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Knowledge of Malaria Transmission, Treatment Adherence, and Antimalarial Drug Resistance Awareness among Adults in Osun State, Nigeria: A Cross-Sectional Study

*[1]Odediji Saheed Adeyinka, [2]Amoo Kazeem Olarewaju, [3]Olawuyi Abdullah Olaleye, [4]Amoo-Adeboye Basirat Opemipo, [5]Surakat Olabanji Ahmed and [6]Adeleke Monsuru Adebayo

[1]Department of Medical Microbiology and Parasitology, Federal University of Health Science, Ila-Orangun, Osun State, Nigeria.
[2]Medical Research Council Unit, London School of Hygiene & Tropical Medicine, Gambia.
[3]Department of Medical Laboratory Science, Federal University of Health Science Ila-Orangun, Osun State, Nigeria.
[4]Department of Medical Microbiology and Parasitology, Obafemi Awolowo University Teaching Hospital, Ile-Ife, Osun State, Nigeria.
[5]Parasitology and Vector Biology Unit, Department of Animal and Environmental Biology, Osun State University, Osogbo, Osun State, Nigeria.

*Corresponding authors' email: saheed.odediji@fuhsi.edu.ng Phone: +2348062273874

ABSTRACT

Malaria remains a major public health burden in Nigeria, driven by biological vectors and modifiable human behaviors. This study evaluated the knowledge, attitudes, and perceptions regarding malaria transmission, treatment, and drug resistance among adults in Osun State, Nigeria, and examined how cognitive gaps influence are associated with preventive and treatment-seeking behaviors framed within the Health Belief Model. A community-based cross-sectional study was conducted among 1,500 adults aged 18 years and above between June and August 2023, using a pre-tested, interviewer-administered questionnaire. Descriptive statistics, chi-square tests, and multivariable logistic regression were performed. Significant cognitive gaps were identified: 49.5% of participants were unaware of the primary malaria transmission route, and only 27.5% recognized antimalarial drug resistance. Among the 712 participants who reported using antimalarial drugs in the preceding two weeks, 70.5% completed the full treatment course. Awareness of drug resistance independently predicted completing antimalarial treatment (aOR = 1.68; 95% CI: 1.25–2.25; $p < 0.001$) and utilizing formal healthcare sources (aOR = 1.45; 95% CI: 1.12–1.88; $p = 0.005$), but was inversely associated with herbal medicine use (aOR = 0.65; 95% CI: 0.50–0.85; $p = 0.002$). Female gender was an independent predictor of insecticide-treated net use (aOR = 2.15; 95% CI: 1.65–2.80; $p < 0.001$) but was inversely associated with drug resistance awareness (aOR = 0.62; 95% CI: 0.46–0.83; $p = 0.001$). Deficits in malaria-related knowledge, particularly regarding drug resistance, are significantly associated with less favourable maladaptive health-seeking behaviors. Targeted behavioral change communication, integrated with vendor education and healthcare worker engagement, is imperative to improve treatment adherence and curb drug resistance.

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INTRODUCTION

Malaria remains a pervasive public health challenge in sub-Saharan Africa, with Nigeria bearing a disproportionate share of the global burden. The World Health Organization estimated approximately 249 million malaria cases worldwide in 2022, of which Nigeria accounted for approximately 27% of the global burden and 31% of global malaria deaths (World Health Organization, 2023). Despite substantial investments in malaria control, including the distribution of insecticide-treated nets, indoor residual spraying, and artemisinin-based combination therapies, the disease continues to exact a heavy toll on Nigerian communities, particularly in rural and impoverished populations (Bhatt et al., 2015).

The persistence of malaria in endemic regions is not solely attributable to biological factors such as vector abundance or parasite resistance. Behavioral determinants, including insufficient knowledge of transmission mechanisms, misconceptions about causation and prevention, and incomplete adherence to treatment regimens, have been identified as critical contributors to ongoing transmission and the emergence of drug resistance (Tizifa et al., 2018; Degarege et al., 2019; Rouamba et al., 2019). Understanding these cognitive and behavioral factors is essential for designing effective, contextually appropriate interventions that complement biomedical approaches.

The Health Belief Model posits that an individual's engagement in preventive health behaviors is heavily influenced by their perceived susceptibility to the disease, perceived severity, perceived benefits of taking action, perceived barriers, and cues to action (Alyafei & Easton-Carr, 2024). In the context of malaria, a critical component of perceived severity and benefit is the understanding of antimalarial drug resistance. It is important to distinguish between awareness of antimalarial drug resistance and the actual emergence of parasite resistance. While poor adherence is one contributing factor to resistance, antimalarial resistance is multifactorial, involving parasite genetics, drug pharmacokinetics, and transmission dynamics. When populations lack awareness of drug resistance, they are less likely to appreciate the imperative of completing prescribed regimens, inadvertently fostering parasite selection and resistance spread (Cui et al., 2015; Rouamba et al., 2019).

Numerous Knowledge, Attitudes, and Practices studies have been conducted in Nigeria. In Kano State, Dawaki et al. (2016) reported relatively high general malaria awareness (79.7%) among Hausa communities, while Adedotun et al. (2010) found that 93.2% of participants in urban southwestern Nigeria correctly identified mosquito bites as the cause of malaria, indicating strong awareness of transmission routes in that specific population. However, high general awareness does not necessarily translate to specific, actionable knowledge regarding treatment completion and drug resistance. More recent evidence from Osun State indicates that malaria transmission remains year-round, with peak incidence during the rainy season, yet community knowledge of effective prevention strategies remains suboptimal (Bello et al., 2023; Ajibaye et al., 2025). A recent multi-regional review indicated that specific awareness of antimalarial drug resistance in Nigeria remains alarmingly low, averaging approximately 38% (Olowe et al., 2025). Furthermore, research in Senegal demonstrated that even in high-transmission areas, adolescents possess significant gaps in malaria prevention knowledge, with only 34.4% demonstrating good knowledge scores (Tairou et al., 2022).

Despite these regional insights, there is a paucity of data specifically exploring the nexus between drug resistance awareness and actual treatment-seeking behaviors in southwestern Nigeria. Osun State presents a unique ecology characterized by year-round transmission and a diverse healthcare landscape, ranging from tertiary hospitals to informal patent medicine vendors (Ajibaye et al., 2025; Bello et al., 2023). This study aimed to: (1) evaluate the knowledge, attitudes, and perceptions regarding malaria transmission, treatment, and drug resistance among adults in Osun State, Nigeria; (2) identify sociodemographic factors associated with awareness of drug resistance and insecticide-treated net usage; and (3) examine the association between awareness of drug resistance and treatment-seeking behaviors, including treatment completion, drug source, and use of herbal medicine. By applying the Health Belief Model framework, we explored how specific cognitive gaps, particularly concerning drug resistance, influence preventive behaviors and treatment adherence, thereby providing an evidence base for targeted public health interventions.

MATERIALS AND METHODS

Study Design and Setting

This community-based cross-sectional study was conducted in Osun State, southwestern Nigeria, between June and August 2023. Osun State covers an area of approximately 9,251 km² and lies between latitudes 7°30′ N and 4°30′ E, with its capital in Osogbo (Abiodun & Akinola, 2019). The state has a tropical rainforest climate with annual rainfall ranging from 1,000 mm to 2,500 mm, providing ideal breeding conditions for Anopheles mosquitoes (Aderele et al., 2020). Malaria transmission occurs year-round, with peak incidence during the rainy season (Odediji et al., 2025). Osun State has a diverse population with varying access to healthcare, particularly between urban and rural communities. Socioeconomic barriers, including the high cost of antimalarial drugs and limited healthcare coverage, contribute to suboptimal malaria prevention and treatment practices (Bello et al., 2023). These challenges are compounded by widespread self-medication and informal drug use (Ogidan et al., 2025).

Sample Size Determination

The minimum sample size was calculated as 384 using Cochran's formula: $n = Z^2p(1-p) / d^2$. Where: $Z = 1.96$ (95% confidence level); $p = 0.50$ (assumed prevalence of adequate malaria knowledge, to maximize sample size); $d = 0.05$ (margin of error). To account for the cluster sampling design effect (estimated at 2.0) and to ensure adequate statistical power for multivariable logistic regression with up to 10 predictor variables (requiring at least 100 events per variable), the sample was increased to 1,500 participants. This sample size also permitted robust stratified subgroup analyses by gender, residence, and occupation.

Sampling Strategy and Participants

A multi-stage stratified cluster sampling approach was employed. Osun State was stratified by its three senatorial districts (Osun Central, Osun East, and Osun West) and by urban/rural residence. Within each stratum, local government areas were randomly selected, followed by systematic random sampling of households (every nth household) within each selected local government area. Within each household, one adult aged 18 years or above was randomly selected for interview. Participants were eligible if they provided informed written consent and had resided in the study area for at least six months. Individuals with severe cognitive impairment or acute illness precluding interview were excluded. Of the 1,500 participants, 1,050 (70.0%) were recruited through probability-based household sampling, while 450 (30.0%) were recruited from outpatient departments of selected health facilities to capture both the general and care-seeking populations. Sensitivity analyses comparing these two groups revealed no significant differences in key outcomes (drug resistance awareness: $\chi^2 = 1.24$, $p = 0.265$; ITN use: $\chi^2 = 0.89$, $p = 0.345$), suggesting that facility recruitment did not substantially bias the findings. However, this mixed recruitment strategy is acknowledged as a limitation.

Data Collection

Data were collected using a structured, interviewer-administered questionnaire developed based on a comprehensive review of malaria Knowledge, Attitudes, and Practices literature (Adedotun et al., 2010; Dawaki et al., 2016; Tairou et al., 2022) and aligned with the constructs of the Health Belief Model. The Health Belief Model constructs were operationalised as follows: perceived susceptibility (belief about likelihood of malaria infection), perceived severity (belief about seriousness of malaria), perceived benefits (belief in efficacy of ITNs and treatment completion), perceived barriers (reported obstacles to ITN use and treatment adherence), and cues to action (exposure to mass media malaria messaging and healthcare worker advice).

The questionnaire was developed in English, translated into Yoruba (the local language), and back-translated into English by independent bilingual translators to ensure semantic equivalence. It was pre-tested on 50 adults in a neighboring local government area (not included in the final sample) to assess clarity, comprehensibility, and internal consistency. Cronbach's alpha for the knowledge domain was 0.78, indicating acceptable reliability. The final questionnaire captured information on: socio-demographic characteristics; malaria history; preventive practices; knowledge of malaria transmission; awareness of antimalarial drug resistance; and treatment-seeking behaviors. Data collection was conducted by trained research assistants. Inter-rater reliability was assessed during training, achieving a Cohen's kappa coefficient of 0.82. "Insecticide-treated net use" was operationally defined as having slept under an insecticide-treated net the night preceding the survey. "Correct knowledge" of malaria transmission was defined as correctly identifying mosquito bites as the primary transmission route. "Awareness of drug resistance" was defined as correctly identifying that parasites can become resistant to antimalarial drugs and that this can lead to treatment failure.

Outcome Measures

The primary outcomes were: (1) awareness of antimalarial drug resistance; (2) completion of full treatment course (analyzed only among participants who reported initiating antimalarial treatment in the preceding two weeks); and (3) consistent insecticide-treated net use.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using SPSS version 28.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for sociodemographic and clinical variables. Bivariate analyses were conducted using chi-square tests to examine associations between sociodemographic factors and awareness of drug resistance; sociodemographic factors and insecticide-treated net usage; and awareness of drug resistance and treatment-seeking behaviors. Multivariable logistic regression was performed to identify independent predictors of treatment adherence, formal healthcare utilization, herbal medicine use, consistent insecticide-treated net use, and drug resistance awareness. Variables with $p < 0.20$ in bivariate analyses were entered into multivariable logistic regression models. Multicollinearity was assessed using Variance Inflation Factors (all VIF < 5.0). Model fit was evaluated using the Hosmer-Lemeshow goodness-of-fit test. Interaction terms (e.g., gender × education) were tested but were not statistically significant and were therefore excluded from final models. Missing data were minimal (<2%) and handled through complete case analysis. Adjusted odds ratios, 95% confidence intervals, and p-values were reported. The significance level was set at $p < 0.05$ (two-tailed).

Ethical Considerations

Ethical approval was obtained from the Health Research Ethics Committee of Osun State's Ministry of Health (Ref: OSHREC/PRS/569T/776). Written informed consent was obtained from all participants prior to data collection. Participation was voluntary, and participants were assured of their right to withdraw at any time without penalty. Data confidentiality was maintained throughout the study, adhering to the World Health Organization's guidelines for research involving human subjects (World Health Organization, 2011).

RESULTS AND DISCUSSION

Socio-demographic Characteristics and Associations with Drug Resistance Awareness and ITN Usage

A total of 1,500 adults participated in the study. The mean age was 26.74 ± 10.72 years, with the largest age group being 20–30 years (57.0%). The majority of respondents were female (77.0%) and resided in urban areas (65.0%). Students constituted the largest occupational group (52.0%), followed by traders (15.0%) and healthcare workers (15.0%). Table 1 presents the socio-demographic characteristics and their overall associations with awareness of drug resistance and insecticide-treated net usage. Significant associations were found between drug resistance awareness and age ($\chi^2 = 11.52$, df = 4, p = 0.021), gender ($\chi^2 = 7.04$, df = 1, p = 0.008), occupation ($\chi^2 = 45.60$, df = 3, p < 0.001), and residence ($\chi^2 = 6.35$, df = 2, p = 0.042). Insecticide-treated net usage was significantly associated with gender ($\chi^2 = 56.23$, df = 1, p < 0.001) and residence ($\chi^2 = 8.10$, df = 2, p = 0.018), but not with age ($\chi^2 = 5.42$, df = 4, p = 0.250) or occupation ($\chi^2 = 4.20$, df = 3, p = 0.400). Notably, awareness of drug resistance was highest among healthcare workers (53.3%) compared to students (23.1%). Females demonstrated significantly higher insecticide-treated net usage (43.6%) compared to males (21.2%; p < 0.001), while males exhibited higher awareness of drug resistance (31.9% vs 26.2%; p = 0.008).

This finding aligns with the broader literature on gender disparities in malaria-related behaviors. The higher insecticide-treated net use among women is consistent with previous studies in Nigeria (Dawaki et al., 2016) and across sub-Saharan Africa, where women often assume primary responsibility for household health and childcare. However, the inverse association with drug resistance awareness, where males demonstrated higher awareness, represents a critical divergence. This contrast suggests that preventive behaviors and knowledge of treatment complexities are governed by distinct socio-behavioral determinants. We hypothesize that males may have greater access to formal employment and differentially exposed health information sources, whereas women's engagement with health systems may be more focused on preventive and childcare-related services. These interpretations require further qualitative exploration to validate the underlying socio-cultural drivers.

Table 1: Sociodemographic Characteristics and Associations with Drug Resistance Awareness and ITN Usage

Variable	Category	Frequency (N=1500) n (%)	Aware of DR n (%)	χ^2 (df)	p-value	Using ITN n (%)	χ^2 (df)	p-value
Age (years)	< 20	277 (18.5)	65 (23.5)	11.52 (4)	0.021	115 (41.5)	5.42 (4)	0.250
	20–30	855 (57.0)	240 (28.1)			312 (36.5)		
	31–40	218 (14.5)	57 (26.1)			80 (36.7)		
	41–50	75 (5.0)	24 (32.0)			32 (42.7)		
	> 50	75 (5.0)	26 (34.7)			38 (50.7)		
Gender	Male	345 (23.0)	110 (31.9)	7.04 (1)	0.008	73 (21.2)	56.23 (1)	<0.001
	Female	1155 (77.0)	302 (26.2)			504 (43.6)		
Occupation	Student	780 (52.0)	180 (23.1)	45.60 (3)	<0.001	290 (37.2)	4.20 (3)	0.400
	Trader	225 (15.0)	60 (26.7)			90 (40.0)		
	Healthcare Worker	225 (15.0)	120 (53.3)			105 (46.7)		
	Others	270 (18.0)	52 (19.3)			92 (34.1)		
Residential Area	Urban	975 (65.0)	285 (29.2)	6.35 (2)	0.042	410 (42.1)	8.10 (2)	0.018
	Peri-urban	142 (9.5)	35 (24.6)			48 (33.8)		

Variable	Category	Frequency (N=1500) n (%)	Aware of DR n (%)	χ² (df)	p-value	Using ITN n (%)	χ² (df)	p-value
	Rural	383 (25.5)	92 (24.0)			119 (31.1)		

Note: DR = Drug Resistance; ITN = Insecticide-Treated Net.

Clinical Characteristics and Their Association with Knowledge of Drug Resistance

Table 2 presents the clinical characteristics of participants. Overall, 51.0% of respondents experienced a fever lasting 3–5 days. The mean body temperature was 36.79 ± 1.21 °C, with most participants afebrile at the time of interview. Awareness of drug resistance did not differ significantly across fever duration categories (ANOVA p = 0.085 for mean temperature; chi-square p = 0.940 for proportions aware), suggesting clinical severity did not influence knowledge of drug resistance.

This disconnection is particularly concerning. It implies that even severe malaria episodes do not catalyze learning about proper treatment, challenging the assumption that personal illness experience fosters accurate knowledge. This finding necessitates a shift from passive, experience-based knowledge acquisition to active, structured education. Interventions should be embedded at multiple touchpoints: antenatal clinics (leveraging the high female turnout), school health programs (targeting the large student population), and community-led action in rural areas where knowledge was lowest.

Table 2: Clinical Characteristics and Their Association with Knowledge of Drug Resistance

Variable	Category	Frequency (N=1500)	Percent (%)	Mean Body Temperature ± SD (°C)	Aware of Drug Resistance n (%)	p-value
Duration of Current Fever (days)	1–2 days	435	29.0	36.65 ± 0.98	105 (24.1%)	0.085
	3–5 days	765	51.0	36.82 ± 1.15	220 (28.8%)	—
	> 5 days	300	20.0	37.10 ± 1.42	87 (29.0%)	0.940
Overall/Total		1500	100.0	36.79 ± 1.21	412 (27.5%)	

Knowledge, Attitudes, and Perceptions

Table 3 summarizes the cognitive gaps identified among participants. Only 50.5% correctly identified the route of malaria transmission, while 49.5% provided incorrect or incomplete responses. Awareness of antimalarial drug resistance was particularly low: only 27.5% of participants were aware of drug resistance as a concept. Furthermore, while 57.5% perceived malaria as a serious health problem, only 25.0% understood the importance of completing a full course of treatment.

The finding that only 27.5% of respondents were aware of antimalarial drug resistance represents a central and concerning result. This level of awareness is substantially lower than the approximately 38% recently reported in a multi-regional Nigerian review (Olowe et al., 2025) and the 34.4% good knowledge score reported among Senegalese adolescents (Tairou et al., 2022).

The Health Belief Model (Alyafei & Easton-Carr, 2024) provides a useful theoretical framework for understanding this phenomenon. According to this model, low awareness diminishes perceived susceptibility to treatment failure and reduces the perceived benefit of treatment adherence low awareness diminishes perceived susceptibility to treatment failure and reduces the perceived benefit of treatment adherence. This theoretical insight suggests that interventions should focus not only on disseminating information about resistance but also on enhancing perceived personal risk.

The cognitive gap wherein only 25.0% of respondents understood the necessity of completing a full treatment course represents a fundamental barrier to effective case management. This gap, coupled with the high rate of patent medicine vendor patronage (21.0%), creates a high-risk combination where patients obtain drugs without appropriate counseling on completion.

Table 3: Cognitive Gaps among Respondents Regarding Malaria Transmission and Drug Resistance

Cognitive Domain	Category	Frequency (N=1500)	Percent (%)	p-value
Knowledge of Malaria Transmission	Correctly Identified	758	50.5	<0.001
	Incorrectly Identified	742	49.5	
Awareness of Drug Resistance	Aware	412	27.5	<0.001
	Not Aware	1088	72.5	
Perception of Malaria Severity	Considered Serious	862	57.5	<0.001
	Did Not Consider Serious	638	42.5	
Understanding of Treatment Completion	Understands Importance	375	25.0	<0.001
	Does Not Understand Importance	1125	75.0	

Preventive and Curative Behaviours

Table 4 presents data on antimalarial drug use and treatment-seeking behaviors, stratified by awareness of drug resistance. Overall, 47.5% (n=712) of respondents reported using antimalarial drugs in the last two weeks. Among these 712 participants who initiated treatment, 70.5% (n=502) completed the full course. Source of antimalarial drugs and treatment completion were analyzed exclusively among this subgroup. Insecticide-treated net usage was reported by 38.5% of participants. Awareness of drug resistance was significantly associated with positive health-seeking behaviors. Participants aware of drug resistance were significantly more likely to: complete the full treatment course (77.6% vs 67.5%; p < 0.001); obtain drugs from formal healthcare sources (hospital/clinic: 59.5% vs 51.2%; p = 0.002); and avoid herbal/traditional medicine (33.8% vs 43.2% using herbal medicine; p = 0.002).

One of the most pivotal findings of this study is the strong, independent association between awareness of drug resistance and positive health-seeking behaviors. After adjusting for sociodemographic confounders, participants aware of drug resistance were 68% more likely to complete the full antimalarial treatment course (aOR = 1.68; 95% CI: 1.25–2.25) and 45% more likely to obtain drugs from formal healthcare sources (aOR = 1.45; 95% CI: 1.12–1.88). This aligns with the Health Belief Model's proposition that perceived threat motivates protective action (Alyafei & Easton-Carr, 2024). However, because of the cross-sectional design, the temporal direction of these associations cannot be definitively established. It is equally plausible that individuals who utilize formal healthcare sources acquire greater knowledge of drug resistance during their clinical visits, rather than awareness independently driving formal healthcare use.

Conversely, participants unaware of drug resistance were significantly more likely to rely on patent medicine vendors (23.1% vs 16.2%) and herbal/traditional medicine (43.2% vs 33.8%). In multivariable analysis, awareness of drug resistance was inversely associated with herbal medicine use (aOR = 0.65; 95% CI: 0.50–0.85; p = 0.002). This reliance on informal treatment pathways echoes concerns raised by Bello et al. (2023) in their study of elderly populations in Osun State. The use of herbal medicines, which may contain sub-therapeutic doses of active ingredients, delays effective care. However, evidence linking herbal medicine use to antimalarial resistance selection in humans remains limited. This potential pathway warrants further investigation.

Table 4: Antimalarial Drug Use and Treatment-Seeking Behaviour by Awareness of Drug Resistance

Variable	Category	Total (N=712) n (%)	Aware of DR (n=210) n (%)	Not Aware of DR (n=502) n (%)	p-value
Completed Full Course of Treatment	Yes	502 (70.5)	163 (77.6)	339 (67.5)	<0.001
	No	210 (29.5)	47 (22.4)	163 (32.5)	
Source of Antimalarial Drugs	Hospital/Clinic	382 (53.7)	125 (59.5)	257 (51.2)	0.002
	Pharmacy	180 (25.3)	51 (24.3)	129 (25.7)	
	Patent Medicine Vendor	150 (21.0)	34 (16.2)	116 (23.1)	
Use of Herbal/Traditional Medicine	Yes	288 (40.5)	71 (33.8)	217 (43.2)	0.002
	No	424 (59.5)	139 (66.2)	285 (56.8)	

Note: Denominator for treatment completion and drug source is 712 (participants who used antimalarial drugs in the preceding two weeks).

Independent Predictors of Treatment Adherence and ITN Use

Multivariable logistic regression analyses were performed to identify independent predictors of treatment adherence, formal healthcare utilization, herbal medicine use, consistent insecticide-treated net use, and drug resistance awareness, adjusting for sociodemographic confounders. Results are presented in Table 5. For treatment adherence, awareness of drug resistance emerged as a strong independent predictor (aOR = 1.68; 95% CI: 1.25–2.25; p < 0.001). Healthcare workers also demonstrated significantly higher treatment adherence compared to students (aOR = 2.10; 95% CI: 1.50–2.95; p < 0.001). For formal healthcare utilization, awareness of drug resistance was an independent predictor (aOR = 1.45; 95% CI: 1.12–1.88; p = 0.005), as was urban residence (aOR = 1.30; 95% CI: 1.02–1.65; p = 0.035) and healthcare worker occupation (aOR = 3.20; 95% CI: 2.20–4.65; p < 0.001). For herbal medicine use, awareness of drug resistance was inversely associated (aOR = 0.65; 95% CI: 0.50–0.85; p = 0.002) , indicating that those aware of drug resistance were 35% less likely to use herbal medicine. Healthcare workers were also significantly less likely to use herbal medicine (aOR = 0.50; 95% CI: 0.35–0.70; p < 0.001).

For consistent insecticide-treated net use, female gender was the strongest predictor (aOR = 2.15; 95% CI: 1.65–2.80; p < 0.001). Awareness of drug resistance was not independently associated with insecticide-treated net use (aOR = 1.10; 95% CI: 0.85–1.42; p = 0.450), suggesting that knowledge of drug resistance does not necessarily translate to preventive behaviors like insecticide-treated net use. This highlights the need for targeted messaging that links treatment adherence and preventive behaviors, rather than treating them as separate health actions.

For drug resistance awareness, healthcare workers demonstrated significantly higher awareness compared to students (aOR = 3.80; 95% CI: 2.60–5.50; p < 0.001). Female gender was inversely associated with drug resistance awareness (aOR = 0.62; 95% CI: 0.46–0.83; p = 0.001), indicating that males had higher awareness. Urban residence was also associated with higher awareness (aOR = 1.40; 95% CI: 1.05–1.85; p = 0.020). Healthcare workers demonstrated markedly higher awareness of drug resistance (53.3% in bivariate analysis) compared to students (23.1%) and other occupational groups. This finding mirrors observations from Senegal (Tairou et al., 2022) and underscores the potential of healthcare workers as community educators. Systematically leveraging this cadre through structured outreach programs, including community health education sessions and school-based health promotion, could significantly improve information diffusion and address knowledge gaps in the wider population. We hypothesise that gendered differences in healthcare decision-making and exposure to health information may explain the observed patterns; however, this requires further qualitative investigation. Systematically leveraging healthcare workers through structured outreach programs could significantly improve information diffusion and address knowledge gaps in the wider population.

Table 5: Multivariable Logistic Regression for Predictors of Health-Seeking Behaviors and Drug Resistance Awareness

Predictor Variable	Treatment Completion aOR (95% CI), p	Formal Healthcare Use aOR (95% CI), p	Herbal Medicine Use aOR (95% CI), p	ITN Use aOR (95% CI), p	DR Awareness aOR (95% CI), p
Aware of Drug Resistance (Yes vs. No)	1.68 (1.25–2.25), <0.001	1.45 (1.12–1.88), 0.005	0.65 (0.50–0.85), 0.002	1.10 (0.85–1.42), 0.450	—
Gender (Female vs. Male)	0.95 (0.75–1.20), 0.650	0.88 (0.70–1.10), 0.260	1.05 (0.85–1.30), 0.630	2.15 (1.65–2.80), <0.001	0.62 (0.46–0.83), 0.001
Residence (Urban vs. Rural)	1.25 (0.98–1.60), 0.070	1.30 (1.02–1.65), 0.035	0.80 (0.60–1.05), 0.110	1.15 (0.90–1.47), 0.250	1.40 (1.05–1.85), 0.020
Occupation (HCW vs. Student)	2.10 (1.50–2.95), <0.001	3.20 (2.20–4.65), <0.001	0.50 (0.35–0.70), <0.001	1.40 (1.00–1.95), 0.050	3.80 (2.60–5.50), <0.001

Note: aOR = Adjusted Odds Ratio; CI = Confidence Interval; DR = Drug Resistance; HCW = Healthcare Worker.

Implications for Malaria Control and Policy:
The exceptionally low awareness of drug resistance (27.5%) represents a critical leverage point for intervention. To curtail the cycle of transmission and resistance, malaria control programs must evolve beyond commodity distribution to implement sustained, culturally resonant, and demographically targeted behavioral change communication. Specifically, interventions should: (1) prioritize drug resistance education, emphasize the consequences of incomplete treatment and the threat of resistance to individual and community health; (2) leverage healthcare workers as educators, establish structured community outreach programs to disseminate accurate information; (3) regulate informal drug distribution channels, strengthen oversight of patent medicine vendors and community pharmacies; (4) develop gender-sensitive messaging, address men specifically on treatment adherence while reinforcing preventive behaviors among women; and (5) integrate education into routine healthcare contacts, capitalize on antenatal care, school health programs, and community health worker visits.

Limitations
This study has several limitations that should be acknowledged. First, the cross-sectional design precludes causal inference between knowledge gaps and behaviors; while associations were identified, the temporal direction cannot be definitively established. Second, the sample, while large, was disproportionately female (77.0%) and urban (65.0%), which may affect generalizability to the wider male and rural populations of Osun State. This bias reflects recruitment through health facilities and community outreach programs, which may have attracted more women and urban residents. Third, data on behaviors such as insecticide-treated net use and treatment adherence were self-reported and subject to recall and social desirability biases. Third, the mixed household and outpatient health-facility recruitment strategy may introduce selection bias by over-representing care-seeking populations; this should be considered when interpreting the findings. Fourth, data on behaviors such as insecticide-treated net use and treatment adherence were self-reported and subject to recall and social desirability biases. Fifth, the study measured awareness of drug resistance but not the depth of understanding regarding mechanisms or implications. Sixth, we did not conduct parasitological confirmation of malaria diagnoses, relying instead on self-reported fever and treatment history. Future studies should adopt longitudinal designs to explore causal pathways, employ mixed-method approaches to contextualize cognitive-behavioral gaps, and incorporate biological endpoints to validate self-reported malaria episodes.

CONCLUSION
This study identifies profound and statistically significant gaps in knowledge, attitudes, and perceptions related to malaria transmission, treatment, and drug resistance among adults in Osun State, Nigeria. Awareness of drug resistance was independently associated with treatment completion, formal healthcare utilisation, and lower herbal medicine use, but not with ITN use. Female gender was independently associated with higher ITN use, while male gender and healthcare worker occupation were associated with higher drug resistance awareness. Given the cross-sectional design, these findings demonstrate associations rather than causal relationships. Interventions aimed at improving drug resistance education and treatment completion should be prioritised, and healthcare workers should be engaged as community educators. Longitudinal studies are needed to establish causal pathways.

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