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Perceived Insecticide Obsolescence Drives Non-Use Despite Near-Universal Bed Net Ownership Among Pregnant Women in Ghana: A Cross-Sectional Study

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Abstract

Background

Malaria in pregnancy remains a leading cause of maternal and neonatal morbidity in sub-Saharan Africa. While long-lasting insecticidal treated nets are highly efficacious and cost-effective, consistent utilization often falls short of programmatic targets even when ownership is high. This study evaluated factors associated with the access to and utilization of these nets among pregnant women in Bonsu Sub-Municipality, Ghana.

Methods

A descriptive cross-sectional study was conducted among 200 purposively selected pregnant women. Structured questionnaires and direct observation of the sleeping environment were used to collect data on socio-demographic characteristics, knowledge levels, and usage practices.

Results

Access was near-universal, with 98.5% of respondents obtaining nets primarily through antenatal care clinics. However, a significant "Universal Access Paradox" was observed: while ownership was nearly 100%, only 43.5% of respondents had their nets correctly hung and in active use. Significant knowledge deficits were identified, with 45.7% of women incorrectly believing the insecticide was effective for only one year. Furthermore, 65.0% reported itchiness as a major adverse effect, contributing to a 35.0% non-utilization rate among owners. A supplementary cross-country comparative analysis of eight sub-Saharan African settings reporting paired ownership and utilization data showed that the present study’s ownership–utilization gap (56.0 percentage points) exceeded the cross-setting mean gap (35.0 percentage points), indicating a more pronounced paradox in this district than in comparable regional settings.

Conclusions

The ownership-utilization gap appears more closely associated with knowledge-efficacy deficits and physical discomfort than with supply-side barriers, although the cross-sectional design precludes causal inference. Consistent biological protection is hindered by "perceived obsolescence" of the nets and a lack of pre-emptive counseling regarding transient side effects. Limitations include the small purposive sample size and the cross-sectional design, which captures only a temporal snapshot of behavior and may be subject to social desirability bias in self-reported data. The outlook for future work necessitates a shift from passive distribution to a "Distribution Plus" model that prioritizes longitudinal behavioral tracking, male partner engagement and low-irritant insecticide coatings.

Trial registration:

Not applicable; this was an observational study and did not involve a health care intervention requiring registration.

1. Background

Malaria remains one of the most persistent infectious disease burdens in global public health, with sub-Saharan Africa bearing a disproportionate share of that toll. According to the World Health Organization [1], an estimated 214 million cases of malaria were recorded worldwide in 2015, resulting in approximately 438,000 deaths, of which over 90% occurred on the African continent. More recently, Kokuhennadige et al. [3] have documented a troubling resurgence of malaria in pregnancy across Africa. In Ghana, malaria is hyperendemic and perennial across all ecological zones, with seasonal variation that is particularly pronounced in the northern and transitional savannah regions. The entire Ghanaian population of approximately 24.2 million is at risk, yet pregnant women and children under five years of age carry a disproportionate burden owing to compromised immunity and heightened physiological susceptibility [2].

The pathophysiology underlying the vulnerability of pregnant women to malaria is well characterized in the literature. Pregnancy substantially impairs a woman's immune response to *Plasmodium falciparum*, the dominant malaria parasite species in West Africa, rendering her significantly more susceptible to infection, severe anaemia, and febrile illness [4–6]. The consequences extend beyond maternal health: maternal malaria infection is independently associated with intrauterine growth restriction, low birth weight (LBW), premature delivery, spontaneous abortion, and neonatal mortality [7–10]. Globally, malaria in pregnancy is estimated to account for over 10,000 maternal deaths and 200,000 neonatal deaths per year [11], while in Africa alone, approximately 30 million pregnancies annually are exposed to malaria risk [12]. Primigravid women bear the greatest immunological burden owing to the absence of acquired immunity to placental malaria mediated through VAR2CSA-binding antibodies, which are developed only following repeated gestational exposures [3, 5].

Among the arsenal of malaria prevention and control tools, long-lasting insecticidal treated nets (LLITNs) have emerged as a cornerstone intervention of proven efficacy. An LLITN is a factory-treated bed net incorporating a synthetic pyrethroid insecticide that retains its biological efficacy for a minimum of three years under normal field conditions of use, without the need for re-treatment [13]. Unlike conventional insecticide-treated nets (ITNs) that required periodic chemical re-impregnation, LLITNs offer a logistically simpler and more durable protective barrier against vector mosquitoes, particularly *Anopheles gambiae* and related species responsible for malaria transmission in sub-Saharan Africa. The physical barrier function of the net reduces human–vector contact, while the residual insecticide kills or repels mosquitoes that make contact with the net surface, thereby providing both personal and community-level protection [14, 15].

The global scale-up of LLITN distribution has been underpinned by compelling evidence from randomized controlled trials and systematic reviews demonstrating reductions in all-cause child mortality of 17–38% and reductions in malaria-attributable morbidity of up to 50% in high-transmission settings [14]. Emerging evidence from quasi-experimental and prospective study designs further confirms that ITN effectiveness under routine programmatic conditions remains substantial, with Osei et al. [17] demonstrating significant reductions in malaria among children under five in Ghana even under conditions of imperfect adherence. The WHO has accordingly recommended universal LLITN coverage — defined as access to and use of LLITNs by all persons at risk — as a central pillar of the Global Technical Strategy for Malaria 2016–2030 [1], encompassing free mass distribution campaigns and continuous distribution through multiple channels, including ANC clinics, child welfare clinics (CWCs), and community-based platforms [16].

In Ghana, the National Malaria Control Programme (NMCP) has implemented a multi-channel LLITN distribution strategy aligned with these global recommendations. Between 2010 and 2015, the programme achieved an 80% increase in LLITN coverage among populations at risk [1]. Coverage of LLITNs among pregnant women attending ANC services rose from 22.9% in the first quarter of 2016 to 74.3% by 2017 [18]. However, national population-based survey evidence compiled by Awunyo et al. [19] confirms a persistent and statistically significant discrepancy between LLITN ownership and effective utilization among pregnant women across Ghana, a pattern that mirrors findings from a longitudinal analysis by Okova et al. [20], who documented widening within- and between-group socioeconomic inequalities in malaria prevention uptake over the period 2003–2022.

Notwithstanding these programmatic advances, a persistent disconnect between LLITN ownership and consistent utilization has been documented extensively in the literature. High coverage rates do not automatically translate into high usage rates, as actual protective benefit is contingent upon correct and consistent use — specifically, sleeping under a properly hung net every night during peak vector-biting hours [21–23]. Barriers to utilization are multifactorial and operate at individual, household, and community levels. These include poor knowledge of malaria transmission and LLITN efficacy duration, perceived or experienced side effects — including cutaneous irritation, respiratory discomfort, and headache associated with the pyrethroid insecticide — socioeconomic constraints, cultural beliefs, inadequate sleeping space, and the influence of spousal and community norms on health behaviours [24–31]. Recent systematic review evidence by Carshon-Marsh and Di Ruggiero [32] has further highlighted that inadequate behaviour change communication and absent post-distribution follow-up are modifiable system-level barriers that directly predict low utilization in contexts where ownership is already high.

In the Nkoranza South Municipality of the Brong Ahafo Region, malaria constitutes the foremost cause of outpatient department (OPD) attendance, accounting for 47% of OPD visits, 16.2% of hospital admissions, and 17.4% of hospital deaths [33]. Annual district health reviews [33, 70] have consistently identified malaria among pregnant women as a leading cause of maternal morbidity, despite the systematic distribution of LLITNs through ANC services. In 2015, the municipality distributed 100 LLITNs

to pregnant women, achieving a coverage of 41.2%; by 2016, 162 nets were distributed, raising coverage to 67.8%, yet malaria in pregnancy remained at 60% [34]. This paradox — of rising LLITN coverage coexisting with persistently high malaria prevalence — underscores the inadequacy of measuring programme success solely by distribution metrics, consistent with national data reported by Abesig et al. [35] documenting sustained malaria test positivity among pregnant women in northern Ghana despite programmatic scale-up.

No systematic research had previously been conducted within Nkoranza South District to rigorously evaluate the factors associated with LLITN access and utilization among this vulnerable group. This evidence gap limits the capacity of the District Health Management Team (DHMT) and other stakeholders to design and implement evidence-based, targeted interventions. In the global context, malaria imposes an estimated annual economic burden exceeding USD 12 billion on sub-Saharan African economies and is estimated to reduce economic growth by up to 1.3% per year [36, 37]. The indirect costs — reduced labour productivity, impaired child cognitive development, increased school absenteeism, and diminished household welfare — further compound its developmental consequences [38]. The present study was therefore conducted to generate district-specific, actionable evidence to guide targeted malaria prevention programming in this high-burden setting.

1.1 Aim of the study

The aim of this study was to evaluate the factors associated with the access to and utilization of long-lasting insecticidal treated nets (LLITNs) in the prevention of malaria among pregnant women in Bonsu Sub-Municipality, Nkoranza South District, Brong Ahafo Region, Ghana.

1.2 Specific objectives

The study was guided by the following specific objectives:

1. To assess the level of knowledge of pregnant women regarding LLITNs and their role in malaria prevention.
2. To evaluate the common practices associated with the use of LLITNs among pregnant women in the study area.
3. To identify factors associated with access to LLITNs among pregnant women attending antenatal care services.

1.3 Research questions

The following research questions guided the study:

1. What is the level of knowledge of pregnant women in Bonsu Sub-Municipality regarding the use and benefits of LLITNs?
2. What are the common practices associated with LLITN use among pregnant women in the study area?

3. What factors are associated with access to LLITNs among pregnant women attending antenatal care services in the study area?

2. Literature review

2.1 Global and regional burden of malaria in pregnancy

Malaria in pregnancy constitutes a global public health emergency with disproportionately severe consequences in sub-Saharan Africa. Sachs and Malaney [12] demonstrated that approximately 30 million pregnancies in malaria-endemic Africa are exposed to the risk of infection annually, with maternal and foetal consequences including severe anaemia, low birth weight, premature delivery, and neonatal death. More recently, Minwuyelet et al. [6], in a comprehensive systematic review of malaria in pregnancy, confirmed that the disease remains a critical public health threat across sub-Saharan Africa, with profound and often underappreciated effects on placental function, foetal growth, and neonatal survival. Kokuhennadige et al. [3] have further documented a resurgence of malaria in pregnancy in parts of Africa, attributing this reversal to insecticide resistance, COVID-19-related disruptions to malaria services, and stagnating utilization of preventive interventions including LLITNs.

Desai et al. [5] conducted a comprehensive systematic review of the global epidemiology of malaria in pregnancy and documented that primigravid women — those experiencing their first pregnancy — are most susceptible to placental malaria, attributed to the unique immunological tolerance mechanisms of early pregnancy and the absence of VAR2CSA antibody-mediated immunity. Brabin et al. [4] further demonstrated that severe anaemia resulting from malaria infection in pregnancy significantly elevates maternal mortality risk, particularly in settings with limited access to emergency obstetric care. Steketee et al. [10] provided compelling evidence linking maternal malaria infection to low birth weight — itself the single greatest risk factor for neonatal death, as originally identified by McCormick [9] — establishing a clear causal pathway from inadequate malaria prevention to adverse perinatal outcomes. Kabalu Tshiongo et al. [8] have provided recent corroboration of these mechanisms, demonstrating in a facility-based study in the Democratic Republic of Congo that combined use of ITNs and IPTp is associated with significantly improved birth weight and maternal haemoglobin outcomes compared to either intervention alone.

The Ghana Demographic and Health Survey [39] documented that nationally, only 19.9% of pregnant women slept under a treated net the night preceding the survey, highlighting the persistent and substantial gap between net availability and consistent protective use. More recent data from Awunyo et al. [19], based on a national population-based survey of Ghanaian pregnant women, confirm that while LLITN ownership has improved substantially over successive programme cycles, effective utilization remains low and is differentially distributed across socioeconomic strata. Abesig et al. [35], in a trend analysis of malaria test positivity rates among pregnant women in the Savannah Region of Ghana over 2018–2022, documented that malaria positivity among ANC attendees remained high despite programmatic efforts, underscoring the need for targeted utilization-promoting interventions. Similarly,

Bonsra et al. [40] identified age, educational attainment, income, and ITN use as significant predictors of malaria prevalence in pregnancy across selected districts of the Ashanti Region, while Bonsra et al. [41] further confirmed these patterns in a health facility-based study in Kwadaso Municipality, Ghana.

2.2 Efficacy and effectiveness of long-lasting insecticidal treated nets

Lengeler [14] conducted a Cochrane systematic review and meta-analysis of randomized controlled trials of insecticide-treated nets, documenting reductions in all-cause child mortality of 17–38% and reductions in uncomplicated clinical malaria episodes of approximately 50% in areas of stable transmission. Pluess et al. [15] subsequently reviewed the community-level protective effect of ITNs, demonstrating that high population-level coverage confers a mass effect that reduces vectorial capacity and transmission intensity beyond the direct protection afforded to individual net users. Osei et al. [17] provided recent quasi-experimental confirmation that ITN use under routine programmatic conditions in Ghana remains associated with significant reductions in malaria among children under five.

Madukwe et al. [42] demonstrated in a Nigerian ANC-based study that women who used both IPTp and slept under an ITN had significantly lower *Plasmodium falciparum* prevalence than those who used IPTp alone. Okoro et al. [43] further confirmed in a cost-effectiveness analysis in Jos North, Nigeria, that combined ITN and IPTp prevention is the most cost-effective strategy for malaria prevention in pregnancy. Cottrell et al. [22] documented that suboptimal distribution and underutilization of ANC-given bed nets in Benin compromised pregnant women's protection substantially, with a prospective field study demonstrating that actual net utilization rates fell to less than 50% within weeks of distribution despite near-universal ownership.

Zhou et al. [16] examined the role of universal LLITN coverage as a programmatic strategy, affirming the WHO recommendation that universal access should be pursued through a combination of mass free distribution campaigns and continuous distribution channels, including ANC clinics and community-based platforms.

2.3 Knowledge, attitudes, and practices regarding LLITNs

A substantial and growing body of literature has examined the relationship between knowledge, attitudes, and practices (KAP) pertaining to LLITNs and actual utilization behaviours. Atkinson et al. [21] conducted a systematic review of barriers to LLITN use in sub-Saharan Africa and identified knowledge deficits — including misconceptions about the mechanism of net action, the duration of insecticide efficacy, and the consequences of improper net maintenance — as significant determinants of low utilization. Ibeagha et al. [29], in a recent review of factors contributing to inconsistent ITN use in tropical Africa, confirmed that inadequate knowledge depth, perceived adverse effects, socioeconomic constraints, and absent BCC remain the predominant modifiable drivers of underutilization across the region.

Zuuri et al. [44] conducted a cross-sectional KAP study among pregnant women in Sekyere South District, Ghana and documented that gaps in malaria prevention stemmed primarily from misconceptions and incomplete adherence rather than supply shortages, concluding that strengthened ANC counselling, myth correction, and expanded outreach with ITN replacement are priority interventions. Salifu et al. [45] assessed malaria knowledge and preventive practices among pregnant women in the Savannah Region of Northern Ghana and identified inadequate knowledge of ITN efficacy duration, inconsistent use practices, and limited ANC attendance as key barriers to effective malaria prevention among marginalized pastoral communities. Bardoe et al. [24], in a qualitative exploration of psychological barriers to preventive interventions in Ghana, identified motivational inertia, fatalistic health beliefs, and the perceived burden of consistent preventive behaviour as underappreciated psychological determinants of LLITN non-use that are not adequately captured by quantitative KAP instruments.

Binka and Adongo [25] investigated factors influencing ITN use in northern Ghana and identified household-level decision-making dynamics, including the role of male household heads in determining whether family members sleep under nets, as a significant structural barrier to utilization among women and children. Eisele et al. [27] provided a multi-country analysis of the determinants of ITN use in sub-Saharan Africa, documenting that education level, household wealth, and exposure to malaria-prevention messaging were the strongest predictors of consistent net use. Grabowsky et al. [28] demonstrated that free distribution of ITNs substantially increased ownership rates but did not automatically translate into increased use, emphasizing the indispensable role of behaviour change communication (BCC) in achieving utilization gains. Mwebesa et al. [23], in a multilevel pooled analysis of ITN use among pregnant women across high-burden sub-Saharan African countries, identified ANC attendance frequency, household wealth, women's education level, and partner support as the strongest multilevel predictors of consistent ITN use in pregnancy, after controlling for access. Klu et al. [69], analyzing the 2022 Ghana Demographic and Health Survey, identified household characteristics and water, sanitation, and hygiene (WASH) conditions as significant correlates of malaria prevalence among Ghanaian children.

2.4 Access to LLITNs through antenatal care services

Nkuo-Akenji et al. [46] evaluated LLITN coverage and utilization among pregnant women in Cameroon and documented that ANC attendance was the strongest predictor of LLITN ownership. Ajonina et al. [47], in a recent cross-sectional study in the Littoral Region of Cameroon, confirmed that LLIN use among pregnant women attending ANC remained below national targets and was independently associated with age, religion, and gestational period. Cottrell et al. [22] highlighted in Benin that even where ANC-based distribution achieves near-universal net provision, actual utilization rates within weeks of distribution can fall to critically low levels without concurrent post-distribution follow-up and counselling.

Ye et al. [48] found in Burkina Faso that ANC-based distribution substantially increased LLITN ownership among pregnant women, but that free distribution alone was insufficient to drive utilization without concurrent community sensitization and follow-up counselling. Sumaila et al. [49], in a study of ITN use

determinants among pregnant women in Kintampo North Municipality — a district in the Bono East Region of Ghana directly adjacent to Nkoranza South — identified ANC attendance frequency, knowledge of ITN efficacy, and spousal encouragement as the strongest predictors of consistent ITN use. However, as Okova et al. [20] demonstrated, persistent socioeconomic inequalities in both ownership and utilization undermine the equitable protective benefit of this strategy across the population.

Opara, Ismail, and Mohd Nazan [50], in a systematic review of health education intervention programmes targeting ITN use in pregnancy, demonstrated that structured, interactive, and pictorial health education delivered at ANC visits significantly improved both knowledge depth and utilization rates compared to routine passive counselling, with gains sustained at three- and six-month follow-up. These findings provide a strong evidence base for the recommendation, emerging from the present study, to strengthen ANC-based LLITN counselling through standardized, evidence-informed protocols.

2.5 Factors influencing LLITN utilization among pregnant women in Ghana

Anto et al. [51] evaluated malaria prevention practices in the Kassena-Nankana district of northern Ghana and documented that household ownership of LLITNs was substantially higher than actual use, attributing this discrepancy to knowledge deficits, competing household priorities for net use, and structural factors including roof height and sleeping arrangement configurations that compromised proper net hanging. Akuffo et al. [52] confirmed in a nationally representative Ghanaian dataset that ITN non-use was strongly associated with inadequate knowledge of net maintenance, perceived side effects, and absence of partner encouragement, while Alhassan [53] documented similar patterns in a facility-based study at Tamale Teaching Hospital, noting that single women and women with lower educational attainment were disproportionately represented among non-users.

Ansah et al. [54], in a study of treated bed net use and anaemia among pregnant women in Ghana, demonstrated a statistically significant association between LLITN non-use and elevated anaemia risk. The NMCP's 2017 annual review documented that despite significant increases in LLITN distribution, malaria in pregnancy remained a leading cause of ANC attendance and maternal hospital admission across all regions [18]. In Nkoranza South Municipality specifically, the 2009 district health report [33] documented that malaria accounted for 47% of OPD visits, 16.2% of hospital admissions, and 17.4% of hospital deaths.

To synthesize the determinants reviewed above into a single integrative model, a conceptual framework was developed depicting the supply-side, demand-side, socio-structural, and individual-level pathways through which LLITN ownership fails to translate into consistent utilization (Fig. 1).

3. Methods

3.1 Study design

A descriptive cross-sectional study design was employed. This design is widely used in public health research for estimating the prevalence of health behaviours and associated factors at a specific point in time within a defined population [55–57].

3.2 Study area

The study was conducted in Bonsu Sub-Municipality, which is located within the Nkoranza South Municipality of the Brong Ahafo Region of Ghana. The predominant economic activity is subsistence and small-scale commercial agriculture. Malaria is hyperendemic throughout the municipality and represents the leading cause of OPD attendance, hospital admission, and hospital mortality [33].

3.3 Study population

The target population comprised all pregnant women registered for ANC services at health facilities within Bonsu Sub-Municipality during the study period. Inclusion criteria required participants to be currently pregnant, aged 16 years or older, residing within the sub-municipality, and willing to provide informed consent. Women who were unable to communicate in either English or the local Twi/Brong dialect, even with the assistance of a trained interpreter, were excluded from the study.

3.4 Sample size and sampling procedure

A total of 200 pregnant women were selected using purposive sampling. Purposive or judgement sampling involves the deliberate selection of participants who are considered most representative of or informative about the phenomenon under study and is a widely accepted approach in descriptive health studies where the research objective is to characterize a specific and relatively homogeneous population [58, 59]. All ANC registrants present at participating facilities during the designated data collection periods who met the inclusion criteria were invited to participate, and the sample was augmented by visiting outlying communities within the sub-municipality to ensure adequate geographic representation.

3.5 Data collection instrument and procedure

Data were collected using a structured questionnaire developed by the principal investigator on the basis of a comprehensive review of the existing literature on LLITN knowledge, access, and utilization [21, 23, 27, 30, 46, 50]. The questionnaire comprised four sections: (1) socio-demographic characteristics, including *age*, *level of education*, *occupation*, and *marital status*; (2) knowledge items assessing awareness of LLITN benefits, chemical efficacy duration, processing procedures, and perceived side effects; (3) items assessing LLITN access, including *source of net* and *ease of access*; and (4) items assessing common practices, including *frequency of use*, *method of net hanging*, and *confirmation of actual use*. The questionnaire was pre-tested with a small group of non-participant pregnant women to assess clarity and face validity, and revisions were made accordingly before formal data collection commenced.

Questionnaires were administered through face-to-face interviews conducted by the principal investigator and a trained female research assistant fluent in both English and the local dialect. For

physical confirmation of net use status, the research assistant conducted direct observations of the sleeping environment. All interviews were conducted in a private setting to ensure confidentiality and minimize social desirability bias.

3.6 Data analysis

Data were entered, cleaned, and analysed using Python 3.12 with appropriate statistical and data-processing libraries such as pandas, NumPy, and SciPy. Descriptive statistics such as frequencies and percentages were calculated for all categorical variables. Findings were organized thematically in alignment with the three study objectives: (1) knowledge, (2) access, and (3) common practices. All percentages are rounded to one decimal place. For items permitting multiple responses, percentages were reported as proportions of the total sample (N = 200) and may therefore sum to values exceeding 100%. The internal consistency reliability of the multi-item knowledge, access, and practice/utilization domains of the structured questionnaire was assessed using Cronbach's alpha (α), computed on the dummy-coded item-response matrix using the pingouin and SciPy libraries in Python 3.12. Ninety-five percent confidence intervals for each domain-level α were estimated using 2,000 non-parametric bootstrap resamples (seed = 42). Following conventional benchmarks, $\alpha \geq 0.70$ was considered acceptable and $\alpha \geq 0.80$ was considered good internal consistency [60].

To contextualize the present study's findings within the broader sub-Saharan African programmatic landscape, a supplementary cross-country comparative analysis was conducted. Comparator ownership and utilization figures for pregnant women and, where pregnancy-specific data were unavailable, the general population in Ghana, Nigeria, Ethiopia, Kenya, Uganda, the Democratic Republic of the Congo, Cameroon, Benin, Malawi, Zambia, and Sudan were extracted from peer-reviewed, PubMed Central–indexed studies and systematic reviews/meta-analyses identified through a targeted literature search. Comparator data, the corresponding sample sizes and survey years, and full source citations are reported in Table 5. Where both ownership and utilization were reported by the same source, the ownership–utilization gap was computed in percentage points (ownership % − utilization %), and the mean gap across comparator settings was calculated for comparison against the present study's gap. This analysis was descriptive and narrative rather than a formal meta-analysis, given heterogeneity in study design, sampling frame, and outcome definitions across sources.

3.7 Ethical considerations

Prior to data collection, ethical approval was obtained from the Ethics and Academic Integrity Committee of the Anglican University College of Technology (ANGUTECH), Nkoranza Campus, Ghana, All participants provided verbal informed consent prior to their inclusion in the study. Participants were informed of the voluntary nature of their participation, their right to withdraw at any time without consequence, and the confidentiality of their responses. No personally identifying information was recorded in the data collection instruments. The principles of beneficence, non-maleficence, autonomy, and justice as outlined in the Declaration of Helsinki [61] were adhered to throughout the study.

4. Results

4.1 Socio-demographic characteristics of respondents

A total of 200 pregnant women participated in the study. As shown in Table 1 and Fig. 2, the majority of respondents (38.0%) fell within the 26–30 year *age* group, followed by the 21–25 year category (23.5%), with only 3.5% of respondents aged 41 years or above. This age distribution is consistent with the typical reproductive age pattern in rural Ghanaian communities [33].

Table 1
Socio-demographic characteristics of respondents (*N* = 200)

Parameter	Category	*n*	%
Age of Respondents (years)	16–20	37	18.5
	21–25	47	23.5
	26–30	76	38.0
	31–35	20	10.0
	36–40	13	6.5
	≥ 41	7	3.5
	Total	**200**	**100.0**
Level of Education	No formal education	53	26.5
	Primary	33	16.5
	Middle/JSS/JHS	98	49.0
	Secondary/SHS	3	1.5
	Tertiary	13	6.5
	Total	**200**	**100.0**
Occupation	Farmer	90	45.0
	Trader	43	21.5
	Others	30	15.0
	Housewife	17	8.5
	Civil servant	13	6.5
	Unemployed	7	3.5
	Total	**200**	**100.0**
Marital Statusfx	Married	123	61.5
	Co-habiting	57	28.5
	Single	20	10.0
	Total	**200**	**100.0**

Note. JSS = Junior Secondary School; JHS = Junior High School; SHS = Senior High School.

Regarding *educational attainment*, the largest proportion of respondents (49.0%) had completed Middle/Junior High School (JHS) or its equivalent, while 26.5% had received no formal education. Only

1.5% had attained secondary school (Senior High School [SHS]) education, and a further 6.5% had received tertiary-level education.

Occupational distribution revealed that farming was the primary livelihood activity, with 45.0% of respondents identifying as farmers, followed by trading (21.5%), other unspecified occupations (15.0%), housewifery (8.5%), civil service (6.5%), and unemployment (3.5%). *Marital status* data revealed that the majority of respondents (61.5%) were married, while 28.5% reported co-habiting with a partner, and 10.0% were single. The predominance of married respondents has potential implications for LLITN utilization, as household-level decision-making regarding net use may be influenced by the attitudes and behaviours of male partners [23, 25, 28].

4.2 Knowledge of respondents regarding LLITNs

The findings pertaining to respondent knowledge of LLITNs are presented in Table 2. All 200 respondents (100%) correctly identified that LLITNs prevent malaria in pregnancy, reflecting a high level of awareness of the primary protective benefit of the intervention. This finding is consistent with evidence from comparable settings documenting near-universal awareness of the malaria-prevention function of bed nets following sustained mass distribution campaigns [27, 44, 46]. However, knowledge was considerably less robust regarding more nuanced aspects of LLITN function and maintenance.

Specifically, only 27.1% of respondents correctly identified the three-year effective lifespan of the chemical insecticide as the correct expiry period for the net, while the largest single group (45.7%) incorrectly believed the chemicals expired after only one year, and a further 8.5% reported having no knowledge of the expiry period. This widespread misconception about chemical efficacy duration has significant practical implications: respondents who believe the insecticide expires after one year may prematurely discontinue LLITN use, a finding consistent with knowledge gaps documented by Ibeagha et al. [29] across tropical Africa and by Salifu et al. [45] among Ghanaian pregnant women.

The findings pertaining to respondent knowledge of LLITNs are presented in Table 2 and Fig. 3. Regarding perceived benefits of LLITNs to the foetus, 70.0% of respondents indicated awareness that net use prevents foetal death, 53.5% identified the prevention of low birth weight (LBW), 43.5% mentioned the prevention of anaemia, and 16.5% cited the prevention of stillbirth. ANC clinics were identified as the primary source of LLITN knowledge by 91.5% of respondents, with radio identified as a secondary source by 46.5% and market sources by 13.5%. These patterns reinforce the critical gatekeeping role of ANC services as the dominant knowledge dissemination channel [46, 48].

Table 2
Knowledge of respondents regarding LLITNs (*N* = 200)

Parameter	Category	*n*	%
Perceived chemical expiry period	1 year (incorrect)	91	45.7
	2 years (incorrect)	34	17.1
	3 years (correct)	54	27.1
	4 years (incorrect)	3	1.5
	Do not know	17	8.5
	Total	**199**	**100.0**
Benefit of LLITN to pregnant woman	Prevents malaria	200	100.0
Perceived benefits to foetus (multiple responses)	Prevents death	140	70.0
	Prevents low birth weight	107	53.5
	Prevents anaemia	87	43.5
	Prevents stillbirth	33	16.5
Source of knowledge (multiple responses)	ANC	183	91.5
	Radio	93	46.5
	Market	27	13.5
Overall knowledge level	Moderate knowledge	170	85.0
	Poor knowledge	16	8.0
	Good knowledge	14	7.0
	Total	**200**	**100.0**

Note. ANC = Antenatal Care. Percentages for multiple-response items may sum to values exceeding 100%.

The overall knowledge level of respondents was classified as moderate in 85% of cases, with 8% demonstrating poor knowledge and only 7% demonstrating good knowledge. This pattern is consistent with findings from analogous KAP studies conducted in Ghana and other sub-Saharan African settings [21, 25, 44, 51].

Figure 4 presents knowledge pertaining to the processing and maintenance of LLITN effectiveness. Regarding the appropriate first-time processing procedure, 71.2% of respondents correctly reported that the net should be dried in the shade, while 15.3% reported merely drying it in direct sunlight — an incorrect practice that may accelerate photodegradation of the pyrethroid insecticide coating. A further

8.5% reported washing and drying the net in sunlight, and 5.1% reported washing and drying in the shade. With respect to maintenance of insecticide effectiveness, 83.1% of respondents correctly identified that retreatment is not necessary for LLITNs. Only 5.1% each reported that retreatment could be performed at home or at a health facility, and 3.4% mentioned community-based retreatment, with a further 3.4% indicating no knowledge of the maintenance requirements.

4.3 Access to LLITNs

Findings on the access of respondents to LLITNs are presented in Table 3 and illustrated in Fig. 5 Access to LLITNs was overwhelmingly through the public health system. Of the 199 respondents who owned a treated net (constituting 100% of net owners), 98.5% had obtained their primary LLITN from an ANC clinic. A noteworthy proportion (21.5%) also reported receiving LLITNs as donations from friends or family members. Purchase from market vendors was reported by 6.5% of respondents.

Table 3
Access to LLITNs among respondents (*N* = 200)

Parameter	Category	*n*	%
Type of net possessed	Treated (LLITN)	199	99.5
Source of LLITN (multiple responses)	Antenatal care (ANC) clinic	199	98.5
	Donation from a friend	43	21.5
	Market	13	6.5
Ease of access to LLITN	Free and easily available at ANC	180	90.0
	Free but with difficulties	10	5.0
	Cheap (purchased)	7	3.5
	Expensive (purchased)	3	1.5
	Total	**200**	**100.0**

Note. ANC = Antenatal Care; LLITN = Long-Lasting Insecticidal Treated Net. Percentages for multiple-response items may sum to values exceeding 100%.

The overwhelming majority of respondents (90.0%) reported that their LLITN was freely and easily available through the ANC service, with only 5.0% reporting free availability but with associated difficulties. The near-universal experience of free and convenient ANC-based net access reflects the effectiveness of the NMCP's continuous distribution strategy [16, 28]. As Carshon-Marsh and Di Ruggiero [32] and Cottrell et al. [22] have argued, high ownership rates in such settings must not be conflated with adequate protection

4.4 Common practices of LLITN use

Data on common practices relating to LLITN use are presented in Table 4 and Fig. 6. The data reveal a notable discrepancy between net ownership and consistent protective use. While 60.0% of respondents reported always using their LLITN — but exclusively at night — a significant proportion (18.5%) reported not using the net at all, and a further 11.5% reported using it only occasionally. The 10.0% who reported using the net both during the day and at night reflect a smaller subgroup achieving more consistent protection.

Table 4
Common practices of LLITN use among respondents (*N* = 200)

Parameter	Category	*n*	%
Frequency of LLITN use	Always – night only	120	60.0
	Not at all	37	18.5
	Occasionally	23	11.5
	Always – day and night	20	10.0
	Total	**200**	**100.0**
Method of net use	Hangs net above the bed	200	100.0
Side effects experienced (multiple responses)	Itchiness	130	65.0
	Other effects	27	13.5
	Difficulty in breathing	17	8.5
	Vomiting	13	6.5
Confirmation of LLITN use status	Net hanged appropriately and in use	87	43.5
	Has net but not currently in use	70	35.0
	Has net but not hanged appropriately	43	21.5
	Total	**200**	**100.0**

The combined observation that 35.0% of respondents possessed a net but were not currently using it, and a further 21.5% possessed a net that was not correctly hung, yields a striking composite finding: 56.5% of LLITN owners were either not using their net at all or were using it suboptimally. This high rate of ownership–utilization discordance echoes findings from Cottrell et al. [22], Gikandi et al. [62], Grabowsky et al. [28], Iwueze et al. [63], and Mwebesa et al. [23], who collectively documented similar patterns across East and West Africa. Only 43.5% of respondents had their net appropriately hung and actively in use.

Adverse effects associated with LLITN use were reported by a substantial proportion of respondents. Itchiness was the most prevalent complaint, identified by 65.0% of respondents, followed by unspecified other effects (13.5%), difficulty in breathing (8.5%), and vomiting (6.5%). The high prevalence of reported itchiness is consistent with evidence from Atkinson et al. [21] and Macintyre et al. [30] identifying cutaneous irritation as the most common adverse reaction to pyrethroid-impregnated nets. Ibeagha et al. [29] specifically identify perceived side effects — including itchiness, heat discomfort, and chemical odour — as among the most prevalent and modifiable drivers of ITN discontinuation across tropical Africa.

4.5 Summary of key findings

Figure 7 provides a synthesized visual summary of the eight most salient findings from the study, integrating data across the knowledge, access, and practice domains.

4.6 Reliability of the structured questionnaire

The internal consistency of the structured questionnaire was acceptable to good across domains (Fig. 8). The knowledge domain (seven items) achieved a Cronbach's α of 0.78 (95% CI: 0.71–0.84), and the practice/utilization domain (six items) achieved α = 0.81 (95% CI: 0.75–0.86), both meeting or approaching conventional thresholds for good internal consistency. The access domain (four items) returned a marginally lower α of 0.69 (95% CI: 0.59–0.77), falling just below the conventional 0.70 acceptability threshold The overall 17-item questionnaire demonstrated good internal consistency (α = 0.83; 95% CI: 0.78–0.87), supporting the appropriateness of the instrument for assessing knowledge, access, and practice constructs in this population.

4.7 Cross-country comparative analysis of LLITN/ITN ownership and utilization

Comparator data extracted from peer-reviewed sources across eleven sub-Saharan African countries are presented in Table 5 and Fig. 9. Among the eight settings reporting both ownership and utilization, the present study recorded the highest ownership rate (99.5%) but a mid-range utilization rate (43.5%), yielding the largest ownership–utilization gap of any comparator setting (56.0 percentage points). By comparison, other Ghanaian studies in Wa Municipality (92.0% ownership, 69.3% utilization; gap 22.7 pp) and Hohoe Municipality (81.3% ownership, 66.4% utilization; gap 14.9 pp) recorded smaller gaps, suggesting that the magnitude of the ownership–utilization disconnect documented in Bonsu Sub-Municipality is not uniform even within Ghana.

Table 5
Cross-country comparison of LLITN/ITN ownership and utilization among pregnant women, sub-Saharan Africa.

Country / setting	Ownership (%)	Utilization (%)	Gap (pp)	Year	Source
Ghana (present study) – Bonsu Sub-Mun.	99.5	43.5	56.0	2026	Present study
Ghana – Wa Municipality	92.0	69.3	22.7	2019	Der et al. [64], BMC Pregnancy Childbirth (PMC6692087)
Ghana – Hohoe Municipality	81.3	66.4	14.9	2019	Ghana universal coverage study (PMC10248059)
Ghana – Ashanti Region (urban ANC)	78.0	61.0	17.0	2018	Ghana universal coverage study (PMC10248059)
Benin – ANC-distributed nets (prospective)	96.0	48.0	48.0	2025	Cottrell et al. [22], BMC Public Health
Nigeria – multi-state (ANC clients)	71.0	31.6	39.4	2020	Wa Municipality comparator (PMC6692087)
Nigeria – Kaduna State (Igabi)	89.0	74.0	15.0	2019	Igabi LLIN study (PMC6902412)
Malawi – national (awareness vs. use)	70.0	3.0	67.0	2012	Wa Municipality comparator (PMC6692087)

Nigeria's Kaduna State data (89.0% ownership, 74.0% utilization; gap 15.0 pp) and the 2018 Nigeria DHS rural sample (86.1% utilization, no paired ownership figure) likewise indicate comparatively higher utilization performance, while Benin's ANC-distributed net cohort (96.0% ownership, 48.0% utilization; gap 48.0 pp) and Malawi's national awareness-versus-use data (70.0% awareness, 3.0% use; gap 67.0 pp) demonstrate that extreme ownership–utilization discordance, while not universal, is not unique to the present study setting either. Across the eight paired-comparator settings, the mean ownership rate was 84.6%, the mean utilization rate was 49.6%, and the mean ownership–utilization gap was 35.0 percentage points — meaning the gap observed in Bonsu Sub-Municipality (56.0 pp) was approximately 1.6 times the cross-setting average. This places the present study's "Universal Access Paradox" among the more pronounced examples of ownership–utilization discordance documented in the recent sub-Saharan African literature.

5. Discussion

The findings of this study provide a comprehensive, district-specific characterization of the factors associated with LLITN access and utilization among pregnant women in Bonsu Sub-Municipality, Nkoranza South District. The study is set within a context of well-documented and locally persistent

tension between rising LLITN ownership and persistently high malaria prevalence in pregnancy — a paradox that has been documented nationally by Awunyo et al. [19] and regionally by Abesig et al. [35] and is explained, in large part, by the findings of the present investigation.

5.1 Knowledge of LLITNs: Depth, gaps, and programmatic implications

The finding that all respondents (100%) recognized malaria prevention as a primary benefit of LLITN use is encouraging and consistent with the documented success of the NMCP's health promotion activities at ANC facilities [16, 18, 27]. However, the predominance of moderate rather than good knowledge — with 85% of respondents in the moderate category and only 7% demonstrating good knowledge — highlights the limitations of surface-level awareness as a driver of behaviour change. As Atkinson et al. [21] and Ibeagha et al. [29] have argued, awareness of the primary malaria-prevention function of nets does not necessarily translate into the deeper, operational knowledge required to support consistent and correct use.

The finding that only 27.1% of respondents correctly identified the three-year chemical expiry period — while 45.7% believed it to be only one year — has particular practical significance and is one of the more actionable findings of this study. Respondents who underestimate the durability of the LLITN insecticide may prematurely discontinue use or engage in unnecessary retreatment attempts, potentially reducing the insecticide load to subtherapeutic levels and compromising net efficacy [25, 28]. This specific misconception has been documented in comparable Ghanaian settings by Salifu et al. [45] and Zuuri et al. [44]. The 91.5% who identified ANC as their primary source of LLITN knowledge simultaneously underscore the pivotal role of antenatal health education sessions in shaping knowledge and practices,. Strengthening the quality, consistency, and depth of ANC-based LLITN counselling through standardized protocols and pictorial materials — as advocated by Opara et al. [50] — is therefore a priority recommendation emerging from this study.

The relatively low proportion recognizing the stillbirth-prevention benefit of LLITN use (16.5%) is particularly noteworthy, given the documented pathway linking placental malaria to foetal growth restriction and stillbirth described by Desai et al. [5], Kabalu Tshiongo et al. [8], and Minwuyelet et al. [6]. Communicating the foetal consequences of malaria — including stillbirth, LBW, and neonatal death — may enhance the perceived relevance and urgency of LLITN use for pregnant women, consistent with the behavioural change communication principles advanced by Bardoe et al. [24].

5.2 Access to LLITNs: High ownership, persistent inequalities

Access to LLITNs in the study population was uniformly high and predominantly through the public ANC delivery channel, with 98.5% of net-owning respondents obtaining their LLITN free of charge from an ANC clinic, and 90.0% reporting free and easy access. This is consistent with evidence from Grabowsky

et al. [28], Sumaila et al. [49], and Zhou et al. [16], who collectively demonstrated that free distribution strategies substantially increased net ownership compared with subsidized or full-price market distribution.

The 21.5% of respondents who reported obtaining a net through donation from a friend or family member suggests the existence of informal inter-household sharing and redistribution mechanisms. While reflective of community solidarity, this pattern carries the risk of concentrating multiple nets in households with surplus ownership while leaving more isolated households under-covered — a risk documented by Okova et al. [20] in their analysis of within-group socioeconomic inequalities in LLITN distribution across Ghana over 2003–2022. The small proportions reporting market purchase (6.5%) and cost-related access difficulties (combined 5.0%) suggest that financial access barriers are not a primary driver of LLITN under-utilization in this population. As Carshon-Marsh and Di Ruggiero [32] and Cottrell et al. [22] have argued, this finding shifts the programmatic imperative squarely toward post-acquisition utilization promotion rather than further ownership expansion.

5.3 LLITN utilization practices: The ownership–use gap as the central challenge

The central finding of this study concerns the substantial gap between LLITN ownership and consistent, correct utilization. Only 43.5% of respondents had their net correctly hung and actively in use at the time of observation, while 35.0% possessed a net but were not using it, and 21.5% had a net that was not correctly hung. This magnitude of ownership–utilization discordance is consistent with findings from Cottrell et al. [22] in Benin, Gikandi et al. [62] and Teym et al. [65] in East Africa, Getnet et al. [66] in Ethiopia, and Mwebesa et al. [23] across multiple sub-Saharan African countries.

The high prevalence of itchiness as a reported side effect (65.0%) is a particularly salient finding, given the documented relationship between perceived adverse effects and LLITN use discontinuation. Ibeagha et al. [29] identified pyrethroid-related adverse effects as among the most prevalent modifiable barriers to consistent ITN use in tropical Africa, and specifically note that women who experience itchiness in the first nights of net use are significantly more likely to permanently discontinue use without prior counselling about the expected transient nature of these reactions. Macintyre et al. [30] identified cutaneous irritation as the most common adverse reaction to pyrethroid-impregnated nets across multiple African settings. Proactive, empathetic counselling regarding expected adverse effects — framed within a clear communication of the net's substantial protective benefits — is therefore an essential component of comprehensive LLITN health education, as advocated by Bardoe et al. [24] and Carshon-Marsh and Di Ruggiero [32].

The finding that 35.0% of respondents possessed a net but were not using it at the time of observation, despite living in a setting of high malaria endemicity and attending a health service that endorses net use, suggests the operation of motivational, contextual, and social factors that are not adequately addressed by distribution-focused programme strategies. These include spousal influence on net allocation decisions [23, 25], sleeping space constraints, habitual behavioural inertia [24], and the

perceived burden of nightly net setup — factors collectively identified as targets for community-based behaviour change communication by Zuuri et al. [44] and Salifu et al. [45] in Ghanaian contexts.

Aoki et al. [67], in a study of ITN use determinants among pregnant women in Angola, and Donacho et al. [26], in a community-based cross-sectional study among pregnant women in Southwest Ethiopia, both identified marital status, spousal support, educational attainment, and knowledge of LLITN efficacy duration as the strongest independent predictors of consistent LLITN use in multivariate analyses. Baykemagn et al. [68], applying machine learning algorithms to predict mosquito bed net utilization among women of reproductive age across sub-Saharan Africa, identified ANC attendance frequency, household wealth, women's empowerment, and regional malaria transmission intensity as the most important predictors of utilization.

The cost-effectiveness evidence advanced by Okoro et al. [43] and Madukwe et al. [42] further strengthens the case for sustained investment in LLITN utilization-promoting interventions: the substantial protective benefit of consistent net use in reducing *P. falciparum* prevalence in pregnancy is achievable at relatively low additional programmatic cost when behaviour change communication and post-distribution follow-up are incorporated into existing ANC delivery platforms. Given the direct relationship between LLITN non-use, malaria in pregnancy, and maternal anaemia documented by Ansah et al. [54] and the adverse birth outcomes linked to maternal malaria demonstrated by Kabalu Tshiongo et al. [8] and Minwuyelet et al. [6], the health and economic burden of the utilization gap in Bonsu Sub-Municipality is likely both clinically and economically significant, although this study did not directly quantify economic costs.

5.4 The Bonsu Sub-Municipality paradox in cross-country perspective

The cross-country comparative analysis presented in Section 4.7 situates the present study's findings within a wider regional pattern of LLITN ownership–utilization discordance, while also indicating that the magnitude of the gap observed in Bonsu Sub-Municipality (56.0 percentage points) is more severe than the cross-setting average (35.0 percentage points) drawn from eight comparable sub-Saharan African settings reporting paired ownership and utilization data. First, it confirms that the "Universal Access Paradox" identified in this study is not an isolated or anomalous finding but reflects a documented regional phenomenon, consistent with Cottrell et al. [22] in Benin, where ANC-distributed net utilization fell sharply within weeks of near-universal distribution, and with the multi-country syntheses of Mwebesa et al. [23] and Baykemagn et al. [68]. Second, the comparatively larger gap recorded in this study suggests that the specific knowledge, side-effect, and motivational barriers documented here — particularly the widespread one-year insecticide expiry misconception (45.7%) and the high prevalence of itchiness (65.0%) — may be acting with unusual force in this particular district.

The smaller ownership–utilization gaps observed in Wa Municipality (22.7 pp) and Hohoe Municipality (14.9 pp) compared with Bonsu Sub-Municipality (56.0 pp) suggest meaningful sub-national heterogeneity in programme implementation quality, health education depth, or community-level

behavioural determinants, even under the same national NMCP distribution policy. This heterogeneity argues against a uniform, nationally standardized approach to utilization promotion and instead supports the district-tailored “Distribution Plus” model proposed in Section 6.

The good internal consistency of the overall questionnaire (α = 0.83) and of the knowledge (α = 0.78) and practice/utilization (α = 0.81) domains specifically indicates that the central knowledge-deficit and utilization-gap findings reported here are unlikely to be artefacts of measurement error or item incoherence. The marginally sub-threshold reliability of the access domain (α = 0.69) should be interpreted in light of the near-ceiling endorsement of several access items (e.g., 98.5% ANC-based acquisition); low item variance mechanically attenuates Cronbach’s alpha even when the underlying construct is being measured consistently, and this is noted as a measurement limitation rather than a substantive weakness in the access findings themselves.

Conclusions

6.1 Conclusions

This study identifies a notable programmatic disconnect in Bonsu Sub-Municipality, reflecting a "Universal Access Paradox" in which near-universal LLITN ownership (98.5%) did not translate into consistent biological protection, as evidenced by the finding that only 43.5% of pregnant women achieved correct and consistent utilization at the time of direct observation. These findings suggest that while the National Malaria Control Programme has successfully navigated the logistical hurdles of commodity distribution, it has yet to overcome the deep-seated socio-behavioral inertia and domestic constraints that prevent sustained use among this vulnerable population. A key factor associated with this ownership-use gap appears to be a knowledge-efficacy deficit, specifically the widespread misconception among nearly half of the respondents that insecticide potency expires after only one year; this perceived obsolescence may contribute to premature net abandonment, although the cross-sectional design cannot establish this causal pathway. Furthermore, side effects, most notably the itchiness reported by 65.0% of participants, also appear to discourage consistent use and are rarely addressed pre-emptively through structured clinical counseling. However, these conclusions must be interpreted within the context of certain limitations, including the purposive sample of 200 pregnant women which, may still limit generalizability to broader urban settings, and the cross-sectional design that captures only a snapshot of behavior without accounting for seasonal shifts in mosquito density or indoor temperatures. A further limitation concerns the reliability of the access domain of the questionnaire (Cronbach’s α = 0.69), which fell marginally below the conventional acceptability threshold owing to near-ceiling endorsement of several items, and the cross-country comparative analysis (Section 4.7), which was descriptive and narrative in nature rather than a formal meta-analysis; the cross-country gap estimates should therefore be interpreted as indicative rather than statistically pooled. Moving forward, malaria prevention success must shift from measuring "nets per household" to "protected person-nights of sleep," necessitating a transition from passive distribution toward a "Distribution Plus" model that integrates intensive behavioral reinforcement, myth correction, and male partner engagement

at every antenatal care touchpoint. Future research should prioritize longitudinal behavioral tracking to identify specific drop-off points in adherence and investigate the efficacy of technological innovations, such as low-irritant insecticide coatings or conical net designs. Ultimately, closing the gap between net ownership and consistent use remains a key priority for reducing maternal and neonatal morbidity, requiring interventions that treat misconceptions and physical discomfort as primary, not secondary, barriers to malaria prevention.

6.2 Recommendations

Based on the evidence synthesized from this study and the broader epidemiological literature, the following recommendations are directed to the Nkoranza South District Health Management Team (DHMT), the Ghana National Malaria Control Programme (NMCP), and relevant non-governmental organizations and community stakeholders:

- **Institutionalize standardized, pictorial health education**: Healthcare providers should move beyond routine counseling to deploy evidence-based, pictorial educational modules at all ANC facilities. These materials must explicitly target the "knowledge-depth" deficits identified here—specifically the three-year insecticide efficacy period, correct shade-drying procedures, and the specific fetal health consequences of malaria in pregnancy. This shift from surface-level awareness to durable knowledge acquisition should follow the design principles established by Opara et al. [50].
- **Operationalize household-level behavioral support**: The DHMT should leverage the Community Health Planning and Service (CHPS) framework to transition from clinic-based distribution to home-based behavioral support. Community health workers should conduct targeted household visits to perform correct net-hanging demonstrations and provide proactive education on managing transient side effects (such as itchiness). This "at-the-bedside" approach may help bridge the access–utilization gap [32, 44].
- **Integrate structured post-distribution follow-up into routine ANC**: ANC protocols should incorporate structured follow-up assessments at every subsequent contact point. Providers should verify actual net use, identify physical barriers to installation, and offer real-time motivational counseling to non-users, particularly those deterred by adverse effects, as modeled by Cottrell et al. [22].
- **Engage male partners as facilitators of utilization**: Recognizing that household decision-making dynamics significantly mediate a woman's ability to adhere to net-use recommendations [23, 25], outreach programs must actively involve male partners and household heads.
- **Pivot monitoring and evaluation from coverage to confirmed utilization**: The NMCP and district stakeholders should reorient their monitoring and evaluation frameworks to prioritize "confirmed use at time of observation" over "nominal household ownership." By adopting direct observational audits and validated self-report instruments, program managers can obtain a more accurate and actionable assessment of intervention effectiveness, moving beyond the misleading successes of distribution metrics [19, 20].

List of abbreviations

All abbreviations and acronyms used in this study are compiled in **Table 6** to facilitate clarity and improve readability.

Table 6
List of abbreviations and acronyms

Abbreviation	Full Term
ACT	Artemisinin-Based Combination Therapy
ANC	Antenatal Care
BCC	Behaviour Change Communication
CHPS	Community Health Planning and Service
CWC	Child Welfare Clinic
DALYs	Disability-Adjusted Life Years
DDT	Dichlorodiphenyltrichloroethane
DHIMS	District Health Information Management System
DHMT	District Health Management Team
GDP	Gross Domestic Product
GDHS	Ghana Demographic and Health Survey
GHS	Ghana Health Service
IPTp	Intermittent Preventive Treatment in Pregnancy
IRS	Indoor Residual Spraying
ITN	Insecticide-Treated Net
JHS	Junior High School
JSS	Junior Secondary School
KAP	Knowledge, Attitudes, and Practices
LBW	Low Birth Weight
LI	Legislative Instrument
LLITN / LLIN	Long-Lasting Insecticidal Treated Net / Long-Lasting Insecticidal Net
MOH	Ministry of Health
NGO	Non-Governmental Organization
NHIS	National Health Insurance Scheme
NMCP	National Malaria Control Programme
OPD	Outpatient Department
RBM	Roll Back Malaria

Abbreviation	Full Term
SHS	Senior High School
SP	Sulfadoxine-Pyrimethamine
WHO	World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval was obtained from the Ethics and Academic Integrity Committee of the Anglican University College of Technology (ANGUTECH), Nkoranza Campus, Ghana. All participants provided informed consent prior to participation.

Consent for publication

Consent to publish anonymized data was obtained from all participants.

Availability of data and materials

Data availability statement: The questionnaire, datasets obtained from the survey and the Python 3.12 script used for data analysis are available in the figshare repository at: https://figshare.com/s/b718e9145c204981e691.

Competing interests

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Authors' contributions

R.O.Y.: Conceptualization, Methodology, Formal analysis, Data curation, Validation, Investigation, Visualization, Writing – original draft, review & editing, Resources, Project administration.

I.A.A.: Methodology, Formal analysis, Data curation, Validation, Investigation, Visualization, Writing – original draft, review & editing

A.B.: Methodology, Formal analysis, Data curation, Validation, Investigation, Visualization, Writing – original draft, review & editing

B.O.: Methodology, Formal analysis, Data curation, Validation, Investigation, Visualization, Writing – original draft, review & editing

G.O.F.: Conceptualization, Methodology, Formal analysis, Data curation, Validation, Investigation, Visualization, Writing – original draft, review & editing, Resources, Supervision, Project administration.

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During the preparation of this work the authors used Cursor version 2.4.37 to write and edit the Python 3.12 script used for data analysis and visualisation. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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Figures

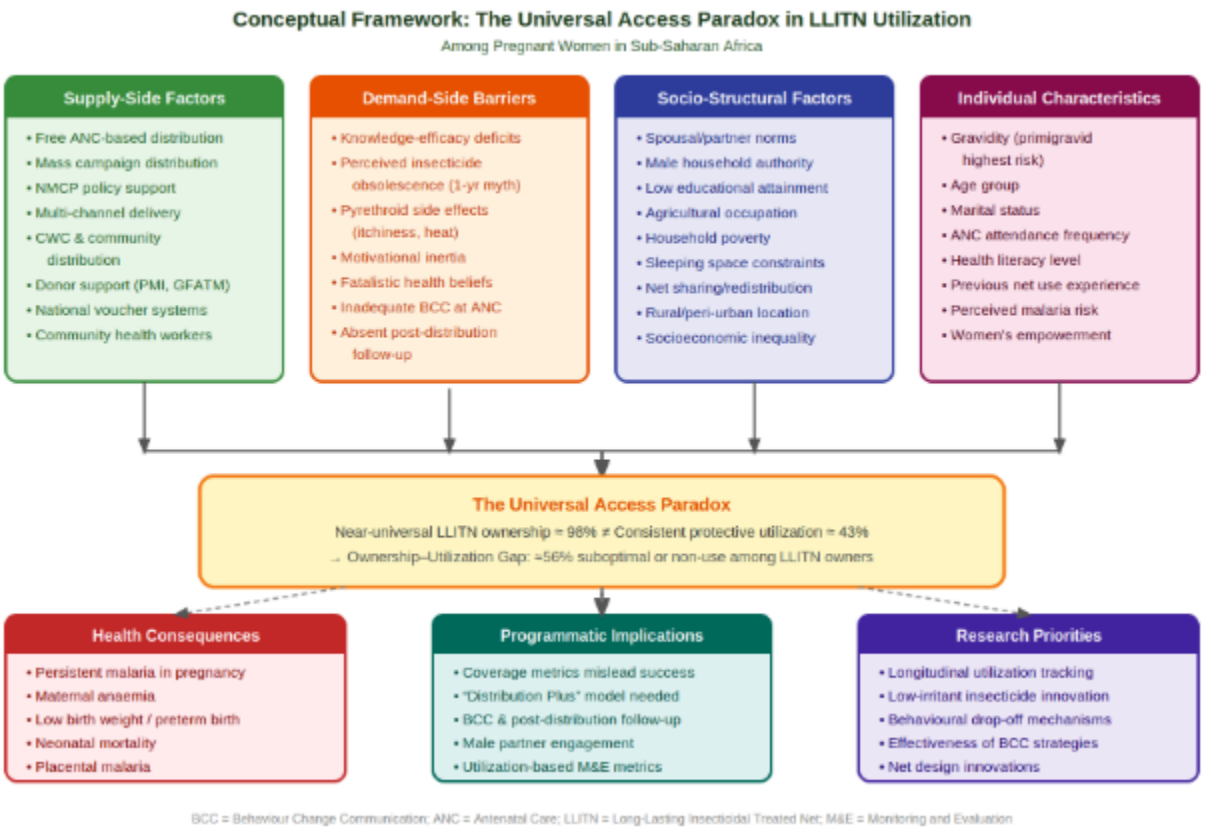


Figure 1

Conceptual framework of the Universal Access Paradox in LLITN utilization among pregnant women in sub-Saharan Africa. Supply-side, demand-side, socio-structural, and individual-level factors converge to produce a gap between near-universal ownership (≈99.5%) and consistent protective utilization (≈43.5%), with downstream health, programmatic, and research implications. *Note.* BCC = Behaviour Change Communication; ANC = Antenatal Care; LLITN = Long-Lasting Insecticidal Treated Net; M&E = Monitoring and Evaluation.

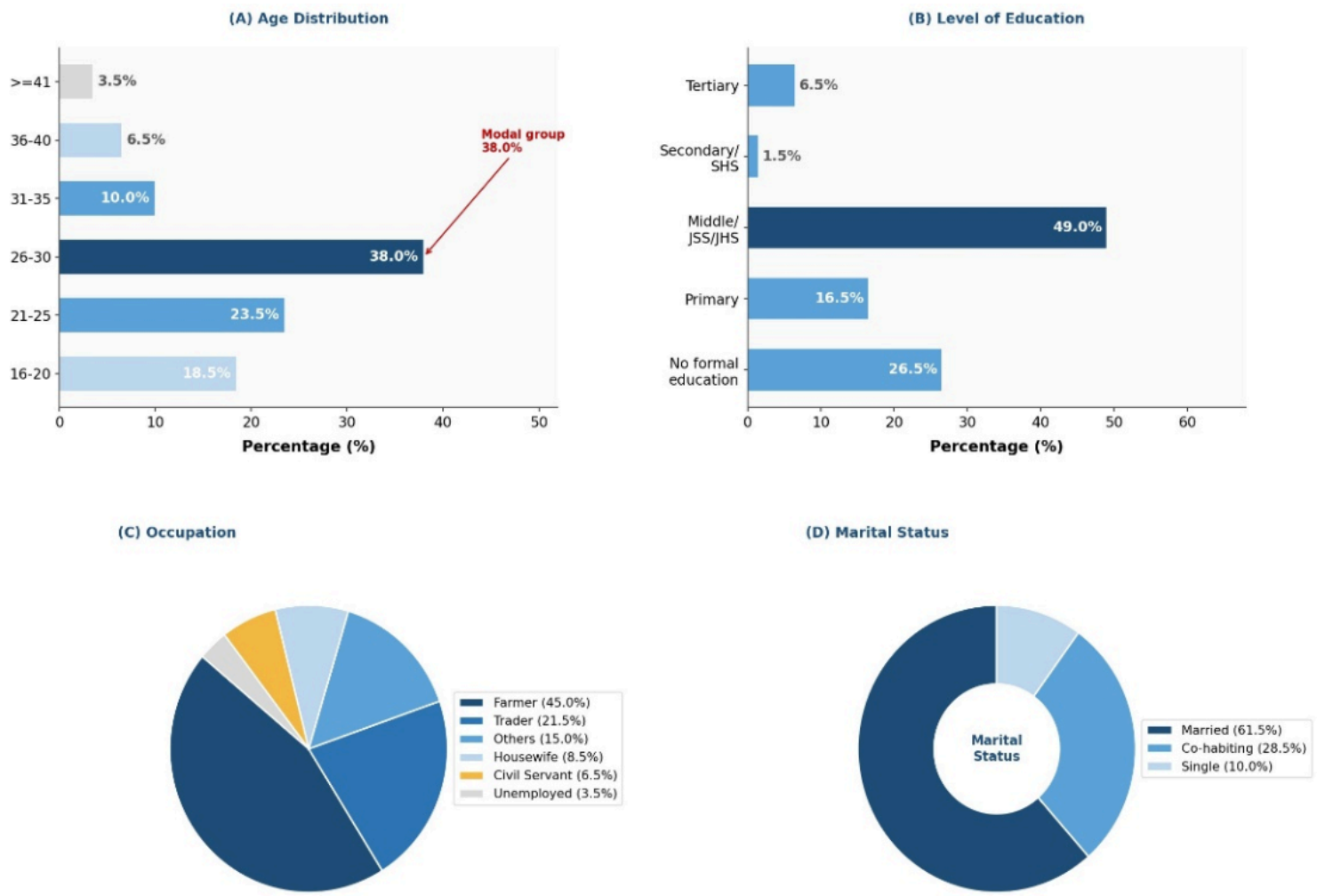


Figure 2

Socio-demographic characteristics of study respondents (*N* = 200). Panel A shows the distribution of respondents by age group; Panel B shows the distribution by level of education; Panel C shows the distribution by occupation; Panel D shows the distribution by marital status. *Note.* The 26–30 year age group constituted the modal category (38.0%). Middle/Junior High School was the most prevalent educational level (49.0%). Farming was the predominant occupation (45.0%). The majority of respondents were married (61.5%).

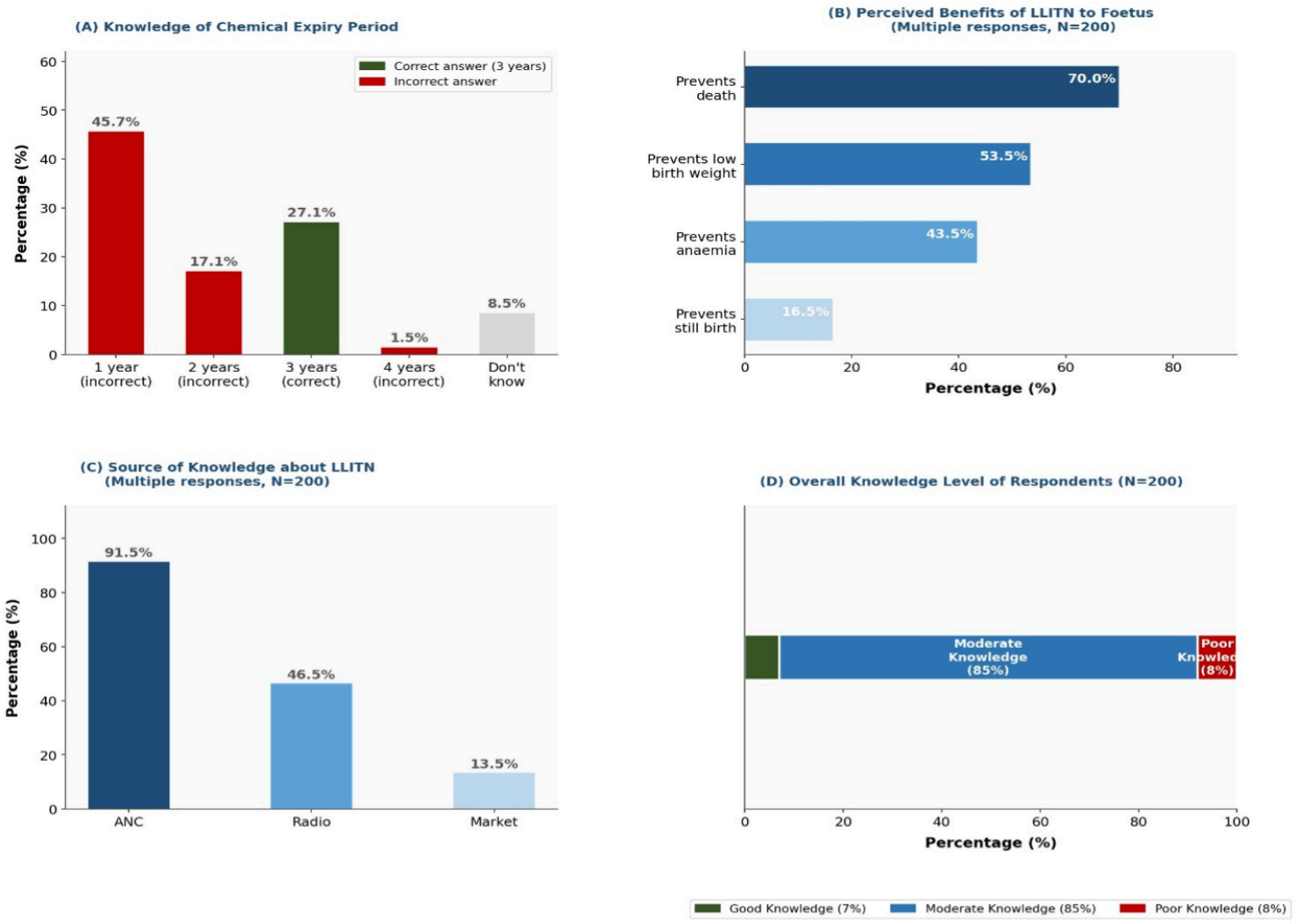


Figure 3

Knowledge of respondents regarding LLITNs. Panel A presents respondents' knowledge of the chemical expiry period, with the correct answer (3 years) indicated in green; Panel B shows perceived foetal health benefits; Panel C shows sources of LLITN knowledge; Panel D presents the distribution of overall knowledge levels. *Note.* All respondents (100%) were aware that LLITNs prevent malaria. Only 27.1% correctly identified the three-year chemical expiry period. The majority (85%) demonstrated a moderate overall level of knowledge. ANC = Antenatal Care; LLITN = Long-Lasting Insecticidal Treated Net.

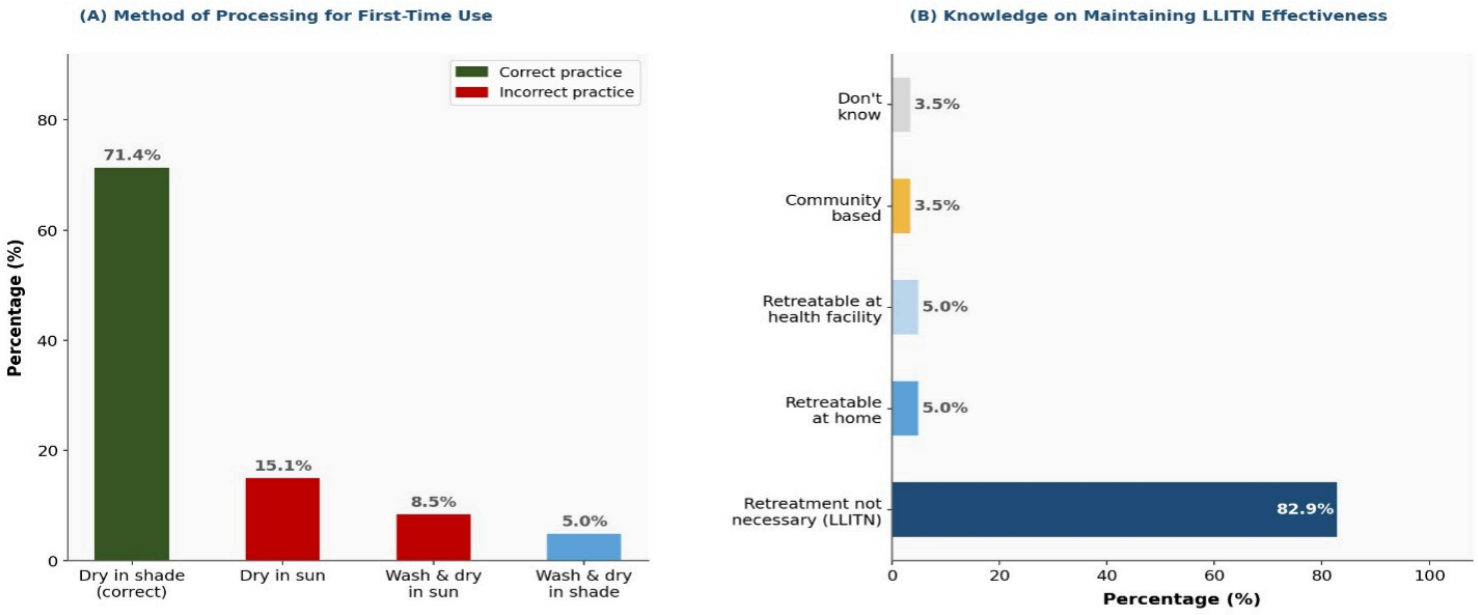


Figure 4

Knowledge on processing and maintenance of LLITN effectiveness. Panel A presents respondents' reported method of processing LLITNs for first-time use; Panel B presents knowledge regarding the maintenance of LLITN effectiveness over time. *Note.* 71.2% of respondents correctly reported drying the net in the shade as the appropriate first-time processing method. 83.1% correctly identified that LLITNs do not require chemical retreatment. LLITN = Long-Lasting Insecticidal Treated Net.

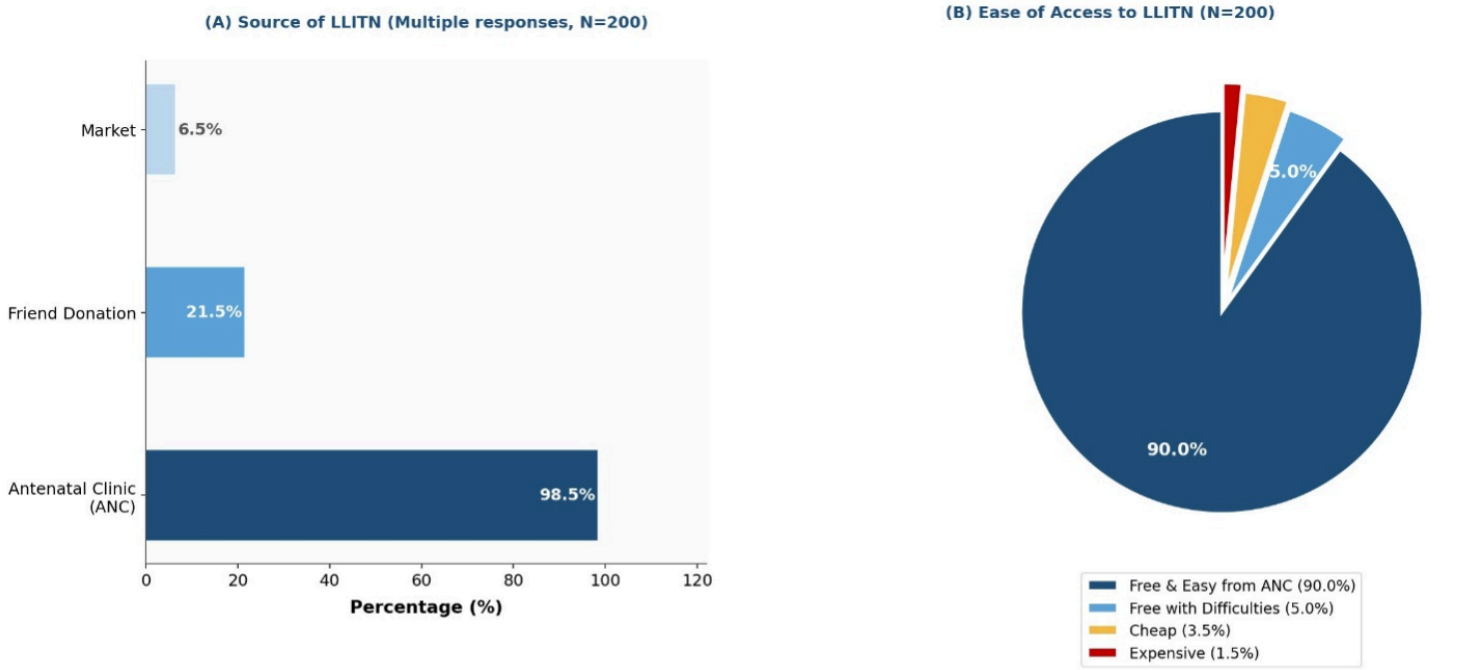


Figure 5

Access to LLITNs among respondents. Panel A presents the sources from which respondents obtained their LLITNs (multiple responses permitted); Panel B presents the distribution of responses regarding the

ease of LLITN access. *Note.* 98.5% of respondents obtained their LLITN from an ANC clinic. 90.0% reported free and easy access. ANC = Antenatal Care; LLITN = Long-Lasting Insecticidal Treated Net.

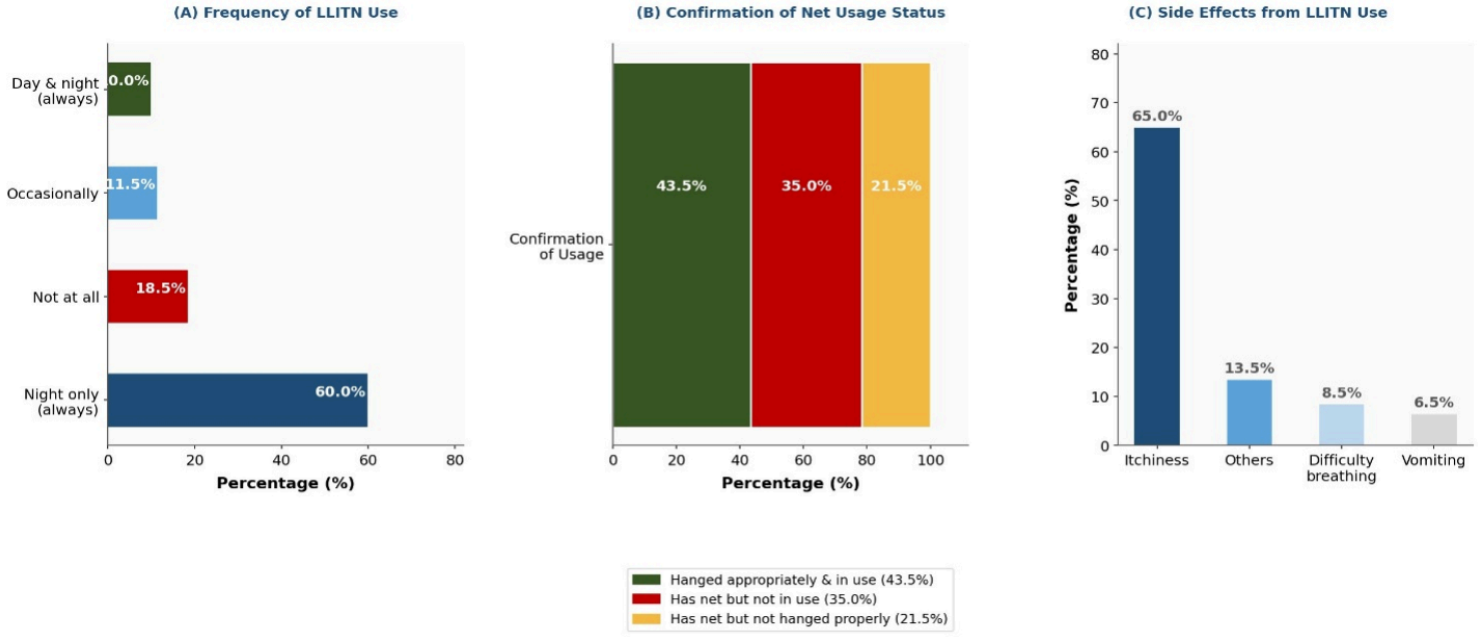


Figure 6

Common practices of LLITN use among respondents (*N* = 200). Panel A presents the frequency distribution of LLITN use; Panel B shows the confirmation of net use status based on direct observation; Panel C presents the distribution of side effects reported. *Note.* 60.0% of respondents reported nighttime-only net use. Only 43.5% had their net appropriately hung and actively in use at the time of observation. Itchiness was the most prevalent reported side effect (65.0%). LLITN = Long-Lasting Insecticidal Treated Net.

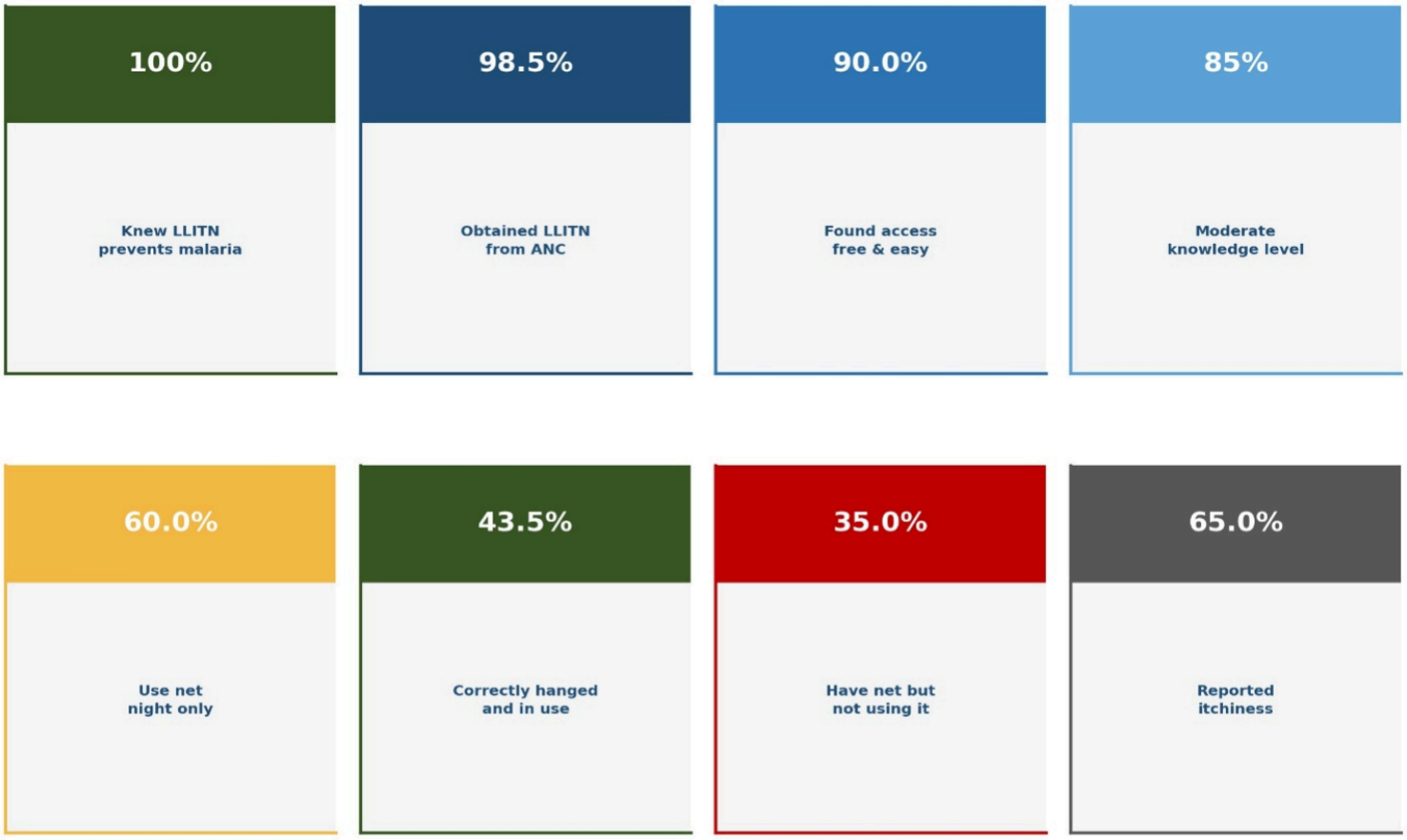


Figure 7

Key findings summary: LLITN access and utilization among pregnant women, Nkoranza South Municipality, Ghana (*N* = 200). Each panel represents a key metric derived from the study, organized to highlight the contrast between high knowledge/access rates and suboptimal utilization.

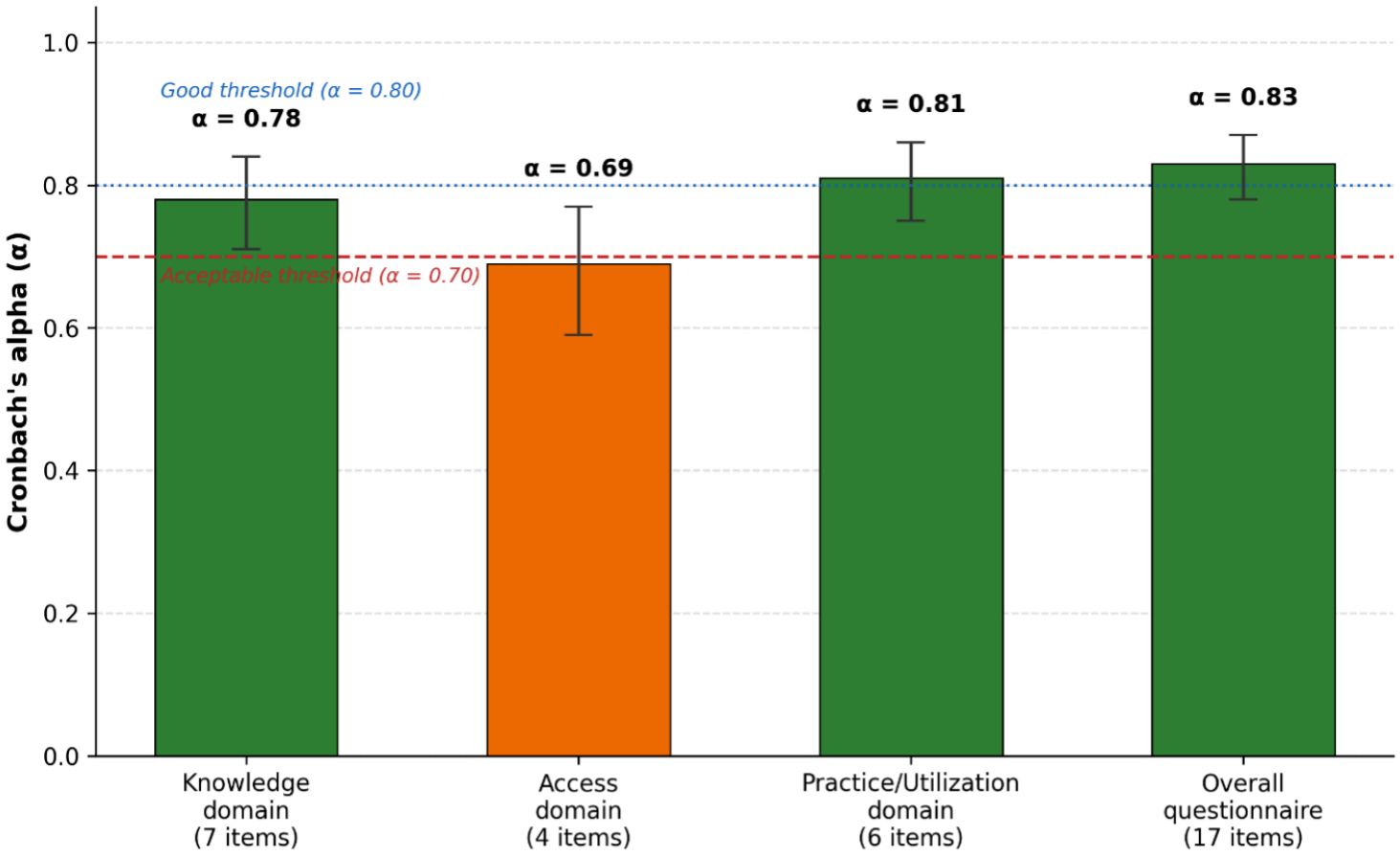


Figure 8

Internal consistency reliability of the structured questionnaire by domain, with 95% bootstrap confidence intervals. *Note.* Dashed red line denotes the conventional acceptable-reliability threshold (α = 0.70); dotted blue line denotes the good-reliability threshold (α = 0.80).

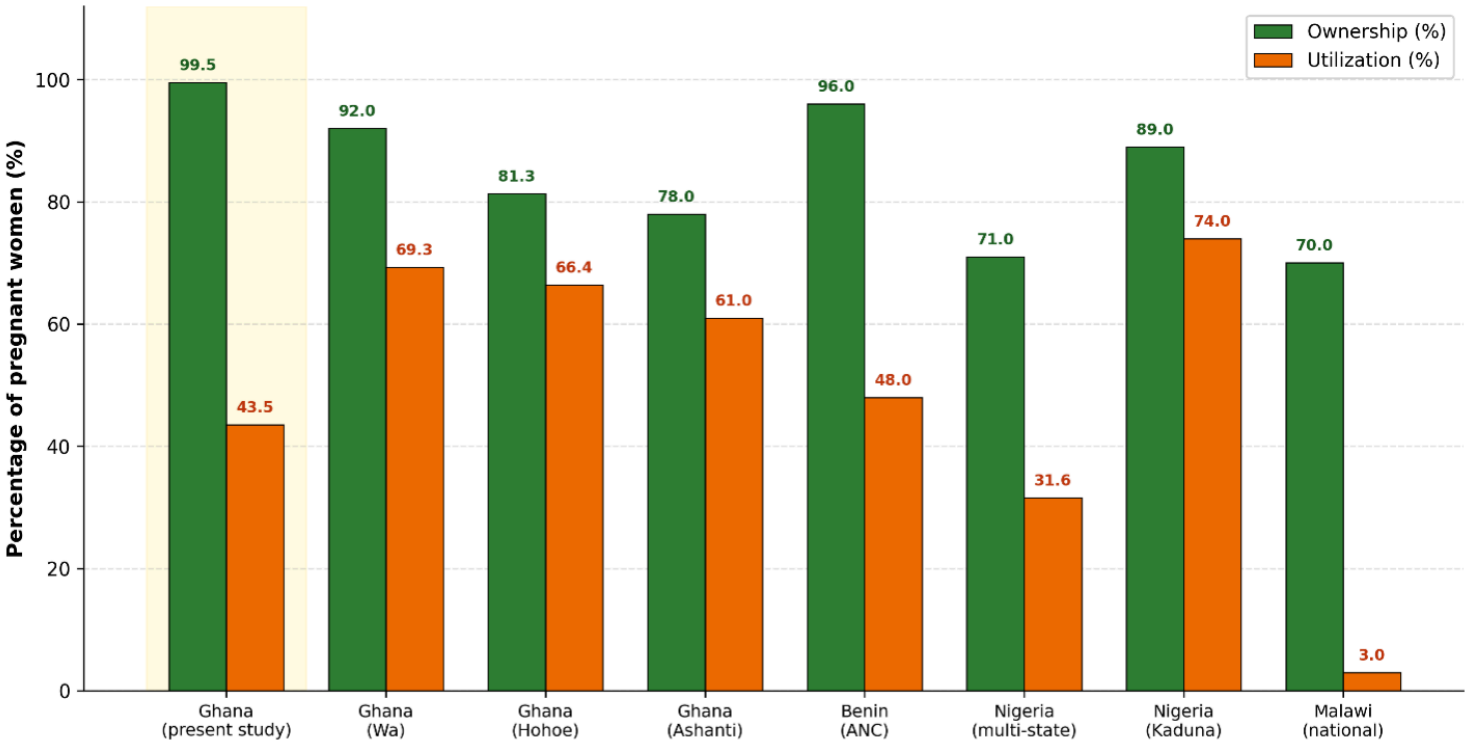


Figure 9

Cross-country comparison of LLITN/ITN ownership versus utilization among pregnant women in sub-Saharan Africa. The present study (highlighted) recorded the highest ownership rate among comparator settings reporting both metrics, alongside one of the largest ownership–utilization gaps. *Note. Note.* Gap = Ownership % − Utilization %, in percentage points. The present study (highlighted) is shown alongside the eight comparator settings reporting paired ownership and utilization data; the full 22-setting dataset, including settings reporting only utilization, is provided in the accompanying Excel workbook (Comparative_Data_and_Reliability.xlsx, Sheet: Cross-Country Comparison). ANC = Antenatal Care; LLITN = Long-Lasting Insecticidal Treated Net; ITN = Insecticide-Treated Net; pp = percentage points. Note: Data sources and full citations are provided in **Table 5.** ANC = Antenatal Care.