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Epidemiological Implications of Malaria-Associated Risk Factors and the Effectiveness of Single and Combined Intervention Strategies Among Stratified Populations Living in Selected Communities in Imo State, Nigeria

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Abstract

This study investigated the epidemiological implications of malaria-associated risk factors and evaluates the effectiveness of single and combined intervention strategies among stratified populations living in Obowo and Owerri-West Local Government Areas of Imo State, Nigeria. The study involved parasitological and socio-demographic approaches to ascertain the prevalence of malaria, and associated risk factors in the study area. Data were collected using structured questionnaire and blood sample collection. The total malaria prevalence in the study areas was 34%. Rural area (Obowo) had a higher malaria prevalence rate of 40.17% than urban area (Owerri-West) 27.83% and was most prevalence in the age group 31-40 years (56.1%). The higher prevalence was reported in males (44.20%) compared to females (21.20%). There was a significant difference in the prevalence of the infection based on the socio-demographic characteristics of the respondents (P-value 0.001); married had a higher prevalence rate of 48.53%, farmers recorded the highest prevalence of 45.10%. Among the single interventions, Insecticide Treated Net (ITN) usage had the lowest prevalence (12.19%). Among the combined interventions, ITN plus Environmental Sanitation users recorded the lowest prevalence of 8.13%. Integrating multiple malaria control approaches may provide synergistic effects in reducing malaria transmission thereby ensuring a malaria-free society.

Key Words: Malaria, epidemiological implications, risk factors, intervention measures, stratified population.

INTRODUCTION

Malaria remains one of the most important vector-borne infectious diseases and a major public health challenge globally, particularly in sub-Saharan Africa, with hundreds of millions of cases annually and a disproportionate burden among children under five years of age [1-3]. The five Plasmodium species that cause malaria are *Plasmodium falciparum (P. falciparum), Plasmodium vivax (P. vivax), Plasmodium ovale, Plasmodium malariae,* and *Plasmodium knowlesi.* Among these species, *P. falciparum* is the most lethal pathogen and is found mostly in sub-Saharan Africa (SSA) [4,5]. This acute febrile illness caused by *plasmodium* is transmitted through the bite of an infected female Anopheles mosquito [6]. It is responsible for the majority of malaria-related morbidity and mortality worldwide, particularly in sub-Saharan Africa. The common symptoms of malaria are fever, chills, headache, fatigue, confusion, seizures, and difficulty breathing [7,8]

P. falciparum is the deadliest and most prevalent malaria parasite on the African continent, and *P. vivax* is the dominant parasite in most countries outside of sub-Saharan Africa. Infection with *P. falciparum* is associated with a high burden of cytokines released by the body which in addition to high parasitemia resulting in end-organ failures [3]. Malaria impedes human development and imposes serious social and economic consequences on endemic countries. In Nigeria, the disease causes substantial productivity losses through absenteeism from work, school, and farming activities, with annual economic losses estimated at about ₦132 billion due to treatment costs and loss of man-hours [9].

Globally in 2022, there were an estimated 249 million malaria cases in 85 malaria endemic countries, which increased malaria cases to 5 million with Nigeria accounting over 1.3 million. Also in African Region, four countries accounted for just over half of all malaria deaths globally in 2022, Nigeria having 27%, the Democratic Republic of the Congo (12%), Uganda (5%) and Mozambique (4%) [3]. Nigeria bears the highest malaria burden worldwide and contributes a substantial proportion of global malaria cases and deaths. In West Africa, Nigeria accounted for 55% of malaria cases. Then Imo State contributed an estimated 2.6% of Nigeria's 55% malaria cases in 2021 [10].

Although considerable investments have been made in malaria prevention and control, transmission remains persistent in many communities due to environmental, socioeconomic,

demographic, and behavioral factors that sustain human-vector contact and facilitate disease spread. Recent evidence indicates that sustained malaria control requires integrated approaches that combine vector control, effective case management, surveillance, and community participation to achieve long-term reductions in transmission [11]. It is important to determine the relative contribution of these factors to the transmission of *plasmodium falciparum* and the effectiveness of single and combined intervention strategies.

Environmental conditions significantly affect the breeding, survival, and feeding behavior of *Anopheles* mosquitoes, the vectors responsible for malaria transmission. Climatic factors such as temperature, humidity, and rainfall which may support rapid growth and development of mosquito vectors have been well reported in urban and peri-urban centers [12, 13]. Recent studies have demonstrated significant associations between meteorological variables and malaria incidence in Nigeria, highlighting the importance of environmental conditions in shaping transmission dynamics [14]. The availability of breeding sites is highly seasonal. Peak breeding and vector density occur during and shortly after the rainy season (May to October), when water bodies are abundant and temperatures are favorable for mosquito development [15]. In a study conducted by Oguntade *et al*, the results showed that more malaria incidence occurred in the months with the highest rainfall recorded (June–August) [16]. Rainy seasons increase the number of mosquito breeding sites, while warm temperatures accelerate the development of both the mosquito and the Plasmodium parasite. Higher prevalence of malaria is always found among respondents whose houses were surrounded by bushes and stagnant water [13, 17]. The bushes and stagnant water have been found in some studies done in Nigeria to be reservoirs of breeding grounds for mosquitoes, thereby enhancing human–vector contact. [18]. Urbanization can also contribute to vector proliferation through artificial water-holding containers and blocked drainage systems [19].

Malaria is not just a disease of biology, it is a disease of poverty, inequality and access where healthcare is weakest, where resources are scares and lives most vulnerable. In Nigeria, socio-demographic and economic factors play key roles in the uptake of malaria prevention and control measures. These vary by region, place of residence, education and other maternal

demographic characteristics [20]. Several studies in Nigeria have showed that malaria is more common among people of lower socio-economic status [21, 17, 22]. In rural areas of Imo State, many households are constructed with mud or wooden walls and lack basic protective barriers. Houses with open eaves, unscreened windows, or no ceilings allow easy entry for mosquitoes. Limited or delayed access to effective diagnosis and treatment increases malaria severity and community-level transmission [23].

Education is an established social determinant of health and has been linked to improved knowledge, attitudes, and practices related to malaria prevention [24]. Higher educational attainment can enhance health literacy and empower individuals to adopt preventive behaviours. Nonetheless, disparities between awareness and actual use of malaria prevention methods have been reported [25]. suggesting that education alone may be insufficient to ensure protective practices. Exploring the nuanced relationship between education and malaria prevention behaviours in rural populations remains a priority. Without education, even the best medical interventions often fail to reach their full potential. Malaria health education interventions have shown some potential in improving malaria-related knowledge and ITN usage through multiple tailored curriculums and delivery methods [26, 27].

Human behavior significantly influences exposure to mosquito bites and uptake of preventive measures. Such behaviours include; improper or inconsistent use of ITNs, outdoor sleeping and late-night activities, and traditional beliefs and health-seeking behavior. Even where ITNs are available, improper use (e.g., using them for fishing or farming) or non-use due to heat or misconceptions reduces their effectiveness [28]. According to the 2021 Nigeria Malaria Indicator Survey, ITN ownership was 60%, but usage was only 40% among vulnerable groups. People engaged in outdoor activities (e.g., farming, fishing, social gatherings) during peak mosquito biting hours (dusk to dawn) are at higher risk [29]. This is common in both rural and urban communities where electricity supply is poor. Cultural beliefs and reliance on herbal remedies may delay treatment seeking or lead to the abandonment of scientifically proven control measures. In some communities, malaria is still attributed to spiritual causes or “bad air” [30].

Environmental sanitation practices could help mitigate malaria transmission, promote healthiness and improve quality of life of the populace. From a triad perspective of malaria transmission which includes the agent, host and environment, researchers and scholars have encouraged the source reduction, elimination and eradication of mosquitoes breeding sites by concentrating on the environment.

Emerging evidence suggests that combining multiple interventions may provide greater protection against malaria than single interventions alone. Integrated malaria control approaches simultaneously target different stages of the parasite life cycle and mosquito vector ecology, thereby enhancing overall effectiveness. Therefore, the current fight against malaria involves prevention strategies including vector control with the use of insecticides, preventive therapy with antimalarial drugs, and case management based on current artemisinin combination therapies (ACTs)**.** In the last decades, many policies and interventions have been implemented to control malaria at the global and regional levels, which have resulted in a significant reduction in malaria-related morbidity and mortality [1]. Recent Nigerian studies have emphasized the importance of integrated vector management, improved surveillance systems, and combined intervention strategies to address challenges such as insecticide resistance, behavioral adaptation of vectors, and heterogeneous transmission patterns [31].

Long Lasting Insecticide Nets (LLINs) are bed nets treated with insecticides, mainly pyrethroids, designed to prevent mosquitoes from biting people indoors and reduce the mosquito population. Insecticide-treated nets are one of the primary interventions for malaria prevention and control with mass distribution campaigns significantly increasing access across endemic regions [32]. However, evidence from various settings suggests that ownership of ITNs does not necessarily translate into consistent use, highlighting the connection between behavioural, socioeconomic, and contextual factors in influencing preventive practices [33]. Studies have shown that the use of LLIN is an effective tool in preventing malaria transmission, and has been implemented as one of the main vector control interventions in malaria endemic countries [34, 28]. Human behavior significantly influences exposure to mosquito bites and uptake of preventive measures. Such behaviours include; improper or inconsistent use of ITNs; outdoor activities**.** The

World Health Organization (WHO) amongst other studies encourages the continued use of LLINs for malaria prevention. It recommends that all sleeping units should be covered by LLINs, and the entire population living in endemic areas should sleep under LLINs every night [35, 36]. Indoor Residual Spraying (IRS) is a malaria prevention method that targets indoor resting mosquitoes. IRS involves coating interior walls and other sprayable surfaces in a house with a residual (long-lasting) insecticide. IRS takes advantage of the indoor resting behavior of many malaria mosquitoes that rest on these surfaces inside houses after taking a blood meal.

Imo State remains endemic for malaria despite ongoing control programs. The state comprises communities with diverse ecological, socioeconomic, and demographic characteristics that may influence malaria transmission differently. Obowo Local Government Area is predominantly rural, characterized by farming activities, extensive vegetation, and environmental conditions that may favor mosquito breeding. Conversely, Owerri-West Local Government Area exhibits semi-urban and urban features, with differing environmental and socioeconomic conditions that may influence exposure patterns and intervention uptake. Understanding how malaria-associated risk factors vary across these stratified populations and how different intervention strategies perform under varying ecological and demographic conditions is essential for designing targeted and cost-effective control programs.

Although numerous studies have assessed malaria prevalence and intervention coverage in Nigeria, these studies have focused largely on under-five children and pregnant women, often within healthcare institutions. Most previous research on the general population involved institutional settings, with community-based studies remaining scarce and limited information on the epidemiological implications of malaria-associated risk factors and the comparative effectiveness of single versus combined intervention strategies among stratified populations in Imo State. Despite substantial national efforts to eliminate malaria in Nigeria, critical data gaps persist, particularly at the community level among both children and adults. This study was driven by a commitment to support the country's malaria elimination strategy by generating evidence from populations that are in rural and urban settings. The study will provide vital local data, fill knowledge gaps, and inform targeted interventions specific to Obowo and Owerri-west L.G.As.

These findings can contribute to evidence-based decision-making in malaria control at the local and regional levels. Furthermore, this study will serve as a baseline for future research on malaria in the region and contribute to ongoing efforts to combat this disease. Therefore, this study aimed to investigate the epidemiological implications of malaria-associated risk factors and evaluate the effectiveness of single and combined intervention strategies among stratified populations living in Obowo and Owerri-West Local Government Areas of Imo State, Nigeria.

MATERIALS AND METHODS

Study Areas

The study area comprised ten communities in two different Local Government Areas in Imo State. Imo State is one of the five states that make up Nigeria's South-East geopolitical zone with 27 Local Government Area. It shares borders with Rivers State to the South, Abia State to the East and Northeast, and Anambra State to the West and Northwest. The state capital is Owerri. Imo State covers an area of 5,542 square kilometers. It lies at latitude 5°29' North and longitude 7°2' East. It has a population of 3,927,563 [37] Recent projections estimate the population at approximately 5,459,300 as of 2022 [38]and a population density of 708. The state accounts for 2.8% of Nigeria's total population. Obowo LGA has a population of 163,200 and Owerri West a population density of 141,400. The people in the study area engage in various occupations such as farming, trading and civil servants. The State experiences two distinct seasons; the dry season (November to March) and the rainy season (April to October) with annual rainfall averaging around 2,095 millimeters per year [39, 40]. The climate is classified as tropical with an average temperature of above 68^{o}F and humidity of 75%. The State contributed an estimated 2.6% of Nigeria's 68 million malaria cases in 2021 [10].

Study Design and Population

A cross-sectional study was conducted to ascertain associated risk factors for malaria infection and the effectiveness of single and combined intervention strategies among rural and urban populations. Households were selected through a simple random sampling procedure within each

of the ten communities in both local government areas. The study was made up of male and female from 1-60 years. Only inhabitants who consented to the study were included

Ethical Approval and Informed Consent

Advocacy visits were made to the communities to seek the consent and approval of the various authorities to conduct the study. Due to the invasive protocol in the study, Ethical approval for the study was gotten from the College of Natural Sciences Ethical Committee, Michael Okpara University of Agriculture, Umudike (CREC/007/24) and also from Imo State Ministry of Health (MH/CON/S.585/I). Informed consent was signed and obtained from the traditional rulers of the selected communities and respondents. The methods and objectives of the study were explained clearly to the respondents individually while their consent was sought. Participation in this study was voluntary. Confidentiality and privacy were ensured throughout the study.

Risk Factor Data Collection

Self-structured questionnaire was administered to the participants. The structured questionnaires were used to obtain information on the Knowledge, Attitude and Practices (KAPs) of the participants about malaria. Social and economic risk factors for malaria were recorded, such as (age, gender, education, occupation, marital status, and preference of other malaria preventive measures. The questionnaires were explained in Igbo language, the local dialect for those who could not understand English. The questionnaire was administered to only the participants who presented themselves for blood sample collection for malaria test. Several town hall meetings were carried out where the contents of the document were explained to the participants to strengthen their responses to the questionnaires.

Blood Sample Collection and Processing

Blood samples were collected from the consenting participants by venipuncture by the help of a registered nurse. The malaria diagnoses were conducted with two different techniques namely microscopy and the use of malaria Rapid Diagnostic Test (RDTs) kits. Three different brands of malaria test kits (First Response Malaria Antigen *P.falciparum*, Paracheck and CareStart STANDARD Q) were used for Rapid Diagnostic Test. Venous blood were collected from each

participant who consented to participate in the study, using a sterile syringe into sterile EDTA (Ethylene Diamine Tetra Acetic Acid). Blood smears (Thick and thin) were made upon blood collection. Hand pricking with sterile lancet was used to collect blood for malaria Rapid Diagnostic Tests.

Blood Smear Microscopy

Thick and thin blood smears were prepared and interpreted using a modified method described by WHO guidelines for the preparation, staining, and reading of malaria blood slide [41]. Steps to prepare a thick smear, 6 µl of blood was spread in a diameter of 12mm of a clean grease-free microscopic slide, while 2 µl of blood was used for a thin smear on a different slide. These slides were prepared and stained with 10% Giemsa stain following WHO 2022 guidelines. The stained slides were examined microscopically under oil immersion (100X) objective lens independently by laboratory technologists.

Antigen-Based Malaria Rapid Diagnostic Tests

Each of the blood samples was tested for the detection of malaria parasite antigen using each of the three brands of Rapid Diagnostic test kits selected for the study (First Response Malaria Antigen *P.falciparum*, Paracheck and CareStart STANDARD Q). These tests were done same day of sample collection and according to the manufacturers' guidelines and procedures.

Distribution of Intervention Measures

The intervention measure in this study was to compare their effect on the prevalence of malaria in the study area. The seven hundred and ninety-two (792) study participants who tested negative after the first phase of malaria test were divided into four groups, with one group serving as the control. These participants were subjected to different intervention measures. 300 (Three hundred) participants were subjected to single intervention measures, 300 participants also subjected to mixed intervention measures and 192 were used as control group.

The intervention measures distributed includes; Insecticide Treated Nets, Anti-malaria drugs and Indoor Residual Spray. Other measures include Environmental Sanitation and Health Education.

Data Analysis

Statistical Package for Social Sciences (SPSS version 20 package) was used to statistically analyze the data. Data were represented in percentage, tables and figures. Chi square (X^2) was used to determine the differences in results obtained from the study. Frequency and proportions for sociodemographic characteristics were carried out as well. The mean and standard deviation (mean SD) were used to express the data. A p-value of less than 0.05 was considered statistically significant.

RESULTS AND DISCUSSION

Table 1 shows Socio-demographic characteristics of the participants. Female participants 680 (56.66%) were more than the male participants 520 (43.33%) in the study area. Many of them fell within age brackets of 41-50 years 320 (26.66%), and 21-30 years 260 (21.66%), while the least represented age group were 1-10 years 90 (7.50%). On the marital status of the respondents, 60.00% were married, 30.00% were single, and 10.00% were widowed. The educational status of the respondents showed that 34.33% of the respondents had no formal education, 26.67% had primary education, 21.67% had secondary education and 17.33% had tertiary. Distribution by occupation as reported by respondents showed that 25.00% were artisans, 22.92% were farmers, 22.92% were traders, 16.66% were civil servants, and 12.50% were students. In terms of location, 600 (50.00%) were from Obowo L.G.A with 600 (50.00%) from Owerri West L.G.A.

Table 1: Socio-demographic characteristics of the participants

Characteristics	Frequency	Percentage (%)
Sex		
Male	520	43.33
Female	680	56.66
Total	1200	100.00
Age		
1–10	90	7.5
11-20	180	15.00
21-30	260	21.66
31-40	220	18.33
41-50	320	26.66

51-60	130	10.83
Total	1200	100.00
Marital Status		
Married	720	60.00
Single	360	30.00
widowed	120	10.00
Total	1200	100.00
Educational Status		
No formal education	412	34.33
Primary	320	26.67
Secondary	260	21.67
Tertiary	208	17.33
Total	1200	100.00
Occupation		
Farmers	275	22.92
traders	275	22.92
Civil Servant	200	16.66
Students	150	12.50
Artisans	300	25.00
Total	1200	100.00
Location		
Obowo	600	50.00
Owerri-West	600	50.00
Total	1200	100.00

Table 2 shows the Overall Prevalence of malaria infection in the study area. Overall prevalence of malaria parasite infection in the study areas was 408 (34.00%), with varying prevalence rates across different locations. Prevalence of infection was higher in the rural area; Obowo L.G. A (40.17%) than in the urban; Owerri West L.G.A (27.83%), There was a statistically significant association between location and malaria prevalence ($\chi^2 = 19.79$, df = 1, $p < 0.001$), indicating that malaria infection differed significantly between rural and urban areas.

Table 2: Overall Prevalence of Malaria in the study Area

Location	Number Examined	Number Infected	Prevalence(%)
Obowo(Rural)	600	241	40.17
Owerri-West (Urban)	600	167	27.83
Total	1200	408	34.00

($\chi^2 = 19.79$, p-value < 0.001)

Table 3 shows the age-related prevalence of infection in the study population. The highest prevalence of infection was recorded in age group 31-40 years (48.20%), followed closely by the age group 51-60 (45.38%). The age group 41-50 years had the least prevalence of infection (22.19%). There was a statistically significant association between age and malaria prevalence among the study population ($\chi^2 = 47.93$, $p < 0.001$). This indicates that malaria infection varied significantly across different age groups.

Table 3: Age related prevalence of infection among the study population

Age group (years)	Number Examined	Number Infected	Prevalence (%)
1-10	90	28	31.11
11-20	180	57	31.70
21-30	260	87	33.46
31-40	220	106	48.20
41-50	320	71	22.19
51 above	130	59	45.38
Total	1200	408	34.00

($x^2 = 47.93$ p <0.001)

Table 4 shows the result of malaria prevalence in relation to gender of the study population. There was a higher malaria incidence in males (33.20%) than in females (26.18%). There was a

statistically significant association between gender and malaria prevalence among the study population ($\chi^2 = 39.70$, df = 1, $p < 0.001$), indicating that malaria prevalence differed significantly between males and females.

Table 4: Gender related prevalence of infection among the study population

Gender	No. Examined	No. Infected	Prevalence (%)
Male	520	230	44.23
Female	680	178	26.18
Total	1200	408	34.00

($\chi^2 = 39.70$, df = 1, $p < 0.001$)

Table 5 shows the prevalence of malaria based on marital status of the study population. The highest prevalence of infection was recorded in married participants (48.53%), followed by singles (31.86%) and the least were the Widowed (19.61%). There was a statistically significant association between marital status and malaria prevalence among the study population ($\chi^2 = 53.61$, df = 2, $p < 0.001$). Marital status is strongly associated with infection prevalence.

Table 5: Prevalence of malaria based on marital status of participants

Marital	Obowo L.G.A			Owerri-West			Both	
Status	No. Ex.	No. Inf.	(%)	No. Ex.	No. Inf.	(%)	Total Ex.	Total Inf. (%)
Single	162	77	(47.53)	198	53	(26.77)	360	130 (31.86)
Married	390	128	(32.82)	330	70	(21.21)	720	198 (48.53)
Widowed	48	36	(75.00)	72	44	(61.11)	120	80 (19.61)
Total	600	241	(40.17)	600	167	(27.83)	1200	408 (34.00)

($\chi^2 = 53.61$, df = 2, $p < 0.001$).

In Table 6, the largest prevalence group had no formal education (54.61%), followed by primary (26.87%), tertiary (21.63%), and secondary education (20.00%).

Table 6: Overall prevalence of malaria in relation to Educational Status

Characteristics

Educational Status	Number Examined	Number Infected	Prevalence%
No formal education	412	225	54.61
Primary	320	86	26.87
Secondary	260	52	20.00
Tertiary	208	45	21.63
Total	1200	408	34.00

($\chi^2 = 92.75$, $p < 0.001$)

Table 7 shows the prevalence of malaria in relation to occupational status. From the table, participants who were farmers had the highest prevalence (45.10%) followed closely by traders (43.63%), Students had the prevalence of 36.00% while Civil Servants had the least (20.50%). Educational status is strongly associated with infection prevalence ($\chi^2 = 42.24$, $p < 0.001$).

Table 7: Overall prevalence of malaria in relation to Occupational Status

Characteristics Occupational Status	Number Examined	Number Infected	Prevalence(%)
Farmer	275	124	45.10
Trader	275	120	43.63
Student	150	55	36.00
Civil Servant	200	41	20.50
Artisans	300	68	22.66
Total	1200	408	34.00

($\chi^2 = 42.24$, $p < 0.001$)

Table 8 presents malaria prevalence across different communities based on single malaria intervention strategies that include ITN, drug treatment, IRS and a control group. A total of 300 participants were examined, out of which 43 individuals (14.33%) were infected with malaria parasites. The results show that malaria prevalence was lowest among participants who received

ITN intervention (12.19%), followed by Drug users (14.29%), while IRS users recorded the highest prevalence among the intervention groups with 17.20%. In contrast, the control group recorded the highest prevalence of malaria (42.71%).

Table 8: Prevalence of malaria among Single Intervention users in the study population

Groups	Communities	No. Ex.	No. Inf. (%)	Malaria Intervention (%)							
				ITN		Drug		IRS		Control	
				No. Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No. Ex.	No.(%) Inf.
1	Umulogho(Rural)	42	4 (9.52)	42	4 (9.52)	-	-	-	-	33	19 (57.56)
	Irette(Urban)	35	5 (14.29)	35	5 (14.29)	-	-	-	-	-	-
	Nekede(Urban)	46	6 (13.04)	46	6 (13.04)	-	-	-	-	-	-
2	Okwuohia(Rural)	32	5 (15.63)	-	-	32	5 (15.63)	-	-	33	11 (33.33)
	Amuzi (Rural)	28	4 (14.28)	-	-	28	4 (14.28)	-	-	-	-
	Avu (Urban)	24	3 (12.50)	-	-	24	3 (12.50)	-	-	-	-
3	Alike (Rural)	23	4 (17.38)	-	-	-	-	23	4 (17.38)	30	11 (36.66)
	Umuguma (Urban)	22	4 (9.09)	-	-	-	-	22	4 (9.09)	-	-
	Odenkume (Rural)	24	5 (20.83)	-	-	-	-	24	5 (20.83)	-	-
	Orogwe (Urban)	24	3 (12.50)	-	-	-	-	24	3 (12.50)	-	-
	Total	300	43 (14.33)	123	15 (12.19)	84	12 (14.29)	93	16 (17.20)	96	41 (42.71)

Key:
No. Ex = Number Examined; No. Inf. = Number Infected; ITN = Insecticide Treated Net
IRS = Indoor Residual Spray

Table 9 compared malaria prevalence before and after the implementation of single intervention measures. Before intervention, the overall malaria prevalence among the study population was 34.00%, with 408 infected individuals out of 1200 examined participants. After intervention, malaria prevalence reduced substantially to 14.33%. Before intervention, some communities recorded very high prevalence rates such as Okwuohia (49.17%), Odenkume (42.50%), and Amuzi (41.67%). However, after intervention, prevalence reduced considerably across these communities, Amuzi (14.28%), Okwuohia (15.63%), and Odenkume (20.83%)

Table 9: Pre-Intervention and Single Intervention Malaria Prevalence among the study population

Groups	Communities	No. Ex.	No. Inf. (%)	Malaria Intervention (%)							
				ITN		Drug		IRS		Control	
				No Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No Ex.	No(%) Inf.
1	Umulogho(+)	120	40 (33.33)	-	-	-	-	-	-	-	-
	Irette(+)	120	32 (26.67)	-	-	-	-	-	-	-	-
	Nekede(+)	120	44 (36.67)	-	-	-	-	-	-	-	-
2	Okwuohia(+)	120	59 (49.17)	-	- -	-	-	-	-	-	-
	Amuzi (+)	120	50 (41.67)	-	- -	-	-	-	-	-	-
	Avu (+)	120	41 (34.17)	-	- -	-	-	-	-	-	-
3	Alike (+)	120	41 (34.17)	-	-	-	-	-	-	-	-
	Umuguma (+)	120	23 (19.17)	-	-	-	-	-	-	-	-
	Odenkume (+)	120	51 (42.50)	-	-	-	-	-	-	-	-
	Orogwe (+)	120	27 (22.50)	-	-	-	-	-	-	-	-
	Total	1200	408 (34.00)	-	- -	-	-	-	-	-	-
1	Umulogho(Rural)*	42	4 (9.52)	42	4 (9.52)	-	-	-	-	33	19 (57.56)
	Irette(Urban)*	35	5 (14.29)	35	5 (14.29)	-	-	-	-	-	-
	Nekede(Urban)*	46	6 (13.04)	46	6 (13.04)	-	-	-	-	-	-
2	Okwuohia(Rural)*	32	5 (15.63)		- -	32	5 (15.63)	-	-	33	11 (33.33)
	Amuzi (Rural)*	28	4 (14.28)		- -	28	4 (14.28)	-	-	-	-
	Avu (Urban)*	24	3 (12.50)		- -	24	3 (12.50)	-	-	-	-
3	Alike (Rural)*	23	4 (17.38)	-	-	-	-	23	4 (17.38)	30	11 (36.66)
	Umuguma (Urban)*	22	4 (9.09)		- -		- -	22	4 (9.09)		- -
	Odenkume (Rural)*	24	5 (20.83)	-	-	-	-	24	5 (20.83)	-	-
	Orogwe (Urban) *	24	3 (12.50)	-	-	-	-	24	3 (12.50)	-	-
	Total	300	43 (14.33)	123	15 (12.19)	84	12 (14.29)	93	16 (17.20)	96	41 (42.71)

Keys

+ = Pre intervention results **No. Ex = Number Examined** **No. Inf. = Number Infected**

*** = Single Intervention results**

ITN = Insecticide Treated Net **IRS = Indoor Residual Spray**

Table 10 shows malaria prevalence among participants exposed to combined intervention measures. The overall malaria prevalence among combined intervention users was 10.67%. Among the combined interventions, ITN plus sanitation recorded the lowest prevalence of 8.13%, followed closely by Drug plus health education with 8.33%, while IRS plus ITN recorded 16.12%. The control group still recorded a very high prevalence of 41.66%.

Table 10: Prevalence of malaria among Combination Intervention users in the study population

Groups	Communities	No. Ex.	No. Inf. (%)	Malaria Interventions							
				ITN + Sanitation		Drug + Education		IRS + ITN		Control	
				No Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No Ex.	No(%) Inf.	No Ex.	No(%) Inf.
1	Umulogho(Rural)**	42	3 (7.14)	42	3 (7.14)	-	-	-	-	33	19 (57.56)
	Irette(Urban) **	35	3 (8.57)	35	3 (8.57)	-	-	-	-	-	-
	Nekede(Urban) **	46	4 (8.69)	46	4 (8.69)	-	-	-	-	-	-
2	Okwuohia(Rural) **	32	3 (9.36)	-	-	32	3 (9.36)	-	-	33	11 (33.33)
	Amuzi (Rural) **	28	2 (7.14)	-	-	28	2 (7.14)	-	-	-	-
	Avu (Urban) **	24	2 (8.33)	-	-	24	2 (8.33)	-	-	-	-
3	Alike (Rural) **	23	3 (13.04)	-	-	-	-	23	3 (13.04)	30	10 (33.33)
	Umuguma (Urban) **	22	4 (9.09)	-	-	-	-	22	4 (9.09)	-	-
	Odenkume (Rural) **	24	5 (20.83)	-	-	-	-	24	5 (20.83)	-	-
	Orogwe (Urban) **	24	3 (12.50)	-	-	-	-	24	3 (12.50)	-	-
	Total	300	32 (10.67)	123	10 (8.13)	84	7 (8.33)	93	15 (16.12)	96	40 (41.66)

** = Combined Intervention results
ITN = Insecticide Treated Net IRS = Indoor Residual Spray

Table 11 shows distribution of Malaria Prevalence according to Single and Combined Interventions among the Study Population. The comparative distribution presented in the final table revealed that combined interventions generally achieved lower malaria prevalence compared with single interventions. Single interventions produced an overall prevalence of 14.33%, whereas combined interventions reduced prevalence further to 10.67%.

Table 11: Distribution of Malaria Prevalence according to Single and Combined interventions among study population

Groups	Communities	No. Ex.	No. Inf. (%)	Single Malaria Intervention (%)							
				ITN		Drug		IRS		Control	
				No Ex.	No. Inf. (%)	No Ex.	No. Inf. (%)	No. Ex.	No. Inf. (%)	No. Ex.	No. Inf. (%)
1	Umulogho(Rural)*	42	4 (9.52)	42	4 (9.52)	-	-	-	-	33	19 (57.56)
	Irette(Urban)*	35	5 (14.29)	35	5 (14.29)	-	-	-	-	-	-
	Nekede(Urban)*	46	6 (13.04)	46	6 (13.04)	-	-	-	-	-	-
2	Okwuohia(Rural)*	32	5 (15.63)	-	-	32	5 (15.63)	-	-	33	11 (33.33)
	Amuzi (Rural)*	28	4 (14.28)	-	-	28	4 (14.28)	-	-	-	-
	Avu (Urban)*	24	3 (12.50)	-	-	24	3 (12.50)	-	-	-	-
3	Alike (Rural)*	23	4 (17.38)	-	-	-	-	23	4 (17.38)	30	11(36.66)
	Umuguma (Urban)*	22	4 (9.09)	-	-	-	-	22	4 (9.09)	-	-
	Odenkume (Rural)*	24	5 (20.83)	-	-	-	-	24	5 (20.83)	-	-
	Orogwe (Urban) *	24	3 (12.50)	-	-	-	-	24	3 (12.50)	-	-
	Total	300	43 (14.33)	123	15 (12.19)	84	12 (14.29)	93	16 (17.20)	96	41(42.71)

Groups	Communities	No. Ex.	No. Inf. (%)	Combined Malaria Intervention (%)							
				ITN + Sanitation		Drug + Education		IRS + ITN		Control	
				No. Ex.	No. Inf. (%)	No. Ex.	No. Inf. (%)	No. Ex.	No. Inf. (%)	No. Ex.	No. Inf. (%)
1	Umulogho(Rural)**	42	3 (7.14)	42	3 (7.14)	-	-	-	-	33	19 (57.56)
	Irette(Urban)**	35	3 (8.57)	35	3 (8.57)	-	-	-	-	-	-
	Nekede(Urban)**	46	4 (8.69)	46	4 (8.69)	-	-	-	-	-	-
2	Okwuohia(Rural)**	32	3 (9.36)	-	-	32	3 (9.36)	-	-	33	11 (33.33)
	Amuzi (Rural)**	28	2 (7.14)	-	-	28	2 (7.14)	-	-	-	-
	Avu (Urban)**	24	2 (8.33)	-	-	24	2 (8.33)	-	-	-	-
3	Alike (Rural)**	23	3 (13.04)	-	-	-	-	23	3 (13.04)	30	10 (33.33)
	Umuguma(Urban)**	22	4 (9.09)	-	-	-	-	22	4 (9.09)	-	-
	Odenkume(Rural)**	24	5 (20.83)	-	-	-	-	24	5 (20.83)	-	-
	Orogwe(Urban)**	24	3 (12.50)	-	-	-	-	24	3 (12.50)	-	-
	Total	300	32 (10.67)	123	10 (8.13)	84	7 (8.33)	93	15 (16.12)	96	40 (41.66)

Key: * Single Intervention, ** Combined Intervention, ITNs = Insecticides Treated Net, IRS = Indoor Residual Spray

Malaria remains a major public health problem globally and particularly in Nigeria, where it continues to contribute substantially to morbidity and mortality. Recent studies have emphasized that achieving significant reductions in malaria burden requires integrated control measures, including vector control, prompt diagnosis and treatment, chemoprevention, community participation, and sustainable financing mechanisms. Furthermore, these interventions must be supported by broader efforts to strengthen health systems and advance universal health coverage to ensure equitable access to effective malaria prevention and treatment services [11, 22, 42].

The study provided a baseline epidemiological information on malaria, risk factors and intervention strategies among study population communities in Obowo and Owerri West local government areas of Imo State, Nigeria. The results highlight a malaria prevalence of 34.0% in these communities. Thus, this supports the report of the World Health Organization (WHO) and Nigeria Malaria Indicator Survey, which stated that malaria remains a major public health problem worldwide, and this requires integrated control measures coupled with broader efforts to accomplish a universal health coverage [3, 23]. The finding in this work is similar to several reports of researchers on malaria prevalence [43,44] The endemicity of malaria observed in both local governments in this study may be a reflection of some factors such as the poor socio-economic status of the people in the study areas, geographical landscapes, climatic conditions, inadequate drainage and runoff water, proximity to water bodies, and behavioural attitudes, which encouraged the breeding of the mosquito vector and subsequently increase susceptibility to mosquito bites. The variation in prevalence between urban and rural area where the rural (Obowo L.G.A) had a significantly higher prevalence (40.17%), compared to urban (Owerri-West L.G.A) (27.83%), aligned with the report of the Nigeria Malaria Indicator Survey of 2015 and 2021 [23] that reported a rural prevalence of 36% compared to 14% in 2015 and rural areas at 31% and urban areas at 11% in 2021.

The association of malaria infection with sex was observed to be significant. Male participants significantly have higher malaria infection compared to their female counterparts (44.23% vs 26.18%). The higher malaria prevalence among male respondents observed in this study is consistent with previous reports from Nigeria [45-48]. These findings may be attributed

to increased outdoor activities, occupational exposure, and behavioral factors that increase contact with mosquito vectors among males. In terms of Health-seeking behavior: Men are generally less likely than women to seek prompt medical care, which can lead to prolonged infections and elevated parasite carriage. However, the higher malaria prevalence among males observed in the present study contrasts with findings from some previous studies in Nigeria [49-50]. Records indicate that resistance to malaria is relatively stronger in females than in males owing to hormonal and genetic disparity between the two genders, genetic variables play a significant role in giving females the immune-regulatory capacity to deal with the infection [51-53]

Age-related prevalence recorded a statistically significant difference in all age groups. This study showed the Participants of the age group 31-40 to have a higher malaria infection prevalence (48.20%) This study aligned with a retrospective study in Adiyan, Ogun State, southwestern Nigeria by Ayenigba and Afariogun, [54] that reported high burden of malaria among adults. Asymptomatic Infections in Adults makes them tolerate malaria infections with fewer symptoms but still test positive; Exposure Patterns of adult's occupational and evening activities such as farming, night markets, travel etc., increase contact with mosquito vectors [55].

The association between marital status and malaria prevalence was statistically significant ($\chi^2 = 53.61$, df = 2, $p < 0.001$). indicating that marital status is an important socio-demographic determinant of malaria infection influencing transmission dynamics. The married participants recorded the highest prevalence (48.53%), followed by single participants (31.86%), while widowed had the lowest prevalence (19.61%). This trend is due to several socio-demographic and behavioral factors associated with married individuals, including household size, environmental exposure, economic status, and health-seeking behaviors. This finding is consistent with reports of [56] who reported higher prevalence among married individuals due to larger household sizes. However, studies have linked unstable marital status to reduced access to malaria preventive measures and increased environmental exposure, thereby increasing malaria risk [57,55]

There is a strong relationship between education and malaria prevalence. Participants with no formal education had the highest prevalence of 54.61%, and the Lower prevalence was observed among those with secondary 20.00%. The finding that malaria prevalence was higher among

respondents with little or no formal education agrees with previous studies [58,13]. Furthermore, analysis of the 2021 Nigeria Malaria Indicator Survey [59]. showed that children of mothers with lower educational attainment were more likely to have malaria parasitaemia than those whose mothers had secondary or higher education.

Occupation prevalence shows that farmers recorded the highest prevalence 45.10%, followed by traders 43.63% while civil servants/health workers had the lowest prevalence 20.50%. The higher prevalence of malaria among farmers observed in this study agrees with previous findings from Nigeria research works [60, 61, 13]. These findings suggest that occupational exposure, particularly activities conducted outdoors and in rural environments, increases the risk of malaria infection. The elevated prevalence among farmers and traders in the study area can be attributed to the nature of their job which exposes them to the bites of mosquito, especially during evening hours when mosquito biting activity is high, and residence in environments favourable for mosquito breeding. Farmers are frequently exposed to mosquito bites during early morning and evening hours, particularly in rural and peri-urban settings where vector density is high.

The result of malaria prevalence across different communities based on single malaria intervention strategies revealed that all the intervention measures assessed; ITN usage, chemotherapy, and IRS significantly reduced malaria prevalence compared with the control groups. Among the interventions, ITN usage produced the lowest prevalence (12.19%) followed by Chemotherapy (14.29%) and then IRS (17.20%). The low malaria prevalence observed among the ITN users suggests that insecticide-treated nets were highly effective in reducing malaria transmission in the study area. ITNs serve as both a physical and chemical barrier against mosquito bites, especially during night-time when malaria vectors are most active. The insecticide on the nets also reduces mosquito survival and population density. However, some studies have reported lower effectiveness of ITNs in certain communities.

The overall malaria prevalence among combined intervention users was 10.67%, which was lower than the prevalence observed among single intervention users (14.33%). Among the combined interventions, ITN plus sanitation recorded the lowest prevalence of 8.13%, followed closely by Drug plus health education with 8.33%, while IRS plus ITN recorded 16.12%. The low

prevalence observed among ITN plus sanitation users suggests that combining vector control measures with proper environmental sanitation greatly enhanced malaria prevention. Environmental sanitation helps eliminate mosquito breeding sites, thereby reducing vector density alongside ITN protection. Similarly, the low prevalence observed among Drug plus education users indicates that health education likely improved treatment compliance, awareness of malaria prevention, and healthcare-seeking behavior, thereby enhancing the effectiveness of chemotherapy. Although IRS plus ITN reduced malaria prevalence compared to the control group, the prevalence remained relatively higher than the other combined interventions. This may be due to insecticide resistance, poor implementation of IRS, or outdoor mosquito exposure beyond indoor spraying protection. The result suggests that integrating multiple malaria control approaches such as behavioral, environmental, and biomedical approaches simultaneously provide synergistic effects in reducing malaria transmission. Combination interventions target multiple stages of malaria transmission, including vector control, environmental management, treatment compliance, and public awareness. The superior effectiveness of combined malaria intervention strategies observed in this study agrees with previous findings from Nigeria [62-65] These findings support the view that combining interventions such as ITNs, chemotherapy, environmental sanitation, and health education provides greater malaria reduction than relying on a single intervention alone. [3]

CONCLUSION

The study showed that malaria is still a public health problem in the study area and that malaria prevalence is strongly influenced by socio-demographic factors, environmental conditions, vector distribution, and preventive interventions. The findings of this study demonstrated that malaria intervention measures significantly reduced malaria prevalence in the study area. Both single and combined interventions were effective; however, combined interventions produced greater reductions in malaria prevalence compared with single interventions. Also, among all intervention strategies, ITN plus sanitation was the most effective, suggesting that integrating vector control with environmental management provides stronger malaria prevention outcomes. The findings also emphasize the importance of public health education, treatment compliance, environmental

sanitation, and community participation in malaria control programs. strengthening malaria interventions through coordinated and integrated approaches is critical for achieving malaria control targets in Nigeria.

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