particularly the 21–30-year and 31–40-year groups. Malaria prevalence was lowest among participants under the ITN intervention (4.59%), followed by those receiving drug intervention (5.71%) and

IRS (7.14%), whereas the control group recorded the highest malaria prevalence (17.14%). Thus, malaria infection was significantly different across the intervention groups, with the control group showing substantially greater malaria prevalence ($\chi^2 = 25.409$, df = 3, $p < 0.001$).

Table 5: Pre and intervention combination results of malaria prevalence

The combination of interventions further reduced malaria prevalence. The intervention phase recorded 34 infections among 735 individuals (4.62%), compared with 45/735 (6.25%) in the corresponding earlier/pre-intervention results. The individual combined-intervention groups recorded 5/196 (2.55%) for ITN + sanitation, 3/140 (2.14%) for drug + education, 6/154 (3.89%) for IRS + ITN, and 20/245 (8.16%) in the control group when calculated directly from the counts. The association between intervention category and infection status revealed a **significant difference** ($\chi^2 = 11.00$, df = 3, $p = 0.012$).

Table 6: Malaria Prevalence in Relation to Age, Gender, and Combined Control Interventions

The age- and sex-specific results demonstrated a marked reduction in malaria infections among participants receiving combined interventions. Infection was particularly concentrated among males aged 21–30 years, where the control group recorded 5 infections, compared with 2 in the ITN + sanitation group, 1 in the drug + education group, and 2 in the IRS + ITN group. Similar reductions were observed across several other age categories. The analysis showed a statistically significant association between malaria infection and intervention category **($\chi^2 = 11.004$, df = 4, $p = 0.027$).** The p-value was below the 0.05 significance threshold; therefore, the null hypothesis of no association was rejected. This finding demonstrates a statistically significant difference in malaria infection status among the intervention groups.

Table 1 Prevalence of Malaria Parasitaemia in the Study Area

LGA	Communities	No examined	No (%) Infected
Obowo	Avutu	200	60(14.35)
	Umuariam	200	75(17.94)
	Ehume	200	100(23.92)
	Amuzi	200	56(13.39)
	Sub total	**800**	**291(69.61)**
Owerri-North	Orji	200	61(14.59)
	Akwakuma	200	19(4.54)
	Amakohia	200	23(5.50)
	Works layout	200	24(5.74)
	Sub total	**800**	**127(30.38)**
	Total	**1,600**	**418(26.12)**

($\chi^2 = 87.10$, df = 1, $p < 0.001$).

Figure 2: Prevalence of Malaria in the Study communities

Table 2: Distribution of Malaria Prevalence by Age and Gender

Age	Males		Females		Both gender	
(years)	No examined	No (%) Infected	No examined	No (%) Infected	No examined	No (%) Infected
0-10	38	10(1.44)	48	06(0.65)	86	16(1.0)
11-20	121	36(5.21)	139	20(2.19)	260	56(3.50)
21-30	149	66(9.56)	214	52(5.71)	363	118(7.35)
31-40	166	59(8.55)	197	42(4.61)	363	101(6.31)
41-50	147	43(6.23)	220	30(3.29)	367	73(4.56)
>51	67	36(5.21)	92	18(1.97)	161	54(3.37)
Total	**690**	**250(15.62)**	**910**	**168(10.5)**	**1,600**	**418(26.12)**

Gender ($\chi^2 = 64.21$, df = 1, $p < 0.001$) **Age ($\chi^2 = 25.53$, df = 5, $p < 0.001$).**

Table 3: Pre and intervention results of malaria prevalence

Groups	Communities/ Status	No Examined	No (%) infected	Malaria intervention coverage (%)						Control	
				ITN		Drug		IRS			
				No Examined	No (%) infected	No Examined	No (%) infected	No Examined	No (%) infected	No Examined	No (%) infected
1	Avutu (Rural) +	200	60(14.35)	-	-	-	-	-	-	-	-
	Orji (Urban) +	200	61(14.59)	-	-	-	-	-	-	-	-
2	Umuariam (Rural) +	200	75(17.94)	-	-	-	-	-	-	-	-
	Akwakuma (Urban) +	200	19(4.54)	-	-	-	-	-	-	-	-
3	Ehume (Rural) +	200	100(23.92)	-	-	-	-	-	-	-	-
	Amakohia (Urban) +	200	23(5.50)	-	-	-	-	-	-	-	-
4	Amuzi (Rural) +	200	56(13.39)	-	-	-	-	-	-	-	-
	Workslayout (Urban) +	200	24(5.74)	-	-	-	-	-	-	-	-
	Total	**1,600**	**418(26.12)**	-	-	-	-	-	-	-	-
1	Avutu (Rural) *	113	05(0.68)	113	5(2.55)	-	-	-	-	-	-
	Orji (Urban) *	83	04(0.54)	83	4(2.04)	-	-	-	-	-	-
2	Umuariam (Rural) *	83	05(0.68)	-	-	83	5(3.57)	-	-	-	-
	Akwakuma (Urban) *	57	03(0.40)	-	-	57	3(2.14)	-	-	-	-
3	Ehume (Rural) *	93	07(0.95)	-	-	-	-	93	7(4.54)	-	-
	Amakohia (Urban) *	61	04(0.54)	-	-	-	-	61	4(2.59)	-	-
4	Amuzi (Rural) *	138	27(3.67)	-	-	-	-	-	-	138	27(11.02)
	Workslayout (Urban) *	107	15(2.04)	-	-	-	-	-	-	107	15(6.12)
	Total	**735**	**70(9.52)**	**196**	**9(4.59)**	**140**	**8(5.71)**	**154**	**11(7.14)**	**245**	**42(17.14)**

Key:

+ = Pre results

*** = Intervention results**

ITN =Insecticide Treated Net

IRS =Indoor Residual Spray

($\chi^2 = 25.41$, df = 3, $p < 0.001$)

Table 4: Malaria Prevalence and Uptake of Preventive Interventions by Age and Gender

Age (years)	Gender	No Examined	No (%) infected	Malaria intervention coverage (%)							
				ITN		Drug		IRS		Control	
				No examined	No (%) infected	No examined	No (%) infected	No examined	No (%) infected	No examined	No (%) infected
0-10	M	29	02(2.85)	08	0(0.00)	06	01(1.42)	04	0(0.00)	11	01(1.42)
	F	51	02(2.85)	13	0(0.00)	12	0(0.00)	05	0(0.00)	21	02(2.85)
11-20	M	45	06(8.75)	15	01(1.42)	05	0(0.00)	07	01(1.42)	18	04(5.71)
	F	49	05(7.14)	19	01(1.42)	10	01(1.42)	11	0(0.00)	09	03(4.28)
21-30	M	72	12(17.14)	19	02(2.85)	14	01(1.42)	17	02(2.85)	22	07(10.00)
	F	90	08(11.42)	21	01(1.42)	15	02(2.85)	27	01(1.42)	27	04(5.71)
31-40	M	72	11(15.71)	07	02(2.85)	16	0(0.00)	15	03(4.28)	24	06(8.57)
	F	84	06(8.57)	22	0(0.00)	12	01(1.42)	20	01(1.42)	30	04(5.71)
41-50	M	48	07(10.00)	13	01(1.42)	08	01(1.42)	13	01(1.42)	14	04(5.71)
	F	80	04(5.71)	17	0(0.00)	18	0(0.00)	16	01(1.42)	29	03(4.28)
>51	M	43	05(7.14)	14	01(1.42)	08	01(1.42)	08	0(0.00)	13	03(4.28)
	F	72	02(2.85)	18	0(0.00)	16	0(0.00)	11	01(9.09)	27	01(1.42)
Total		**735**	**70(9.52)**	**196**	**09(12.85)**	**140**	**08(11.42)**	**154**	**11(15.71)**	**245**	**42(60.00)**

($\chi^2 = 25.409$, df = 3, $p < 0.001$).

Table 5: Pre and intervention combination results of malaria prevalence

Groups	Communities/status	No Examined	No (%) infected	Malaria intervention coverage (%)						Control	
				ITN + Sanitation		Drug + Education		IRS + ITN			
				No Examined	No (%) infected	No Examined	No (%) infected	No Examined	No (%) infected	No Examined	No (%) infect
1	Avutu (Rural) *	113	3(0.40)	113	3(1.53)	-	-	-	-	-	-
	Orji (Urban) *	83	3(0.40)	83	3(1.53)	-	-	-	-	-	-
2	Umuariam (Rural) *	83	3(0.40)	-	-	83	3(2.14)	-	-	-	-
	Akwakuma (Urban) *	57	2(0.27)	-	-	57	2(1.42)	-	-	-	-
3	Ehume (Rural) *	93	4(0.68)	-	-	-	-	93	4(3.24)	-	-
	Amakohia (Urban) *	61	3(0.40)	-	-	-	-	61	3(1.94)	-	-
4	Amuzi (Rural) *	138	17(2.31)	-	-	-	-	-	-	138	17(6.9
	Workslayout (Urban) *	107	10(1.36)	-	-	-	-	-	-	107	10(4.0
	Total	**735**	**45(6.25)**	**196**	**6(3.06)**	**140**	**5(3.57)**	**154**	**8(5.19)**	**245**	**27(11**
1	Avutu (Rural) +	113	3(0.40)	113	3(1.53)	-	-	-	-	-	-
	Orji (Urban) +	83	2(0.27)	83	2(1.02)	-	-	-	-	-	-
2	Umuariam (Rural) +	83	2(0.27)	-	-	83	2(1.42)	-	-	-	-
	Akwakuma (Urban) +	57	1(0.13)	-	-	57	1(0.71)	-	-	-	-
3	Ehume (Rural) +	93	4(0.54)	-	-	-	-	93	4(2.59)	-	-
	Amakohia (Urban) +	61	2(0.27)	-	-	-	-	61	2(1.29)	-	-
4	Amuzi (Rural) +	138	12(1.62)	-	-	-	-	-	-	138	12(4.8
	Workslayout (Urban) +	107	8(1.08)	-	-	-	-	-	-	107	8(3.26
	Total	**735**	**34(4.62)**	**196**	**5(2.55)**	**140**	**3(2.14)**	**154**	**6(3.89)**	**245**	**20(7.8**

Key:

***** **= Pre results**

+ **= Intervention results**

ITN **=Insecticide Treated Net**

IRS **=Indoor Residual Spray**

($\chi^2 = 11.00$, df = 3, p = 0.012).

Table 6: Malaria Prevalence in Relation to Age, Gender, and Combined Control Interventions

Age (years)	Gender	No Examined	No (%) Infected	Malaria intervention coverage (%)							
				ITN + Sanitation		Drug + Education		IRS + ITN		Control	
				No examined	No (%) infected	No examined	No (%) infected	No examined	No (%) infected	No examined	No (%) infected
0-10	M	29	01(2.91)	08	0(0.00)	06	0(0.00)	04	0(0.00)	11	01(2.94)
	F	51	0(0.00)	13	0(0.00)	12	0(0.00)	05	0(0.00)	21	0(0.00)
11-20	M	45	02(5.88)	15	0(0.00)	05	0(0.00)	07	0(0.00)	18	02(5.88)
	F	49	02(5.88)	19	0(0.00)	10	0(0.00)	11	01(2.94)	09	01(2.94)
21-30	M	72	10(29.41)	19	02(5.88)	14	01(2.94)	17	02(5.88)	22	05(14.70)
	F	90	03(8.82)	21	01(2.94)	15	0(0.00)	27	0(0.00)	27	02(5.88)
31-40	M	72	05(14.70)	07	01(2.94)	16	01(2.94)	15	0(0.00)	24	03(8.82)
	F	84	03(8.82)	22	0(0.00)	12	01(2.94)	20	01(2.94)	30	01(2.94)
41-50	M	48	04(11.76)	13	01(2.94)	08	0(0.00)	13	01(2.94)	14	02(5.88)
	F	80	01(2.91)	17	0(0.00)	18	0(0.00)	16	0(0.00)	29	01(2.94)
>51	M	43	02(5.88)	14	0(0.00)	08	0(0.00)	08	01(2.94)	13	01(2.94)
	F	72	01(2.91)	18	0(0.00)	16	0(0.00)	11	0(0.00)	27	01(2.94)
Total		**735**	**34(4.62)**	**196**	**05(14.70)**	**140**	**03(8.82)**	**154**	**06(17.64)**	**245**	**20(58.82)**

($\chi^2 = 11.004$, df = 4, p = 0.027).

Discussion

The present study assessed malaria prevalence and examined the effectiveness of selected malaria control interventions, including insecticide-treated nets (ITNs), antimalarial drug treatment, indoor residual spraying (IRS), sanitation and combinations of these interventions in rural and urban communities of southeastern Nigeria. The findings demonstrate a substantial malaria burden in the study population, but also indicate considerable reductions in malaria prevalence following the implementation of individual and combined interventions. These findings are important in the context of Nigeria, which continues to carry one of the largest malaria burdens globally. The World Health Organization reported that Nigeria accounted for approximately 25.9% of malaria cases in the WHO African Region in 2023, while the country remains a major contributor to malaria-related mortality globally (8). More recent national evidence continues to emphasize the need for sustained and locally tailored malaria prevention and control strategies.

Prevalence of Malaria Parasitaemia in the Study Area

The overall prevalence of malaria in the present study was 26.12%, with 418 positive cases among 1,600 individuals examined. The burden was markedly higher in the rural communities of Obowo LGA, which accounted for 69.61% of all positive cases, compared with 30.38% recorded in the urban communities of Owerri-North LGA. Among the individual communities, Ehume recorded the highest prevalence contribution (23.92%), followed by Umuariam (17.94%), Orji (14.59%), Avutu (14.35%) and Amuzi (13.39%). Conversely, Akwakuma recorded the lowest contribution at 4.54%. These findings suggest important geographical heterogeneity in malaria transmission within the study area. The higher malaria burden observed in the rural communities may be related to differences in housing conditions, environmental management, access to health services, mosquito breeding habitats and uptake of malaria prevention measures. Rural communities may have greater exposure to mosquito breeding sites and less access to prompt diagnosis and treatment. This interpretation is consistent with Nigeria's malaria control experience, where transmission varies substantially according to ecological, socioeconomic and intervention-related factors. The national malaria profile emphasizes that malaria transmission occurs throughout Nigeria, although its intensity varies geographically and is strongly influenced by environmental and climatic conditions (8, 10). The finding is also consistent with recent Nigerian evidence showing that access to and use of malaria prevention interventions remain uneven. A 2025 analysis of the Nigerian Malaria Indicator Survey found substantial variation in ITN ownership and utilization across population groups and geographic areas (32). Similarly, Barrow et al. (33) reported that ITN use among women of reproductive age in Nigeria remained suboptimal, with an estimated weighted prevalence of 41.5%. These findings reinforce the importance of considering the local context when interpreting malaria prevalence and intervention effectiveness. The persistence of a relatively high prevalence in the present study despite the availability of malaria interventions is not unexpected. Nigeria remains a high-transmission country, and the WHO 2025 Nigeria country profile continues to identify malaria as a major public health problem (34). Consequently, malaria control programmes need to combine vector control, early diagnosis, effective treatment, environmental management and behavioural interventions rather than relying on a single control measure.

Distribution of Malaria Prevalence by Age and Gender

The age- and sex-specific findings showed that malaria occurred across all age groups, although the highest number of infections was observed among individuals aged 21–30 years, with 118 infections (7.35%), followed by those aged 31–40 years, with 101 infections (6.31%). Individuals aged 41–50 years recorded 73 infections (4.56%), while those aged 11–20 years and those older than 51 years recorded 56 (3.50%) and 54 (3.37%) infections, respectively. The

lowest prevalence was observed among children aged 0–10 years, with 16 infections (1.0%). Males generally recorded a higher proportion of malaria infections than females, with 250 infections (15.62%) compared with 168 infections (10.50%) among females. The relatively greater burden among males may reflect differences in exposure to mosquito bites resulting from occupational, recreational or behavioural activities. Men may spend more time outdoors during evening and night-time periods when malaria vectors are actively seeking blood meals. However, sex differences in malaria prevalence are not necessarily consistent across Nigerian populations because malaria risk is also influenced by age, immunity, occupation, housing characteristics, socioeconomic conditions and intervention use. The concentration of infections among young and middle-aged adults in this study is noteworthy because malaria control programmes frequently emphasize young children and pregnant women as particularly vulnerable groups. Although children under five years remain at high risk of severe malaria, transmission and infection can occur in older age groups, particularly in high-transmission settings. Recent Nigerian evidence has also highlighted the importance of asymptomatic and subclinical malaria infections among different age groups. A 2025 systematic review and meta-analysis estimated a pooled prevalence of asymptomatic malaria of approximately 33% in Nigeria, with particularly high prevalence among children, emphasizing the importance of persistent infection reservoirs in malaria transmission (35). The relatively low prevalence among the 0–10-year age group in the present study may therefore reflect differences in exposure or the effect of preventive measures rather than an absence of transmission. It is also possible that younger children were more likely to benefit from household-level protection such as mosquito nets and parental supervision.

Effect of individual malaria interventions

The intervention results demonstrate an important reduction in malaria prevalence following implementation of malaria control measures. Before intervention, the study recorded 418 infections among 1,600 individuals, whereas the intervention phase involved 735 individuals and recorded 70 infections (9.52%). The intervention groups included ITN, drug treatment and IRS, while a control group was also retained. The intervention-specific results showed prevalence of 4.59% among participants receiving ITNs, 5.71% among those receiving drug intervention, 7.14% among those exposed to IRS, and 17.14% in the control group. The substantially lower prevalence among intervention groups compared with the control group suggests that malaria prevention and control measures were beneficial in the study communities. The particularly low prevalence observed in the ITN group supports the continued use of ITNs as a central component of malaria vector control in Nigeria. This finding is supported by recent evidence from Ebonyi State, where distribution of piperonyl-butoxide (PBO) ITNs was associated with a 46.7% reduction in malaria case incidence during the two years following distribution. The same study reported substantial reductions in human biting rates and indoor resting mosquito density after PBO ITNs were introduced (36). The findings also have relevance for the continuing evolution of ITN strategies in Nigeria. Insecticide resistance, particularly resistance to pyrethroids, represents an important threat to conventional ITNs. The Ebonyi State study by Davis et al. (36) demonstrated that newer PBO-containing nets can provide substantial epidemiological and entomological benefits in areas where pyrethroid resistance is present. Therefore, the relatively low prevalence observed among the ITN group in the present study supports continued investment in ITNs while also highlighting the importance of insecticide-resistance surveillance and appropriate selection of net types.

Recent operational studies in Nigeria have further demonstrated that successful ITN distribution depends not only on the availability of nets but also on effective delivery systems. Adeniyi et al. (37) reported lessons from an ITN campaign in Ondo State, emphasizing the importance of digital systems, accountability and adaptive campaign planning. Similarly, experience from Anambra State demonstrated that security and operational conditions can affect the implementation of ITN campaigns (38). These observations suggest that the effectiveness of ITNs in communities such as those investigated in Imo State depends on both biological efficacy and sustained population access and use.

Malaria Prevalence and Uptake of Preventive Interventions by Age and Gender

The age- and sex-specific intervention findings further demonstrate the protective potential of malaria interventions. In the 0–10-year group, malaria infections were absent among participants exposed to ITN and IRS, whereas the control group recorded infections in both males and females. Similarly, among several older age groups, infection prevalence was considerably lower in intervention groups than in the control group. The highest control-group prevalence occurred among males aged 21–30 years, while ITN, drug and IRS groups generally showed markedly lower prevalence.

These findings suggest that interventions can reduce malaria risk across different age categories. The relatively strong reduction among younger participants is particularly relevant because children remain one of the groups most vulnerable to severe malaria. However, the results also demonstrate that malaria prevention should not be restricted to young children. The occurrence of infection among adults in the intervention and control groups indicates continuing transmission and the importance of protecting the entire community. The higher prevalence observed among males in several age categories may reflect behavioural exposure. However, because the present tables do not provide detailed information on occupation, sleeping patterns, outdoor activities or adherence to interventions, the observed sex differences should be interpreted cautiously. Further studies incorporating these behavioural and socioeconomic variables would provide a better explanation of the sex-specific differences.

Effect of combined malaria interventions

The combination-intervention findings provide further evidence that integrated malaria control may produce greater reductions in malaria prevalence than reliance on a single intervention. The study evaluated ITN plus sanitation, drug treatment plus education, and IRS plus ITN. The overall prevalence was 6.25% across the combined-intervention population compared with 11.02% in the control group during the intervention phase. Specifically, prevalence was 3.06% among participants receiving ITN plus sanitation, 3.57% among those receiving drug treatment plus education, and 5.19% among those receiving IRS plus ITN, compared with 11.02% in the control group. The lowest prevalence was observed in the ITN-plus-sanitation group. This finding suggests that reducing mosquito–human contact through ITNs while simultaneously improving the environmental conditions around households may provide complementary protection. Environmental sanitation may reduce mosquito breeding opportunities, although its contribution to malaria reduction depends strongly on the specific breeding ecology and whether breeding sites are effectively targeted. The drug-plus-education intervention also produced a low prevalence. This finding highlights the importance of combining effective case management with health education. Health education can improve knowledge of malaria symptoms, promote early healthcare-seeking behaviour, encourage adherence to prescribed treatment and reinforce preventive practices. In Nigeria,

however, health education alone does not necessarily guarantee sustained use of preventive interventions. A study of rural–urban differences in southeastern Nigeria reported that exposure to behaviour-change communication was high, but its effect on LLIN and ACT use was relatively weak (39). This suggests that health education should be combined with accessible commodities and supportive community-level interventions.

The IRS-plus-ITN group also demonstrated substantially lower prevalence than the control group. This finding is consistent with evidence that combining indoor vector control measures can provide additional protection. Although much of the strongest recent evidence on combined ITN and IRS comes from outside Nigeria, Nigerian modelling and operational evidence supports targeted deployment of vector-control interventions according to local transmission conditions. Nigeria's malaria strategic approach similarly emphasizes targeted interventions based on epidemiological and contextual characteristics (8, 40).

Comparison of intervention and pre-intervention results

The comparison of intervention and pre-intervention results indicates a clear reduction in malaria prevalence across the study communities. Under the combined interventions, the intervention-phase prevalence was 4.62%, compared with 7.87% in the corresponding control/pre-intervention comparison presented in the table. The reductions were observed across all communities, although the magnitude varied between locations. For example, Amuzi showed a reduction from 4.89% to 1.62%, while Workslayout decreased from 3.26% to 1.08%. The variation between communities suggests that intervention effectiveness may be modified by local environmental, socioeconomic and behavioural conditions. The particularly high baseline contribution from some rural communities may reflect greater exposure to mosquito vectors, inadequate environmental management or reduced access to preventive services. Consequently, malaria interventions should be tailored to local transmission patterns rather than applied uniformly without consideration of ecological and social differences. This findings agrees with Nigeria's High Burden to High Impact approach, which promotes the use of subnational data to identify areas requiring intensified malaria interventions. Modelling work undertaken to support Nigeria's National Malaria Strategic Plan demonstrated that intervention impact could be improved by targeting malaria control resources according to local epidemiological and ecological characteristics rather than applying identical intervention packages across all LGAs (41).

Malaria Prevalence in Relation to Age, Gender, and Combined Control Interventions

The results presented in Table 6 show that mixed malaria interventions were associated with low infection levels across most age and sex categories. The overall prevalence was 4.62% among the mixed-intervention population. ITN plus sanitation recorded five infections, drug plus education recorded three infections, and IRS plus ITN recorded six infections, whereas the control group recorded 20 infections. An important observation is that several intervention categories recorded zero infections among particular age-sex groups. For example, no infection was recorded among females aged 0–10 years across the three intervention groups. Likewise, no infection was recorded among several participants aged 11–20 years who received drug plus education or IRS plus ITN. These findings suggest that combined interventions may offer broad protection across demographic groups. However, the very small numbers in some age-sex-intervention cells require cautious interpretation. Zero observed infections do not necessarily indicate complete protection, particularly where the number examined was small. Therefore, these results should be interpreted as evidence of low observed prevalence rather than evidence that the interventions completely eliminated malaria transmission.

Implications for malaria control in Imo State and Nigeria

The findings have important implications for malaria control programmes in Imo State. First, the relatively high baseline prevalence demonstrates the continuing importance of malaria as a public health problem in southeastern Nigeria. Second, the substantially lower prevalence following interventions indicates that malaria control measures can produce meaningful reductions in infection. Third, the better outcomes observed with combined interventions support an integrated malaria-control approach involving vector control, environmental management, health education, early diagnosis and effective treatment. Recent Nigerian evidence strongly supports maintaining and strengthening this integrated approach. In Ebonyi State, enhanced ITNs were associated with substantial reductions in malaria incidence and mosquito exposure (36). Nationally, recent analyses show that ITN ownership and use remain below optimal levels, indicating that simply distributing nets is insufficient without sustained promotion of correct and consistent use (32, 33). Furthermore, Nigeria's current malaria control strategy continues to emphasize data-driven intervention deployment, surveillance and strengthening of implementation systems. IRS should also be considered strategically rather than routinely across all communities. A recent Nigerian modelling study of IRS in Nasarawa State estimated that IRS was associated with approximately a 10% reduction in malaria transmission over two years, but the authors emphasized the importance of spray frequency and robust surveillance data (42). This is relevant to the present findings, where IRS produced a reduction in malaria prevalence but was less effective than ITN or some combination strategies. Differences may be related to intervention coverage, adherence, insecticide susceptibility, housing characteristics and implementation quality.

Nigeria also faces the challenge of insecticide resistance. Recent national surveillance work emphasizes the importance of vector surveillance and insecticide-resistance monitoring for guiding vector-control decisions (43). Therefore, future malaria interventions in Imo State should include routine monitoring of mosquito vector composition and insecticide susceptibility, particularly where ITNs and IRS are used extensively.

Conclusion

Overall, the findings demonstrate that malaria remains prevalent in the study communities but that targeted malaria interventions were associated with substantial reductions in observed malaria prevalence. The baseline prevalence of 26.12% indicates considerable transmission, particularly in the rural communities. The intervention findings, however, show much lower prevalence among individuals exposed to ITNs, antimalarial treatment, IRS and combinations of these interventions. The strongest results were observed where interventions were combined, particularly ITN with sanitation and drug treatment with education. These findings are consistent with the current direction of malaria control in Nigeria, which emphasizes integrated, data-driven and

context-specific interventions. Nigeria remains responsible for a disproportionately large share of the global malaria burden, making evidence from subnational studies particularly important for improving programme implementation (8, 34). The present findings therefore support continued investment in ITN distribution and utilization, appropriate case management, targeted IRS, environmental sanitation, health education and strengthened surveillance.

Declarations

Ethical Considerations

Ethical approval for the study was obtained from Imo State University Ethical Committee on Neglected Tropical Diseases (IMSU/ETH/ONCHO/NTDs/1.2020) and the Imo State Ministry of Health (MH/PS/16/11/T.I/60). Permission to conduct the study was also obtained from the respective community leaders. The purpose and procedures of the study were explained to prospective participants before enrolment. Written informed consent was obtained from adult participants, while appropriate consent was obtained for

parents or guardians of minorsin accordance with the study requirements.

Consent for publication

Not applicable

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation

Competing Interest

The authors declare no competing interest

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Authors' contribution

Conceptualization: JII and VOI. Funding acquisition and project administration: OGJ and JCO. Sample Collection: JII, VOI, OGJ, JCO, OPU and CCA. Sample processing and data generation: JII, VOI, OGJ, JCO, OPU and CCA. Data curation: VOI, OPU, OGJ, CCA. Formal analysis and data validation: JII, VOI, OGJ and CCA. Data visualization: OGJ and CCA. Resources: OPU and CCA. Supervision: JII, VOI, JCO and OGJ. Writing original draft and editing: JII and VOI. Writing review, and editing: JII VOI, OGJ, JCO, OPU and CCA. All authors reviewed and approved the final manuscript.

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Figures

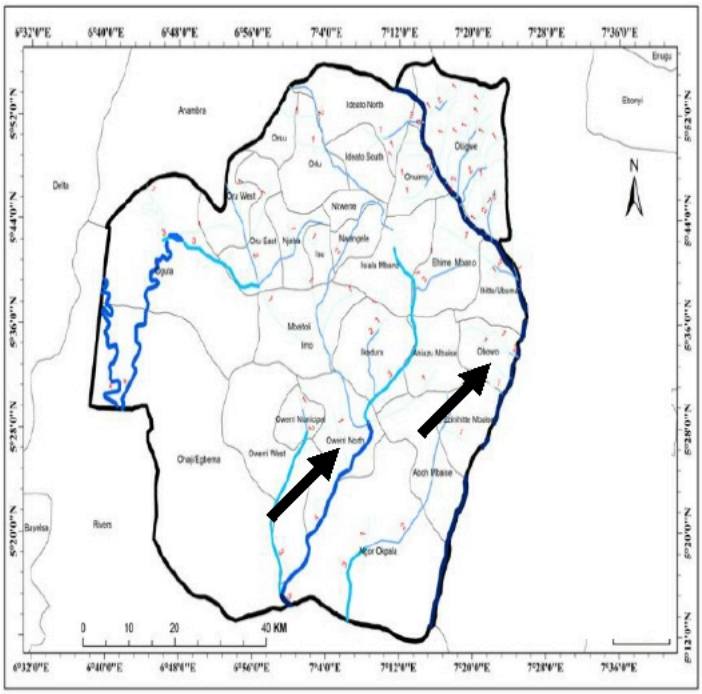


Figure 1

Map of Imo State showing the study local Government Area

Source: (29)

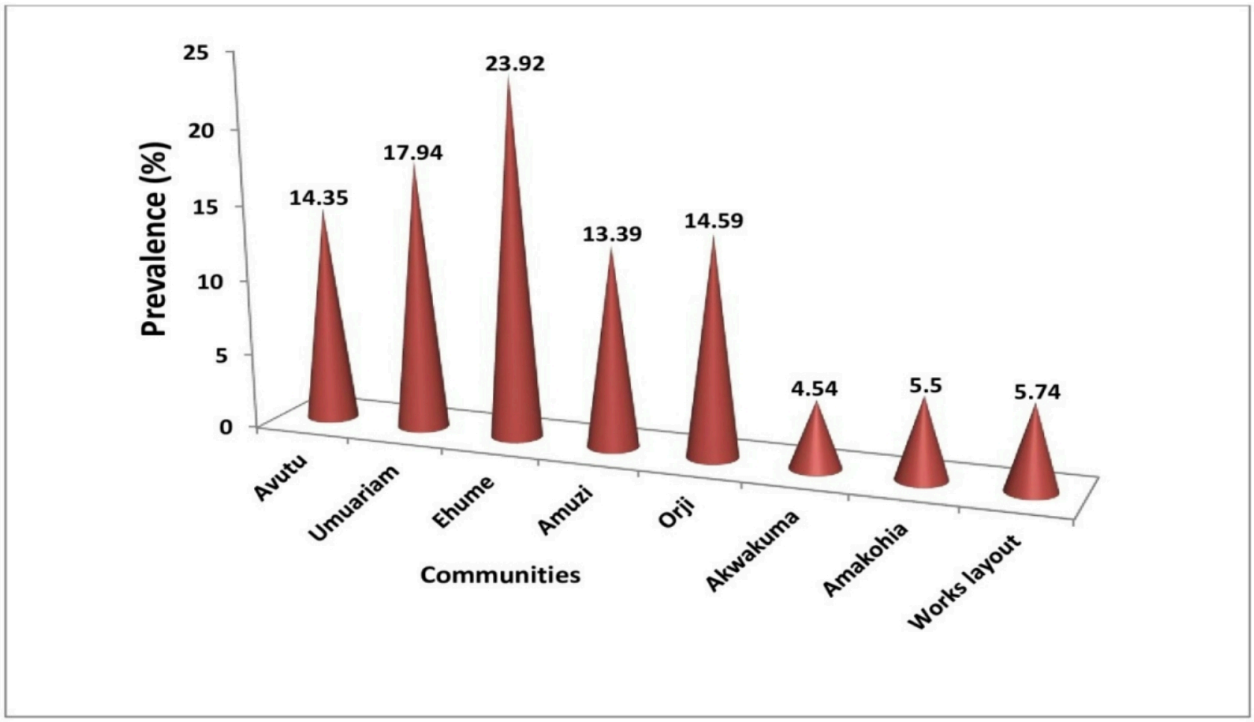


Figure 2

Prevalence of Malaria in the Study communities