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# Knowledge, utilization, and misuse of insecticide-treated nets and community acceptance of picture-embedded nets in rural Tanzania

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## Abstract

**Background:** Insecticide-Treated Nets (ITNs) remain one of the most effective malaria prevention interventions, reducing malaria morbidity and mortality in endemic regions. However, despite widespread distribution of ITNs in Tanzania, consistent utilization and proper maintenance remain challenging. This study assessed community knowledge, perceptions, practices, and factors influencing bed net use, including acceptance of picture-embedded ITNs, in Kilosa District, Tanzania.

**Methodology:** A cross-sectional survey was conducted in four Kilosa District villages, Tanzania, from December 2024 to February 2025. Two hundred households participated, with heads or knowledgeable adults interviewed. Data covered knowledge, perceptions, bed-net use, maintenance, misuse, and willingness to use picture-embedded ITNs. R was used for descriptive and logistic regression analyses.

**Results:** Awareness of mosquitoes, malaria, and bed nets was universal (100%). Although 80% preferred bed nets for mosquito protection, only 44.5% currently used them and 33.5% used them nightly. Heat and discomfort were major barriers. Education level (P=0.003), household lighting (P=0.005), and cooking fuel (P=0.046) were associated with bed net use. Maintenance knowledge gaps and misuse were common. Most preferred education over punishment, while 77% favored picture-embedded ITNs for improved attractiveness and room appearance.

**Conclusions:** Despite high awareness, consistent ITNs use remains low in rural Kilosa. Strengthened community education and picture-embedded ITNs may improve utilization and malaria prevention.

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## Introduction

Despite significant global efforts to control malaria, with the ultimate goal of elimination, the disease remains a leading cause of illness and death in tropical regions, particularly in Sub-Saharan Africa (SSA), which accounted for 94% of all malaria cases and 95% of malaria-related deaths worldwide in 2023 [1]. In Tanzania, malaria prevalence was estimated at 8.1% in 2022, with substantial regional variation, including areas such as the southern zone where prevalence reached 24% [2]. The National Malaria Control Programme (NMCP) and the Zanzibar Malaria Elimination Programme (ZAMEP), along with partner organizations, implement a range of preventive and curative interventions. Among these, the distribution and use of insecticide-treated nets (ITNs) remain a cornerstone strategy for malaria prevention [3-5]. Proper use of ITNs has been shown to reduce malaria morbidity by 50% globally and under-five mortality by 17% [6]. However, the effectiveness of ITNs depends on their availability and consistent, correct usage, which is closely influenced by individual and community knowledge, perceptions, and practices [6].

Several individual and community-level factors determine ITN ownership and use. Studies across SSA have shown that gaps in malaria knowledge, combined with misconceptions about bed-net use, limit their optimal utilization [6,7]. In some communities, bed nets are repurposed for activities such as fishing or tending poultry [8-12]. Additionally, insufficient knowledge can lead to improper maintenance, with bed nets remaining unchanged, torn, untreated, or used in unhygienic conditions [12]. The reasons behind such practices, which divert ITNs from their primary purpose of household malaria prevention, remain poorly understood.

A comprehensive understanding of community knowledge and practices regarding malaria prevention tools, including ITNs, is therefore essential. This study aimed to evaluate knowledge, perceptions, and practices related to bed-net use at the household level in villages within Kilosa District, Tanzania. The findings will contribute to a broader understanding of malaria control challenges in endemic settings and inform strategies to enhance the effectiveness of ITNs in Kilosa District.

## Materials and methods

### Study area

This study was conducted in four villages-Makwambe (S 6°28'31.85" E 37°7'17.50"), Unone (S 6°34'44.99" E 37°4'5.73"), Zombo (S 6°58'39.44" E 36°54'40.84"), and Ihombwe (S 7°17'7.82" E 36°55'19.01")-in Kilosa District, Tanzania. Kilosa District has an annual temperature of 20–32°C and receives 800–1000 mm of rainfall [13], with wet and dry seasons from January–June and July–December, respectively [14]. Agriculture dominates the economy, with maize, sunflower, rice, and sugarcane as major crops [13]. Malaria remains endemic, with prevalence of 14.2% by microscopy and 17.5% by mRDTs [15]. The tropical climate, seasonal rainfall, and agricultural activities favor mosquito breeding and sustained malaria transmission.

### Study design

This study employed a convergent mixed-methods cross-sectional design, integrating quantitative household survey data with qualitative responses obtained through semi-structured interview questions.

### Sample size calculation and sampling

The sample size was calculated using the single population proportion formula at a 95% confidence level. Although national estimates of malaria prevalence and ITN ownership are available, no recent study has assessed community knowledge, perceptions, misuse, and willingness to adopt picture-embedded ITNs in Kilosa District. Therefore, a prevalence of 50% was assumed to maximize variability and obtain the most conservative sample size. Using a 7% margin of error, the minimum sample size was estimated at 196 households and rounded to 200. A total of 200 households (50 per village) were recruited from four study villages. In the absence of a household sampling frame, convenience sampling was adopted. Households were approached consecutively from different geographical sections of each village during different times of the day to maximize participation and reduce selection bias.

### Study population

The study included household heads or knowledgeable adults aged ≥18 years who had lived in selected villages for at least six months and provided written informed consent. Visitors, recent residents, severely ill individuals, and those unable to participate in interviews were excluded.

### Pretesting of data collection tools

The questionnaire was developed from literature and reviewed by malaria and public health experts for validity. It was pretested among 20 households (10% of the sample) in a comparable village. Feedback refined the tool, while Cronbach's alpha ($\alpha \geq 0.70$) assessed internal consistency and reliability.

### Data collection

Data were collected through face-to-face interviews using a standardized questionnaire translated from English into Swahili. The quantitative component assessed knowledge, perceptions, and practices regarding Insecticide-Treated Nets (ITNs), including their use, repair, disposal, acceptance of picture-embedded nets, and local bylaws. The qualitative component explored participants' perspectives on barriers to ITN use, misuse, and acceptance of picture-embedded ITNs through open-ended questions. Household observations by trained researchers subsequently verified bed net ownership, condition, and use, validating self-reported responses.

### Statistical analysis

Data were coded, cleaned, and analyzed in R (v4.4.1). Descriptive statistics summarized participants' sociodemographic, socioeconomic, knowledge, perception, and bed net use characteristics. Logistic regression assessed associations between bed net use and sociodemographic or socioeconomic factors. The model with the lowest Akaike Information Criterion (AIC) was selected.

## Results

### Socio-demographic, socio-economic, and household characteristics of respondents

The study included 200 respondents, predominantly female (53.0%), aged 26-35 years (40.5%), with secondary education (37.0%), farmers (49.5%), and married (73.0%), while most households had brick walls and metal roofs (97.0%), relied on dug-up wells for water (93.0%), electricity for lighting (72.0%), and charcoal for cooking (54.5%) (Table 1).

**Table 1:** Socio-demographic, socio-economic, and household characteristics of respondents across the study villages (N=200).

| Characteristics | Category | n (%) |
|---|---|---|
| **Age (years)** | <25 | 17 (8.5) |
| | 26-35 | 81 (40.5) |
| | 36-45 | 58 (29.0) |
| | ≥46 | 44 (22.0) |
| **Sex** | Female | 106 (53.0) |
| | Male | 94 (47.0) |
| **Education** | No formal education | 40 (20.0) |
| | Primary | 66 (33.0) |
| | Secondary | 74 (37.0) |
| | College | 17 (8.5) |
| | University | 3 (1.5) |
| **Occupation** | Farmer | 99 (49.5) |
| | Business person | 43 (21.5) |
| | Unemployed | 25 (12.5) |
| | Motorcycle driver | 32 (16.0) |
| | Teacher | 1 (0.5) |

| | | |
|---|---|---|
| **Marital status** | Single | 47 (23.5) |
| | Married | 146 (73.0) |
| | Divorced/separated | 3 (1.5) |
| | Widow/widower | 4 (2.0) |
| **Monthly household income (TZS)** | Around 150,000 | 2 (1.0) |
| | Around 300,000 | 1 (0.5) |
| | Around 430,000 | 1 (0.5) |
| | Don't know | 8 (4.0) |
| | Prefer not to say | 188 (94.0) |
| **Roof type** | Metal | 194 (97.0) |
| | Thatched | 6 (3.0) |
| **Wall type** | Brick | 194 (97.0) |
| | Mud | 6 (3.0) |
| **Water source** | Dug-up well | 186 (93.0) |
| | Pump water | 14 (7.0) |
| **Source of lighting** | Electricity | 144 (72.0) |
| | Solar lamps | 55 (27.5) |
| | Rechargeable lamps | 1 (0.5) |
| **Cooking fuel** | Gas | 71 (35.5) |
| | Charcoal | 109 (54.5) |
| | Firewood | 20 (10.0) |

**Table 2:** Unadjusted associations between selected respondent and household characteristics and bed-net use among participants (N=200).

| Characteristics | Category | OR | p-value |
|---|---|---|---|
| **Age (years)** | <25 | 1.00 (Ref.) | - |
| | 26-35 | 1.3 | 0.664 |
| | 36-45 | 1.03 | 0.954 |
| | ≥46 | 0.51 | 0.237 |
| **Sex** | Female | 1.00 (Ref.) | - |
| | Male | 1.31 | 0.353 |
| **Education level** | No formal education | 1.00 (Ref.) | - |
| | Primary | 0.28 | 0.003* |
| | Secondary | 0.69 | 0.409 |
| | College (certificate/diploma) | 0.8 | 0.73 |
| | University | 0.17 | 0.161 |
| **Occupation** | Farmer | 1.00 (Ref.) | - |
| | Business person | 1.14 | 0.72 |
| | Unemployed | 1.29 | 0.544 |
| | Motorcycle driver (boda-boda) | 1.48 | 0.986 |
| | Teacher | 1.21 | 0.688 |
| **Marital status** | Single | 1.00 (Ref.) | - |
| | Married | 0.76 | 0.437 |
| | Divorced/separated | 0.26 | 0.283 |
| | Widow/widower | 2.97 | 0.984 |
| **Roof type** | Metal | 1.00 (Ref.) | - |
| | Thatched | 1.26 | 0.792 |
| **Wall type** | Brick | 1.00 (Ref.) | - |
| | Mud | 0.62 | 0.56 |
| **Water source** | Dug-up well | 1.00 (Ref.) | - |
| | Pump water | 1.14 | 0.824 |
| **Source of lighting** | Electricity | 1.00 (Ref.) | - |
| | Solar lamps | 0.4 | 0.005* |
| | Rechargeable lamps | 10.2 | 0.987 |
| **Cooking fuel** | Gas | 1.00 (Ref.) | - |
| | Charcoal | 0.97 | 0.919 |
| | Firewood | 0.63 | 0.046* |

OR: Odds ratio; Ref: Reference. *Signifying significance at p<0.05.

### Factors associated with bed-net use

Unadjusted analysis showed significant associations between bed-net use and education, lighting source, and cooking fuel (p<0.05) (Table 2). Primary education (p=0.003), solar lighting (p=0.005), and firewood use (p=0.046) were associated with lower odds of bed-net use compared with their respective reference groups (Table 2).

**Table 3:** List of the most common challenges encountered by respondents.

| Challenges | Percentage | Number of respondents |
|---|---|---|
| **Environmental challenges** | | |
| Rice fields | 20% | 40 |
| Stagnant water sources | 15% | 30 |
| Access to protection tools | | |
| High prices or unavailability of repellents/nets | 18% | 36 |
| Lack of access to fumigation/larviciding | 10% | 20 |
| **Effectiveness of methods** | | |
| Fake repellents | 12% | 24 |
| Fake mosquito nets | 8% | 16 |
| **Health concerns** | | |
| Harmful chemicals in repellents/sprays | 10% | 20 |
| Breathing issues from mosquito coils | 5% | 10 |
| **Community and infrastructure issues** | | |
| Poor waste management | 7% | 14 |
| Lack of proper drainage system | 8% | 16 |
| **Behavioral challenges** | | |
| Reluctance to use repellents/nets | 5% | 10 |
| Difficulty in maintaining consistent use | 5% | 10 |
| **Cultural and social believes** | | |
| Misconceptions about modern mosquito control | 5% | 10 |
| **Total** | **100%** | **200** |

### Awareness, challenges, and perceptions regarding mosquito-prevention measures

All respondents (N=200 (100%)) perceived mosquitoes as a major household problem and reported frequent bites. Bites occurred mainly in the evening (99%), especially on the feet and legs (94.5%). Bed nets were the preferred preventive measure (80%), while 17.5% used no prevention method. Despite high mosquito exposure, 97.5% spent nothing on prevention during the previous year (Table 3).

### Environmental and access-related barriers

Environmental conditions were major barriers to mosquito prevention. Respondents reported: "*Tunaishi kwenye mabonde ya mpunga hivyo maji yaliotuama hayaepukiki*" ("We live in rice fields where stagnant water is unavoidable") and "*Mabwawa ya maji yaliyosimama yapo mengi, ambayo yanafanya iwe ngumu kuzuia mbu*" ("Many stagnant water bodies make mosquito control difficult"). These accounted for 35% of barriers: rice fields (20%) and stagnant water (15%). Limited access to repellents/nets (18%) and fumigation/larviciding (10%) was also reported (Table 3).

### Perceived effectiveness and health concerns

Concerns about the effectiveness and safety of available mosquito-prevention methods were also reported (Table 3). Respondents identified counterfeit repellents (12%) and counterfeit mosquito nets (8%) as challenges. Health-related

concerns included perceived harmful chemicals in repellents or sprays (10%) and respiratory problems associated with mosquito coils (5%). These perceptions may influence the acceptability and consistent use of conventional mosquito-control measures.

### Cultural beliefs and misconceptions

Although cultural and social beliefs accounted for only 5% of reported barriers (Table 3), qualitative responses showed that misconceptions discouraged bed-net use. One respondent stated: "*Babu yetu alituambia kulala kwenye neti kunafanya tuwe masikini, hivyo watoto wangu na mimi hatulali kwenye neti*" ("Our grandfather told us not to use bed nets because they will make us poor; therefore, my children and I do not sleep under a bed net"). Another reported: "*Kuna maneno mengi ya waswahili kuwa neti zinapunguza nguvu za kiume na kuongeza kunguni*" ("There are many rumors that bed nets reduce male fertility and increase bedbug infestation"). These beliefs may contribute to inconsistent use despite high malaria-prevention awareness.

### Mosquito exposure, knowledge on preventive practices, and behavioral barriers related to bed-net use

The study revealed a substantial mosquito burden, with all respondents reporting frequent household bites and 90.0% experiencing bites away from home. Exposure was highest in the evening (99.0%), mainly affecting feet and legs (94.5%). Although 80.0% preferred bed nets, 17.5% used no preventive method. Only 44.5% currently used nets, despite universal awareness. Heat was the main barrier (63.5%), while 62.5% recognized their malaria-prevention benefits. Additionally, 97.5% spent nothing annually on mosquito-control tools (Table 4).

**Table 4:** Respondents' knowledge, perceptions, and practices regarding mosquito exposure and preventive measures (N=200).

| Variable | Response | n (%) |
|---|---|---|
| Perceived magnitude of mosquito problem at home | Very big | 200 (100.0) |
| Frequency of mosquito bites at home | Many times, | 200 (100.0) |
| Frequency of mosquito bites when away from home | Many times, | 180 (90.0) |
| | All the time | 6 (3.0) |
| | Only sometimes | 14 (7.0) |
| Time of day mosquitoes bother respondents most | Evening | 198 (99.0) |
| | Night | 2 (1.0) |
| Body part most affected by mosquito bites | Feet and legs | 189 (94.5) |
| | Arms | 8 (4.0) |
| | Face | 2 (1.0) |
| | Back | 1 (0.5) |
| Main method used to protect self/family from mosquito bites | Bed net | 160 (80.0) |
| | Mosquito coil | 4 (2.0) |
| | Repellent lotion | 1 (0.5) |
| | No protection | 35 (17.5) |
| Difficulty protecting self/family from mosquitoes | Yes | 200 (100.0) |
| Annual expenditure on mosquito-protection tools | Nothing | 195 (97.5) |
| | TZS 5,000–10,000 | 1 (0.5) |
| | TZS 10,000–20,000 | 3 (1.5) |
| | TZS 20,000–50,000 | 1 (0.5) |
| Knowledge of bed nets | Yes | 200 (100.0) |
| Ever used a bed net | Yes | 123 (61.5) |
| | No | 77 (38.5) |
| Ever used a treated bed net | Yes | 123 (61.5) |
| | No | 77 (38.5) |
| How bed net was obtained | Government | 78 (39.0) |
| | Purchased | 26 (13.0) |
| | Friend | 7 (3.5) |
| | Do not remember | 12 (6.0) |
| | Do not have a bed net | 77 (38.5) |
| Currently using a bed net | Yes | 89 (44.5) |
| | No | 28 (14.0) |
| | Do not remember | 6 (3.0) |
| | Do not have a bed net | 77 (38.5) |
| Knowledge that bed nets reduce malaria | Yes | 125 (62.5) |
| | No | 50 (25.0) |
| | Do not know | 25 (12.5) |
| Reasons for not using/buying bed nets | Heat | 127 (63.5) |
| | Too expensive | 42 (21.0) |
| | Do not know where to obtain | 17 (8.5) |

| | | |
|---|---|---|
| | Nets unavailable | 8 (4.0) |
| | No mosquitoes | 6 (3.0) |
| Reasons for not using an available bed net | Heat | 8 (4.0) |
| | Net old/dirty or requires retreatment | 6 (3.0) |
| | Unable to hang | 5 (2.5) |
| | Insufficient number of nets | 3 (1.5) |
| | Net does not protect against mosquitoes | 2 (1.0) |
| | Lack of mosquitoes | 2 (1.0) |
| | Net is itchy | 2 (1.0) |
| | Other | 172 (86.0) |

**Table 5:** Bed-net care, maintenance, proper and improper use, perceived consequences, and strategies to improve utilization among respondents (n=200).

| Variable | n (%) | Variable | n (%) |
|---|---|---|---|
| **Net has holes** | | **Frequency of repair** | |
| Yes | 37 (18.5) | Once/month | 36 (18.0) |
| No | 76 (38.0) | Twice/month | 25 (12.5) |
| Do not remember | 10 (5.0) | Once/year | 62 (31.0) |
| No bed net | 77 (38.5) | No bed net | 77 (38.5) |
| **Bed-net maintenance** | | **Reasons for not maintaining nets** | |
| Yes | 36 (18.0) | Lack of knowledge | 36 (18.0) |
| No | 25 (12.5) | Lack of time | 25 (12.5) |
| Do not know | 62 (31.0) | Difficulty repairing | 62 (31.0) |
| No bed net | 77 (38.5) | No bed net | 77 (38.5) |
| **Proper use of bed nets** | | **Improper use of bed nets** | |
| Sleeps under net at night | 159 (79.5) | Uses net for fishing/farming | 87 (43.5) |
| Ensures proper hanging | 33 (16.5) | Sleeps under damaged net | 83 (41.5) |
| Repairs holes | 8 (4.0) | Inconsistent use | 26 (13.0) |
| | | Improper hanging | 4 (2.0) |
| **Perceived main causes of improper use** | | **Suggested strategies to reduce improper use** | |
| Lack of knowledge | 106 (53.0) | Education campaigns | 106 (53.0) |
| Alternative uses (fishing) | 42 (21.0) | Improve distribution | 38 (19.0) |
| Discomfort | 38 (19.0) | Design improvements | 42 (21.0) |
| Worn-out | 11 (5.5) | Replace worn-out nets | 11 (5.5) |
| Insufficient access | 3 (1.5) | Enforce bylaws | 3 (1.5) |
| **Perceived consequences to misuse** | | **Strategies for maximizing bed-net use** | |
| Educate on proper use | 80 (40.0) | Education campaigns | 82 (41.0) |
| Warn/counsel | 53 (26.5) | Improve distribution | 47 (23.5) |
| Provide alternatives | 34 (17.0) | Design improvements | 44 (22.0) |
| Penalize | 23 (11.5) | Regular replacement programmes | 24 (12.0) |
| Do nothing | 10 (5.0) | Enforce proper use | 3 (1.5) |
| **Use of bylaws reduce bed-net misuse** | | | |
| Yes | 104 (52.0) | | |
| No | 59 (29.5) | | |
| Do not know | 37 (18.5) | | |

**Note:** Percentages are based on all respondents (n=200). Variables with multiple responses may not sum to 100%.

### Bed-net care, maintenance, and utilization practices

Although 79.5% reported sleeping under a bed net, gaps in effective use and maintenance persisted (Table 5). Lack of knowledge was the main driver of improper use (53.0%); 43.5% used nets for fishing/farming, and 41.5% slept under damaged nets. Only 4.0% repaired holes. Education and awareness campaigns were the preferred intervention (53.0%), while 52.0% supported bylaws to reduce misuse, highlighting the need for integrated behavior-change and maintenance support (Table 5).

### Awareness and acceptability of picture-embedded ITNs

Although 65.0% had heard of picture-embedded ITNs, 77.0% expressed willingness to use them if effective against mosquito bites (Table 6). Most respondents (77.0%) were willing to pay TZS 5,000-10,000, while improved appearance (35.0%) and cost-effectiveness (25.0%) were the leading perceived advantages (Table 6).

**Table 6:** Respondents' awareness, acceptability, and willingness to adopt insecticide-treated bed nets incorporating pictorial designs (N=200).

| Assessment domain | Variable/response | n (%) |
|---|---|---|
| **Awareness of picture-embedded ITNs** | Ever heard of insecticide-treated bed nets with pictures | |
| | Yes | 130 (65.0) |
| | No | 58 (29.0) |
| | Do not remember | 12 (6.0) |
| **Perceived preventive potential** | Believe picture-embedded ITNs can prevent mosquito bites | |
| | Yes | 130 (65.0) |
| | No | 70 (35.0) |
| **Willingness to adopt** | Would use picture-embedded ITNs if effective against mosquito bites | |
| | Yes | 154 (77.0) |
| | No | 28 (14.0) |
| | Do not know | 18 (9.0) |
| **Willingness to pay** | Amount willing to pay for a picture-embedded ITN (TZS) | |
| | 5,000-10,000 | 154 (77.0) |
| | 10,000-20,000 | 46 (23.0) |
| | Do not know | 0 (0.0) |
| **Perceived comparative advantages** | How picture-embedded ITNs differ from conventional ITNs | |
| | Improved appearance/aesthetics | 70 (35.0) |
| | Cost-effectiveness | 50 (25.0) |
| | Safety | 40 (20.0) |
| | Convenience | 30 (15.0) |
| | Do not know | 10 (5.0) |

## Discussion

The study showed that although awareness of mosquitoes, malaria, and Insecticide-Treated bed Nets (ITNs) was universal, this knowledge did not translate into consistent utilization. Only 44.5% of respondents used bed nets, with heat and discomfort identified as principal barriers. Bed net utilization was significantly associated with education level and socioeconomic characteristics, including lighting source and cooking fuel. Knowledge gaps regarding maintenance and misuse of bed nets for fishing and farming compromised their effectiveness. Respondents favored education and community awareness rather than punitive measures to promote appropriate use. Importantly, picture-embedded ITNs were accepted, with most respondents willing to purchase and use them because of their attractive appearance and educational value. Thus, malaria prevention in rural Tanzania requires sustained ITN access alongside behavior-change interventions, improved education, comfortable net designs, and innovations such as picture-embedded ITNs.

Awareness of mosquitoes and mosquito-borne diseases was universal (100%), consistent with malaria-endemic settings. In India, Chinnakali et al. [16] reported 96% awareness of mosquito transmission of dengue, while Msellemu et al. [17] in Tanzania and Degefa et al. [18] in Ethiopia reported >90% awareness of mosquitoes as malaria vectors. This may reflect sustained malaria campaigns, school health programs, and community interventions. However, frequent evening mosquito exposure was reported, consistent with findings from Kenya and Uganda [19,20], highlighting early-evening and outdoor exposure as persistent malaria-control challenges in sub-Saharan Africa.

Mosquito bites predominantly affected the feet and legs (94.5%), consistent with Mponzi et al. [21] in Tanzania, who reported 88% of bites on exposed lower limbs during farming, and Monroe et al. [22] in Kenya, who found similar patterns. This likely reflects exposure during farming, cooking, and social activities. Complementary measures, including repellents, protective clothing, environmental management, and outdoor vector control, may therefore complement ITN use.

Bed nets were the preferred mosquito-control method for 80% of respondents, consistent with findings from Ghana and Nigeria. Dunn et al. [23] reported that nearly 74% of respondents in Ghana preferred ITNs, while Yukich et al. [24] documented preference exceeding 70% in Nigeria. Despite this preference, 97.5% of respondents reported spending nothing annually on mosquito-control tools and relied mainly on government distribution and donations. Njau et al. [25] reported similar dependence on free ITN distribution in Tanzania, while Bonner et al. [26] and Eteng et al. [27] documented substantial reliance on donor- and government-supported nets in Kenya and Nigeria, respectively. Although these programs are essential for improving access, dependence on free distribution may create challenges for sustainable replacement of damaged or worn nets.

Environmental factors, particularly stagnant water, bushy surroundings, and poor sanitation, were major mosquito-control challenges. Similar findings were reported in Ethiopia [28], while Msellemu et al. [17] linked stagnant water to increased mosquito abundance and malaria burden in Tanzania. Limited access, high costs, and concerns about IRS and mosquito coils were also reported, consistent with concerns about chemical

exposure and respiratory discomfort in other studies [27,29]. Cultural and social beliefs were less common (5%), possibly reflecting malaria education, consistent with findings from Kenya and Uganda [30].

Although awareness of bed nets was universal, only 61.5% had ever used one and 44.5% were current users, indicating a substantial knowledge-practice gap. Similar discrepancies were reported in Ghana, Uganda, and Nigeria. Ahorlu et al. [29] reported high ITN ownership but lower utilization in Ghana, while Renggli et al. [31] found approximately 49% usage in Uganda. Studies in Nigeria reported utilization rates of 42-60% [26]. These findings show that awareness alone is insufficient, as behavioral, environmental, and socioeconomic factors also influence ITN use.

Heat and discomfort were the main barriers to ITN use, consistent with findings from Tanzania [32], Ethiopia [18], and coastal Kenya [33], highlighting the need for better-ventilated, comfortable ITN designs. Government health programs were the main net source, underscoring the importance of national malaria-control initiatives, as shown in Tanzania, Zambia, and Senegal [25,34,35]. However, only 33.5% reported regular use, indicating that access does not ensure consistent utilization, consistent with findings from Kenya and Uganda [36].

Educational attainment and socioeconomic conditions influenced bed-net use: respondents with primary education were less likely to use nets consistently, consistent with findings from Ethiopia, Ghana, Nigeria, and Kenya. Degefa et al. [18] found higher ITN use among those with secondary education, while Ahorlu et al. [29] and Eteng et al. [27] reported greater utilization among more educated households. Conversely, age, sex, occupation, and marital status were not significant predictors, consistent with findings from Senegal, Mali, Uganda, and Zambia [31,34-36]. Solar lighting and firewood use were also associated with lower bed-net use, possibly reflecting resource constraints [36]. In addition, 31% lacked adequate maintenance knowledge, consistent with Dunn et al. [23] and Renggli et al. [31]. Misuse for fishing, poultry keeping, and crop protection has been reported in Tanzania and Uganda [20,37]. Most respondents preferred education and awareness campaigns over punitive measures, supporting participatory approaches.

Acceptance of picture-embedded ITNs was favorable where 65% were aware of them, and 77% were willing to purchase them for TZS 5,000-10,000. Gingrich et al. [38] reported improved acceptance of attractive malaria-prevention tools in Kenya. Picture-embedded ITNs were viewed as attractive and suggesting potential to enhance ITN use and malaria prevention in rural Tanzania.

### Study limitations

The cross-sectional design limits causal inference between socioeconomic factors and ITN use. Self-reported data may have introduced recall and social desirability biases, particularly regarding ITN ownership and utilization.

## Conclusions

The study found universal awareness of mosquitoes, malaria, and ITNs, yet consistent use remained suboptimal, with only 44.5% currently using nets. Heat, discomfort, inadequate maintenance knowledge, misuse, and socioeconomic factors limited utilization. Environmental exposure and reliance on free net distribution further challenged sustained protection. Education and community awareness were preferred to punitive measures. The favorable acceptance of picture-embedded ITNs, with 77% willing to purchase them, indicates a promising complementary strategy. Strengthening ITN access, behavior-change education, maintenance support, environmental control, and development of more comfortable, visually appealing nets could improve consistent ITN use and contribute to malaria prevention in rural Tanzania.

## Declarations

**Ethics approval and consent to participate:** Ethical approval was obtained from the Medical Research Coordination Committee of the National Institute for Medical Research (NIMR) (Ref. NIMR/HQ/R.8a/Vol. IX/4399). Community meetings were held to explain the study, and informed consent was obtained from all participants.

**Availability of data:** The datasets generated in this study are available from the corresponding author upon reasonable request.

**Conflict of interest:** The author declares that no conflict of interest.

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**Author'scontribution:**A.R.I.contributedtoconceptualization, methodology, investigation, data collection, formal analysis, and writing-original draft. L.L.M. contributed to conceptualization, methodology, interpretation of findings, and writing-review and editing. A.L.M. contributed to conceptualization, methodology, interpretation of findings, and writin-review and editing. All authors contributed to the study and manuscript development, critically reviewed the manuscript, and approved the final version for publication.

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