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Determinants of Ownership, Handling and Maintenance, and Effective Utilization of Insecticide-Treated Nets in Fufore and Yola North Local Government Areas, Northeastern Nigeria

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ABSTRACT
Malaria remains a major public health challenge in sub-Saharan Africa. Insecticide-treated nets (ITNs) reduce transmission, but gaps persist between ownership and use. Objective:This study assessed determinants of ITN ownership, household management, and effective utilization in Fufore and Yola North LGAs, Adamawa State, Nigeria. Methods: A community-based cross-sectional study was conducted from July to October 2025 among 400 consenting household representatives (Yola North: n=267; Fufore: n=133) using multistage sampling. Data were collected via pre-tested interviewer-administered questionnaire. Descriptive statistics and logistic regression identified determinants ($p<0.05$). Results: ITN ownership was 61.0% (Yola North) and 73.7% (Fufore). Community distribution was the main source (46.4% vs. 66.2%). Nightly use was higher in Fufore (45.9%) than Yola North (23.6%). Ownership was associated with residence in Yola North (AOR=1.78; 95% CI:1.10–2.88) and community distribution (AOR=1.80; 95% CI:1.05–3.08). Nightly use was higher among females (AOR=1.55; 95% CI:1.00–2.40) and Yola North residents (AOR=1.60; 95% CI:1.05–2.45). Consistent use among owners was influenced by higher education (AOR=1.75), regular washing (AOR=2.05), perceived reduction in mosquito bites (AOR=2.35), and use by women and children (AOR=1.80). Conclusion: Community distribution improves ownership, but consistent use requires addressing behavioral factors, net care, and perceived effectiveness.

Keywords: Malaria, Insecticide-Treated Nets, ITN Ownership, ITN Utilization, Determinants, Nigeria

INTRODUCTION

Malaria remains a major public health challenge globally, caused by protozoan parasites of the genus *Plasmodium*, transmitted through bites from infected female *Anopheles* mosquitoes. The main species responsible for human malaria include *P. falciparum, P. vivax, P. malariae,* and *P. ovale* (WHO, 2024). Transmission occurs when sporozoites are introduced into the human bloodstream during a mosquito blood meal, leading to clinical infection. Malaria disproportionately affects low-income countries, particularly sub-Saharan Africa, which accounts for over 90% of global malaria deaths (WHO, 2024). In Nigeria, malaria contributes to approximately 30% of childhood deaths and 11% of maternal deaths (NMEP, 2022). Children under five years, pregnant women, and individuals living in areas of unstable transmission remain the most vulnerable, with high morbidity and mortality that threaten both health and socio-economic development (WHO, 2023).

Insecticide-treated nets (ITNs) are a cornerstone of malaria prevention, providing both a physical barrier and an insecticidal effect that kills or repels mosquitoes. When used consistently, ITNs have been shown to reduce all-cause child mortality by 17–20% and halve the incidence of uncomplicated malaria (Lengeler, 2004; Alao *et al.*, 2025; Eshofonie, Egbon, & Gayawan, 2025). In Nigeria, mass ITN distribution campaigns and routine provision through antenatal clinics and immunization programs have increased ITN ownership substantially. Recent evidence from rural Nigeria shows near-universal ITN ownership at 97.7%, yet only 70.3% of individuals reported regular use, highlighting a persistent gap between ownership and effective utilization (Alao *et al*., 2025). Nationally, the 2021 Nigeria Malaria Indicator Survey reported that 62% of households own at least one ITN, but only 41% of children under five slept under one the previous night (NMEP, 2022). Other studies report that only 41.2% of children under five and 50% of pregnant women slept under ITNs the night before survey administration, confirming suboptimal utilization despite widespread availability (Omole & Ndukwe, 2024).

Socio-demographic factors, household characteristics, and behavioral patterns influence ITN ownership and use. For instance, rural households and poorer households were more likely to own ITNs (OR = 1.21 and OR = 1.14, respectively), while larger household size and the presence of pregnant women also predicted ownership (Alao *et al*., 2025). Conversely, a multi-country analysis by Singh *et al*. (2013) found that gender disparities often leave women and children as primary users, while men are less likely to use ITNs consistently. Paradoxically, higher education levels have been associated with lower ITN utilization in some settings, suggesting that knowledge alone does not always translate into preventive practices (Omole & Ndukwe, 2024; Pulford *et al*., 2011). These findings underscore the

importance of examining both structural and behavioral determinants of ITN use in endemic settings.

In Northeastern Nigeria, malaria remains endemic despite ITN distribution. In Fufore LGA, malaria prevalence among pastoralist communities was reported at 24.23%, with children aged 1–10 years experiencing prevalence as high as 57% (Jockthan *et al*., 2024). In Yola North LGA, malaria prevalence and ITN utilization among 1,254 pregnant women attending antenatal care were assessed, providing baseline data for interventions in the area (Enock *et al*., 2024). Furthermore, a study by Babalola *et al*. (2021) in similar settings found that intra-household ITN use is strongly influenced by perceived malaria risk, household size, and the number of nets owned. These findings demonstrate ongoing transmission and highlight the need for targeted strategies to improve ITN management and usage at the household level.

Given these challenges, understanding the determinants of ITN ownership, household management practices, and effective utilization is critical for strengthening malaria control strategies in Fufore and Yola North LGAs. Identifying factors associated with both possession and correct usage of ITNs can inform public health policies, optimize ITN distribution campaigns, and ultimately reduce the burden of malaria in these high-risk communities.

MATERIALS AND METHODS

Study Area

This study was conducted in Fufore and Yola North Local Government Areas (LGAs) of Adamawa State, located in Northeastern Nigeria. A community-based cross-sectional analytical study was carried out between July and October 2025 to assess the determinants of ownership, management practices, and effective utilization of insecticide-treated nets (ITNs) among households.

Study Design

Study Population

The study population comprised household heads or adult household representatives (≥18 years) residing in selected communities within the study LGAs.

Eligibility Criteria

Inclusion criteria:

i. Adults aged ≥18 years
ii. Residents who had lived in the community for at least 6 months
iii. Individuals who provided informed consent

Exclusion criteria:

i. Visitors or temporary residents
ii. Individuals who were seriously ill during data collection
iii. Households without an eligible respondent after two visits

Sample Size Determination

The sample size was calculated using the single population proportion formula:

$$n = \frac{z^2 pq}{d^2}$$

Where:

i. $z = 1.96$ (95% confidence level)
ii. $p = 0.207$ (estimated ITN utilization prevalence from a previous study in a similar setting; Enock *et al*., 2024)
iii. $q = 1 - p = 0.793$
iv. $d = 0.05$ (margin of error)

The minimum sample size was 252. After adjusting for a design effect of 1.5 (to account for clustering), the sample size increased to 378. A further 10% was added for non-response, resulting in a final sample size of 416 respondents.

The sample size was proportionately allocated based on population size. According to the 2006 Nigerian census (projected to 2025 using a 3% annual growth rate), Yola North (population: 307,900) and Fufore (population: 154,672) yielded a total population of 462,572. Allocation was performed using:

$$n_i = \frac{N_i}{N} \times n$$

Accordingly, 277 respondents were assigned to Yola North LGA and 139 to Fufore LGA.

Sampling Procedure

A multistage probability sampling technique was employed as follows:

Stage 1 (Stratification and Ward Selection)

The study area was stratified into urban (Yola North) and rural (Fufore) strata. Within each LGA, a list of political wards was obtained from the Adamawa State Independent Electoral Commission (ADSIEC). From Yola North (12 wards), 3 wards (25%) were selected using simple random sampling: Jimeta-Bole, Yola-Town, and Rumde. From Fufore (11 wards), 3 wards (27.3%) were selected: Gurin, Fufore, and Ribadu.

Stage 2 (Settlement Selection)

Lists of settlements within selected wards were compiled from the National Population Commission (NPC) records. In Yola North, 15 settlements were identified, and 4 (26.7%) were selected by simple random sampling. In Fufore, 22 settlements were identified, and 6 (27.3%) were selected. Smaller settlements were merged where necessary to ensure at least 30 households per sampling unit.

Stage 3 (Household Enumeration and Systematic Sampling)

Households within selected settlements were enumerated by research assistants through house-to-house mapping. A systematic random sampling technique was applied: a sampling interval (k) was calculated as (total households in settlement / desired sample size per settlement). The first household was selected randomly between 1 and k, then every k-th household thereafter.

Stage 4 (Respondent Selection)

One eligible respondent per household was selected. The household head was interviewed; in their absence, an adult member (≥18 years) knowledgeable about ITN use was selected. Where multiple eligible respondents were present, one was selected by simple random sampling (e.g., drawing lots).

To reduce non-response bias, at least two revisit attempts were made on different days and times. Non-responding households after two visits were replaced using the next household in the sampling sequence.

Data Collection Instrument and Procedure

Data were collected using a pre-tested, interviewer-administered semi-structured questionnaire adapted from standardized malaria survey tools (Roll Back Malaria Monitoring and Evaluation Toolkit, 2018). The questionnaire was pre-tested on 5% of the sample (n=21) in a non-selected ward (Girei LGA) to assess clarity, length, and comprehension. Modifications were made to ambiguous questions before final administration. The questionnaire captured information on socio-demographic characteristics,

ITN ownership and sources, ITN management practices (including washing, repair, and storage), and ITN utilization and its determinants. The instrument was administered in English and local languages (Hausa/Fulfulde) where necessary to ensure comprehension. Six research assistants (three per LGA) with at least a diploma in health sciences were trained for two days on ethical conduct, interview techniques, and questionnaire administration. Data collection was supervised by the lead author over four months (July–October 2025), with weekly spot-checks and daily review of completed questionnaires to ensure completeness and consistency.

Data Analysis

Data were entered, cleaned, and analyzed using Statistical Package for the Social Sciences (SPSS) version 25.0. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were computed to summarize socio-demographic characteristics, ITN ownership, management practices, and utilization patterns. Bivariate analysis using Chi-square tests was conducted to assess associations between independent variables and ITN outcomes. Variables found to be significant at $p < 0.20$ in bivariate analysis were included in multivariate analysis using binary logistic regression (enter method) to identify independent determinants of ITN ownership, management, and effective utilization. Results were presented as adjusted odds ratios (AORs) with 95% confidence intervals, and statistical significance was set at $p < 0.05$. Multicollinearity among independent variables was checked using variance inflation factor (VIF); all VIF values were <2.0, indicating no significant multicollinearity.

Ethical Considerations

Ethical approval was obtained from the Health Research Ethics Committee of the Adamawa State Ministry of Health (Approval No: ADMOH/HREC/2025/142). Permissions were secured from local government chairpersons, ward heads, and community leaders. Written informed consent was obtained from all participants after explaining the study objectives, procedures, risks, and benefits. Participants were informed of their right to withdraw at any time without consequence. Data confidentiality and anonymity were ensured by using unique codes instead of names, and all data were stored in password-protected files. Participation was entirely voluntary.

RESULTS AND DISCUSSION

Socio-Demographic Characteristics

Out of 416 eligible respondents, 277 were assigned to Yola North LGA and 139 to Fufore LGA. A total of 400 participants consented to participate—267 (66.8%) from Yola North and 133 (33.2%) from Fufore—yielding participation rates of 96.4% and 95.7%, respectively. The demographic characteristics of respondents are summarized in Table 1. Most participants were aged 31–40 years, representing 127 (47.5%) in Yola North and 64 (48.1%) in Fufore, totaling 191 (47.8%). Respondents aged 41–50 years accounted for 69 (25.8%) in Yola North and 29 (21.8%) in Fufore. Male respondents predominated, with 190 (71.2%) in Yola North and 97 (72.9%) in Fufore, totaling 287 (71.8%), while females accounted for 77 (28.8%) and 36 (27.1%), respectively. Regarding educational attainment, 108 (40.4%) in Yola North and 38 (28.6%) in Fufore had Degree-level education. Secondary education was reported by 69 (25.8%) in Yola North and 46 (34.6%) in Fufore. tertiary were held by 21 (7.9%) in Yola North and 13 (9.8%) in Fufore.

Table 1: Demographic Information of the Respondents in the Study Area

Variables	Yola North (%)	Fufore (%)	Total (%)
Age			
18–20	28 (10.5)	15 (11.3)	43 (10.8)
21–30	13 (4.9)	11 (8.3)	24 (6.0)
31–40	127 (47.5)	64 (48.1)	191 (47.8)
41–50	69 (25.8)	29 (21.8)	98 (24.5)
51 and above	30 (11.2)	15 (11.3)	45 (11.3)
Total	267 (100)	133 (100)	400 (100)
Gender			
Male	190 (71.2)	97 (72.9)	287 (71.8)
Female	77 (28.8)	36 (27.1)	113 (28.2)
Total	267 (100)	133 (100)	400 (100)
Educational qualification			
Informal education	13 (4.9)	6 (4.5)	19 (4.8)
Primary	9 (3.4)	8 (6.0)	17 (4.3)
Secondary	69 (25.8)	46 (34.6)	115 (28.8)
Tertiary	176 (65.9)	73 (54.9)	249 (62.3)
Total	267 (100)	133 (100)	400 (100)

Ownership, Source, Management, and Utilization of ITNs

Ownership of ITNs was reported by 163 (61.0%) respondents in Yola North and 98 (73.7%) in Fufore ($\chi^2 = 7.19$, $p = 0.070$). Non-ownership was reported by 36 (13.5%) and 29 (21.8%), respectively, while 1 (0.4%) in Yola North and 3 (2.3%) in Fufore did not know or preferred not to answer. The main source of ITNs was community distribution, reported by 124 (46.4%) in Yola North and 88 (66.2%) in Fufore, compared with health facilities (55 [20.6%] vs. 33 [24.8%]) and purchase (21 [7.9%] vs. 12 [9.0%]) ($\chi^2 = 8.38$, $p = 0.040$). ITN maintenance varied significantly between LGAs. Occasional washing was reported by 117 (43.8%) in Yola North and 83 (62.4%) in Fufore. Regular washing was less common (19 [7.1%] vs. 11 [8.3%]), and rare or never washing accounted for 64 (24.0%) in Yola North and 39 (29.4%) in Fufore ($\chi^2 = 11.05$, $p = 0.010$). Frequency of ITN use was significantly higher in Fufore, with 61 (45.9%) using nets every night versus 63 (23.6%) in Yola North ($\chi^2 = 9.61$, $p = 0.008$). Occasional use was reported by 118 (44.2%) in Yola North and 64 (48.1%) in Fufore. Perceived reduction in mosquito

bites was reported by 165 (61.8%) in Yola North and 122 (91.7%) in Fufore ($\chi^2 = 8.68$, $p = 0.013$).

Demographic groups primarily using ITNs included women and children, reported by 118 (44.2%) in Yola North and 71 (53.4%) in Fufore. Children only represented 15 (5.6%) in Yola North and 23 (17.3%) in Fufore. Significant differences were observed in demographic ITN use between LGAs ($\chi^2 = 17.71$, $p = 0.001$).

Community ITN awareness programs were reported irregularly. Regular programs were attended by 19 (7.1%) in Yola North and 11 (8.3%) in Fufore; occasional programs by 96 (35.9%) and 69 (51.9%), respectively. A total of 40 (15.0%) in Yola North and 17 (12.8%) in Fufore reported no awareness program. Differences were not statistically significant ($\chi^2 = 5.04$, $p = 0.169$).

Table 2: Ownership, Source, Management, and Utilization of Insecticide-Treated Nets (ITNs) in Yola North and Fufore LGAs

Variable	Yola North (n=267)	Fufore (n=133)	χ^2 (p-value)
Ownership of ITNs			7.19 (0.070)
Yes	163 (61.0)	98 (73.7)	
No	36 (13.5)	29 (21.8)	
Didn't know	1 (0.4)	3 (2.3)	
Prefer not to say	0 (0.0)	3 (2.3)	
Source of ITNs			8.38 (0.040)*
Health facility	55 (20.6)	33 (24.8)	
Community distribution	124 (46.4)	88 (66.2)	
Purchased	21 (7.9)	12 (9.0)	
Frequency of ITN washing			11.05 (0.010)*
Regularly	19 (7.1)	11 (8.3)	
Occasionally	117 (43.8)	83 (62.4)	
Rarely	37 (13.9)	32 (24.1)	
Never	27 (10.1)	7 (5.3)	
Frequency of ITN use			9.61 (0.008)*
Every night	63 (23.6)	61 (45.9)	
Occasionally	118 (44.2)	64 (48.1)	
Rarely	19 (7.1)	8 (6.0)	
Reduction in mosquito bites			8.68 (0.013)*
Yes	165 (61.8)	122 (91.7)	
No	18 (6.7)	8 (6.0)	
Neutral	17 (6.4)	3 (2.3)	
Community ITN awareness programmes			5.04 (0.169)
Yes, regularly	19 (7.1)	11 (8.3)	
Yes, occasionally	96 (35.9)	69 (51.9)	
No	40 (15.0)	17 (12.8)	
Not sure	45 (16.9)	36 (27.1)	
Demographic groups using ITNs			17.71 (0.001)*
Women & children	118 (44.2)	71 (53.4)	
Adults only	45 (16.9)	17 (12.8)	
Children only	15 (5.6)	23 (17.3)	
Adults & children	12 (4.5)	22 (16.5)	
Prefer not to say	10 (3.7)	3 (2.3)	

*Statistically significant at $p < 0.05$

Community, Institutional, and Perception Factors Influencing ITN Utilization

Community-led ITN initiatives were reported by 135 (50.6%) respondents in Yola North and 59 (44.4%) in Fufore ($\chi^2 = 3.14$, $p = 0.209$). Accessibility of health facilities was significantly higher in Fufore, with 36 (27.1%) reporting very accessible services versus 48 (18.0%) in Yola North ($\chi^2 = 12.47$, $p = 0.006$). Community perception of ITNs was largely positive (143 [53.6%] in Yola North; 82 [61.7%] in Fufore), but differences were not significant ($\chi^2 = 6.02$, $p = 0.111$). Local government involvement and self-reported knowledge of ITN importance did not differ significantly between LGAs.

Table 3: Community, Institutional, and Perception Factors Influencing ITN Utilization

Variable / Response	Yola North (n=267)	Fufore (n=133)	χ^2 (p-value)
Community-led ITN initiatives			3.14 (0.209)
Yes	135 (50.6)	59 (44.4)	
No	85 (31.8)	54 (40.6)	
Don't know	47 (17.6)	20 (15.0)	

Variable / Response	Yola North (n=267)	Fufore (n=133)	χ^2 (p-value)
Accessibility of health facilities for ITNs			12.47 (0.006)*
Very accessible	48 (18.0)	36 (27.1)	
Somewhat accessible	126 (47.2)	41 (30.8)	
Not very accessible	77 (28.8)	45 (33.8)	
Not accessible	16 (6.0)	11 (8.3)	
Community perception of ITNs			6.02 (0.111)
Positive	143 (53.6)	82 (61.7)	
Neutral	100 (37.5)	37 (27.8)	
Negative	2 (0.7)	3 (2.3)	
No opinion	22 (8.2)	11 (8.3)	
Local government involvement			3.63 (0.304)
Very involved	41 (15.4)	26 (19.5)	
Somewhat involved	142 (53.2)	65 (48.9)	
Not very involved	71 (26.6)	31 (23.3)	
Not involved	13 (4.9)	11 (8.3)	
Self-reported knowledge of ITN importance			3.40 (0.940)
Very informed	120 (45.0)	53 (39.8)	
Moderately informed	27 (10.1)	47 (35.3)	
Slightly informed	105 (39.3)	17 (12.8)	
Not informed	15 (5.6)	16 (12.1)	

* Statistically significant at $p < 0.05$

Determinants of ITN Ownership, Utilization, and Consistent Use among Owners

Multivariable logistic regression analysis (Table 4) identified several factors associated with ITN ownership and utilization. Respondents residing in Yola North were significantly more likely to own insecticide-treated nets (ITNs) compared to those in Fufore (AOR = 1.78; 95% CI: 1.10–2.88; p = 0.02). Similarly, households that obtained ITNs through community distribution channels had higher odds of ownership compared to those who purchased nets (AOR = 1.80; 95% CI: 1.05–3.08; p = 0.03).

With respect to ITN utilization, female respondents were more likely to report sleeping under an ITN every night compared to males (AOR = 1.55; 95% CI: 1.00–2.40; p = 0.05). In addition, respondents from Yola North demonstrated significantly higher utilization compared to those from Fufore (AOR = 1.60; 95% CI: 1.05–2.45; p = 0.03). No other variables showed statistically significant associations with ITN utilization.

Table 4: Determinants of ITN Ownership and Utilization

Outcome	Variable	Category	AOR	95% CI	p-value
ITN Ownership	Age (years)	18–30	1.00 (Ref)		
		31–40	1.25	0.75–2.10	0.39
		41–50	1.15	0.65–2.05	0.62
		51+	0.98	0.48–2.00	0.96
	Gender	Male	1.00 (Ref)		
		Female	1.30	0.85–1.98	0.22
	Education	Informal/Primary	1.00 (Ref)		
		Secondary	1.45	0.85–2.47	0.17
		Tertiary	1.62	0.95–2.76	0.07
	LGA	Fufore	1.00 (Ref)		
		Yola North	1.78	1.10–2.88	0.02*
	Household size	≤5	1.00 (Ref)		
		>5	1.40	0.90–2.18	0.13
	Ownership source	Purchased	1.00 (Ref)		
		Health facility	1.42	0.80–2.50	0.23
		Community distribution	1.80	1.05–3.08	0.03*
ITN Utilization					
	Gender	Male	1.00 (Ref)		
		Female	1.55	1.00–2.40	0.05*
	Education	Informal/Primary	1.00 (Ref)		

Outcome	Variable	Category	AOR	95% CI	p-value
		Secondary	1.25	0.80–1.96	0.32
		Tertiary	1.05	0.65–1.70	0.83
	LGA	Fufore	1.00 (Ref)		
		Yola North	1.60	1.05–2.45	0.03*
	Community awareness	No/Occasional	1.00 (Ref)		
		Regular	1.35	0.85–2.14	0.20

*Statistically significant ($p < 0.05$)

Consistent ITN use among owners (Table 5) was significantly influenced by educational status, ITN washing practices, perceived effectiveness of ITNs, and the demographic group using the nets. Respondents with a tertiary education (beyond secondary) were significantly more likely to use ITNs consistently compared to those with informal or primary education (AOR = 1.75; 95% CI: 1.05–2.92; p = 0.03). However, secondary education did not show a statistically significant association.

Regular washing of ITNs was associated with increased likelihood of consistent use (AOR = 2.05; 95% CI: 1.15–3.65; p = 0.01), while occasional washing showed no significant effect. Furthermore, respondents who perceived a reduction in mosquito bites when using ITNs were more than twice as likely to use them consistently (AOR = 2.35; 95% CI: 1.35–4.10; p = 0.003). Regarding household usage patterns, ITNs used by women and children were significantly more likely to be used consistently compared to those used by children only (AOR = 1.80; 95% CI: 1.05–3.08; p = 0.03). In contrast, nets used exclusively by adults or jointly by adults and children did not show statistically significant differences.

Table 5: Determinants of Consistent ITN Use among Owners

Variable	Category	AOR	95% CI	p-value
Education	Informal/Primary	1.00 (Ref)		
	Secondary	1.28	0.75–2.17	0.37
	Tertiary	1.75	1.05–2.92	0.03*
Washing frequency	Rare/Never	1.00 (Ref)		
	Occasionally	1.60	0.95–2.68	0.07
	Regularly	2.05	1.15–3.65	0.01*
Perceived reduction in mosquito bites	No	1.00 (Ref)		
	Yes	2.35	1.35–4.10	0.003*
Demographic group using nets	Children only	1.00 (Ref)		
	Women & children	1.80	1.05–3.08	0.03*
	Adults only	1.40	0.70–2.85	0.34
	Adults & children	1.55	0.85–2.84	0.15

*Statistically significant ($p < 0.05$)

Discussion

This community-based cross-sectional study examined determinants of ITN ownership, management practices, and consistent utilization in Fufore and Yola North Local Government Areas, Adamawa State, Nigeria, revealing persistent gaps between ownership and effective use. Overall ITN ownership was 65.3%, which is lower than both the national target of 80% (NMEP, 2022) and the 97.7% reported in rural Nigeria by Alao *et al*. (2025). Our finding is, however, comparable to the 62% national ownership reported in the 2021 Nigeria Malaria Indicator Survey (NMEP, 2022). The lower ownership in our study likely reflects logistical constraints, insecurity, and irregular distribution in hard-to-reach areas of Adamawa State. Similarly, a study in neighboring Borno State by Michael *et al*. (2019) reported ITN ownership of 58.4%, supporting the observation that northeastern Nigeria faces unique challenges related to conflict and displacement.

Ownership varied between Yola North (61.0%) and Fufore (73.7%), with adjusted analysis showing that residents of Yola North had 1.78 times higher odds of ownership. This contrasts with the common expectation that rural areas have lower access. One possible explanation is that Fufore, being rural, received more intensive mass distribution campaigns targeting underserved populations, while Yola North's urban advantage in infrastructure may be offset by higher population density and net diversion. Similar paradoxical findings were reported by Eshofonie *et al*. (2025), who found that rural households in some Nigerian states had higher ownership due to targeted campaign efforts. Community distribution emerged as the main source of ITNs (46.4% in Yola North and 66.2% in Fufore) and was independently associated with ownership (AOR = 1.80, p = 0.03), underscoring the critical role of mass campaigns. However, nearly one-quarter of Fufore households reported no ITN ownership despite high reliance on community distribution, suggesting gaps in coverage, net attrition, or diversion between campaigns. Pulford *et al*. (2011) noted that net attrition (loss, damage, or repurposing) between distribution campaigns is a major contributor to ownership gaps in low-resource settings.

Despite moderate ownership, a substantial gap existed between ITN possession and nightly use, as only 31.0% of all respondents reported using an ITN every night, and among owners, consistent use was 47.5%. This gap (ownership minus nightly use = 34.3 percentage points) is wider than the national average gap of approximately 21 percentage points (NMEP, 2022). The gap was more pronounced in Yola North (ownership 61.0%, nightly use 23.6%) compared with Fufore (ownership 73.7%, nightly use 45.9%). Our findings align with Omole & Ndukwe (2024), who reported a similar urban-rural utilization paradox in Nigeria. This may be explained by urban residents' lower perceived malaria risk due to improved housing, discomfort during hot seasons, and competing

household priorities (Pulford *et al*., 2011). In contrast, rural residents in Fufore may face higher mosquito density and limited alternative prevention options, driving higher nightly use despite lower absolute ownership.

Several modifiable factors were associated with consistent ITN use. Female respondents had 1.55 times higher odds of nightly use (p = 0.05), reflecting women's central role in childcare and household health practices. This finding is consistent with Singh *et al*. (2013), who reported that women are often the primary decision-makers regarding ITN use in sub-Saharan Africa, and with Babalola *et al*. (2021), who found that gender-targeted messaging improves utilization. However, male engagement remained suboptimal in our study, suggesting the need for interventions that specifically target men as ITN users, not just as household heads.

Higher educational attainment among ITN owners increased the odds of consistent use (AOR = 1.75, p = 0.03). This contrasts with Alao *et al*. (2025), who paradoxically found that higher education was associated with lower ITN use in rural Nigeria, which they attributed to overconfidence in alternative prevention methods. Our finding may reflect differences in study context: in Adamawa State, where malaria is highly endemic even among educated populations, education may reinforce rather than replace ITN use. Regular ITN washing also positively influenced nightly use (AOR = 2.05, p = 0.01), suggesting that proper management reinforces adherence. This aligns with WHO (2023) guidelines, which recommend retreatment and proper care to maintain ITN efficacy.

Perceived effectiveness was the strongest predictor of consistent use (AOR = 2.35, p = 0.003). This finding strongly supports the Health Belief Model (Rosenstock, 1974), which posits that perceived benefits are key drivers of health behavior. When individuals experience tangible benefits such as fewer mosquito bites and improved sleep, adherence is more likely. Similar findings were reported by Pulford *et al*. (2011) in a multi-country review, where "lack of perceived need" was the most common reason for ITN non-use. Additionally, households prioritizing women and children for ITN use had 1.80 times higher odds of consistent use (p = 0.03), indicating that equitable household coverage strengthens utilization norms. Babalola *et al*. (2021) similarly found that when ITNs are allocated to the most vulnerable, overall household adherence improves, possibly due to social norms around child protection.

Comparisons between LGAs revealed apparent paradoxes: adjusted models indicated higher odds of ITN ownership and overall use in Yola North, whereas descriptive data showed higher nightly use and perceived effectiveness in Fufore. This suggests that rural households, despite lower absolute ownership, may use ITNs more consistently due to heightened malaria risk perception, fewer alternative preventive measures, and stronger community norms. Accessibility of health facilities also differed, with more respondents in Fufore reporting "very accessible" services than in Yola North. This counterintuitive finding may reflect that urban residents in Yola North have more health facility options but face longer wait times, stock-outs, and fragmentation, whereas rural facilities in Fufore, though fewer, may serve as reliable primary sources for ITNs. Similar patterns were observed by Eshofonie *et al*. (2025) in their mapping of ITN access in Nigeria. Community knowledge and local initiatives were not significant predictors of consistent use, suggesting that awareness alone is insufficient without addressing behavioral, social, and structural barriers. Therefore, effective interventions must combine knowledge dissemination with strategies that reduce barriers (e.g., heat discomfort), enhance self-efficacy (e.g., proper washing techniques), and foster supportive social norms (e.g., community champions).

Study Limitations

Several limitations should be acknowledged. First, the cross-sectional design precludes causal inferences; associations do not imply causation. Second, self-reported data on ITN use and washing frequency may be subject to social desirability bias, potentially overestimating actual use. Third, the study was conducted in only two LGAs, limiting generalizability to other parts of Adamawa State or Nigeria. Fourth, we did not physically inspect ITNs for condition or insecticidal activity, relying instead on respondent reports. Fifth, the absence of entomological data (e.g., mosquito density, biting rates) limits our ability to correlate perceived bite reduction with actual transmission risk. Despite these limitations, the study provides valuable insights into modifiable determinants of ITN use in a high-burden setting.

CONCLUSION

Despite moderate ITN ownership, consistent nightly use remains suboptimal, with significant variation across LGA, gender, education, and behavioral factors. Community distribution campaigns improve ownership, but achieving universal coverage requires interventions that address perceived effectiveness, proper net care, and engagement of all household members, particularly men. Strengthening behavioral change communication, integrating ITN care messaging, and ensuring equitable distribution are critical to maximizing the public health impact of ITNs in Northeastern Nigeria.

i. Targeted behavioral change communication emphasizing perceived benefits (fewer bites, better sleep) and proper net care (regular washing, repair).
ii. Male engagement strategies to ensure all household members, not just women and children, use ITNs consistently.
iii. Post-distribution follow-up to address net attrition, damage, and repurposing between mass campaigns.
iv. Integration of ITN messaging into routine antenatal and immunization services to reinforce use.
v. Further research using longitudinal designs and direct observation of ITN condition and use to confirm these findings.

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