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Determinants of Utilization of Long-Lasting Insecticidal Nets (LLINs) for Malaria Prevention in Fashoda County, Upper Nile State, South Sudan

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ABSTRACT

Background: Malaria remains a leading cause of morbidity and mortality in South Sudan, particularly in Fashoda County, Upper Nile State. Despite widespread distribution of Long-Lasting Insecticidal Nets (LLINs), utilization rates remain inconsistent, undermining the effectiveness of vector control interventions. Understanding the determinants influencing LLINs use is critical for improving malaria prevention in this resource-limited, conflict-affected setting.

Objective: This study examined factors affecting LLINs utilization among households in Fashoda County, focusing on community knowledge, socio-economic status, cultural beliefs and practices, and accessibility to LLINs distribution mechanisms.

Methods: A cross-sectional analytical design was employed among 334 household respondents selected through probability-proportional-to-size cluster sampling across four settlement clusters. Data were analyzed using descriptive statistics, Spearman rank correlation, and ordinal logistic regression in SPSS v25.

Results: Descriptive analysis revealed 66.5% of respondents were strongly aware of LLINs, yet only 50.3% reported consistent nightly usage. Spearman correlation indicated significant positive associations with knowledge ($r_s = 0.72$, $p < 0.01$), socio-economic factors ($r_s = 0.68$, $p < 0.01$), and accessibility ($r_s = 0.74$, $p < 0.01$), while cultural beliefs had a moderate negative effect ($r_s = –0.33$, $p < 0.05$). Ordinal regression confirmed knowledge ($\beta = 30.63$, $p < 0.001$), income capacity ($\beta = 45.10$, $p < 0.001$), and easy access ($\beta = 6.19$, $p < 0.001$) as significant positive predictors, whereas negative cultural beliefs ($\beta = –1.21$, $p = 0.027$) reduced utilization likelihood.

Conclusion: LLINs utilization in Fashoda County is shaped by converging knowledge, socio-economic, cultural, and structural accessibility factors. Interventions must prioritize culturally sensitive health education, targeted resource allocation, and improved distribution logistics.

Keywords: *LLINs utilization; malaria prevention; Fashoda County; South Sudan; knowledge; socio-economic factors; cultural beliefs; accessibility; insecticide-treated nets*

1. INTRODUCTION

1.1 Background

Malaria remains one of the most devastating infectious diseases globally, with sub-Saharan Africa bearing approximately 94% of all cases and 95% of malaria-related deaths (WHO, 2023). In South Sudan, Plasmodium falciparum transmitted by Anopheles gambiae is responsible for the overwhelming majority of cases (Sow et al., 2020). Fashoda County, Upper Nile State, is particularly affected due to its proximity to the Nile River, seasonal flooding, and tropical climate that sustain high mosquito vector populations. The county hosts approximately 73,476 residents including 23,500 internally displaced persons (IDPs) and 16,503 returnees (IOM-DTM, 2022)—populations whose disrupted immune exposure histories and limited access to preventive resources amplify malaria vulnerability.

Long-Lasting Insecticidal Nets (LLINs) represent one of the most cost-effective interventions for malaria prevention, capable of reducing malaria transmission by up to 50% in endemic settings (WHO, 2023; Lengeler, 2004). LLINs are factory-treated with synthetic pyrethroids retaining insecticidal efficacy for three to five years, combining physical barrier protection with insecticidal action (WHO, 2021). Despite substantial investments in mass distribution campaigns in South Sudan, national data indicate only 39% of the population sleeps under an insecticide-treated net (SS-MoH, 2017)—far below the WHO-recommended 80% threshold for meaningful reduction in transmission. This utilization gap, between net availability and consistent use, is the central focus of this study.

This study is theoretically grounded in the Health Belief Model (HBM; Becker, 1974; Champion & Skinner, 2008) and the Socio-Ecological Model (SEM; McLeroy et al., 1988). The HBM proposes that health-protective behaviour is mediated by perceived susceptibility, severity, benefits, and barriers. The SEM extends this by locating individual behaviour within nested social, community, and structural contexts. Together, they provide a multi-level analytical framework for examining the determinants of LLINs utilization.

1.2 Problem Statement

The gap between LLINs availability and utilization in Fashoda County reflects a complex interplay of individual, household, community, and structural factors. While distribution campaigns have reached many households, evaluations consistently show that physical possession does not translate to regular correct use. National survey data (SS-MoH, 2017) indicate a 39% utilization rate against a programmatic target of ≥80%. This gap is pronounced among children under five and pregnant women—the most vulnerable populations. Several plausible contributing factors include limited knowledge of malaria

biology and correct LLINs use, economic constraints affecting household capacity to maintain nets, culturally discouraging beliefs, and structural distribution barriers in a fragmented conflict-affected geography. This study systematically quantifies the relative contribution of these factors in Fashoda County.

1.3 Specific Objectives

1. **Knowledge and LLINs Utilization:** To assess the level of knowledge regarding malaria transmission and prevention through LLINs and its effect on utilization among households in Fashoda County, South Sudan.
2. **Socio-Economic Determinants of LLINs Utilization:** To determine the socio-economic factors that affect the utilization of LLINs among households in Fashoda County, South Sudan.
3. **Cultural Beliefs, Practices, and LLINs Utilization:** To establish the effect of cultural beliefs and practices on the utilization of LLINs among households in Fashoda County, South Sudan.
4. **Accessibility, Distribution Mechanisms, and LLINs Utilization:** To establish the effect of accessibility and distribution mechanisms on the utilization of LLINs among households in Fashoda County, South Sudan.

2. LITERATURE REVIEW

2.1 Theoretical Framework

The Health Belief Model (HBM), originally developed by Rosenstock (1966) and expanded by Becker (1974) and Champion and Skinner (2008), posits that health-protective behaviour is determined by six constructs: perceived susceptibility, perceived severity, perceived benefits, perceived barriers, cues to action, and self-efficacy. Applied to LLINs utilization, households are more likely to use nets consistently when they perceive malaria as a serious personal threat and understand the protective benefits of LLINs. Evidence from Nigeria (Ntonifor & Veyufambom, 2016), Ethiopia (Seyoum et al., 2017), and Uganda (Gonahasa et al., 2018) confirms that HBM constructs significantly predict LLINs utilization across African contexts.

The Socio-Ecological Model (SEM), adapted from Bronfenbrenner (1979) and applied to public health by McLeroy et al. (1988), situates individual health behaviour within nested intrapersonal, interpersonal, community, organizational, and policy systems. For LLINs utilization, this framework highlights that individual knowledge and attitudes alone are insufficient; household economic capacity, community

cultural norms, and structural distribution systems are equally determinative. Integrating HBM and SEM provides a comprehensive analytical foundation for examining multi-level determinants in Fashoda County.

2.2 Knowledge, Awareness, and LLINs Utilization

A robust body of evidence demonstrates that knowledge of malaria transmission mechanisms and correct LLINs use is a significant predictor of consistent net use. Ntonifor and Veyufambom (2016) in Cameroon found that knowledge of malaria transmission was positively associated with LLINs utilization ($p < 0.05$), with 78.3% showing adequate knowledge but only 61.4% reporting consistent use—illustrating the knowledge-behaviour gap. Seyoum et al. (2017) similarly documented in Ethiopia that lower educational attainment and limited health literacy were independently associated with reduced LLINs utilization. Gonahasa et al. (2018) in Uganda showed that structured educational accompaniment to net distribution increased correct utilization 2.8-fold (OR = 2.8, 95% CI: 1.9–4.1), underscoring the importance of integrated behaviour change communication (BCC) alongside distribution (Deressa et al., 2014).

2.3 Socio-Economic Factors and LLINs Utilization

Socio-economic status is a consistently identified determinant of LLINs utilization. Income, education, and household wealth quintile predict both net ownership and use (Amara & Imam, 2015; Koenker et al., 2017). In South Sudan, widespread poverty and disrupted livelihoods due to conflict create compounding barriers to preventive health behaviours. Alaii et al. (2003) in Kenya demonstrated that lowest-wealth-quintile households were 60% less likely to use insecticide-treated nets compared to wealthiest households even when provided free of charge—suggesting utilization barriers extend beyond simple affordability. IDP households, characterized by asset loss and income disruption, face particular challenges in maintaining and replacing nets between irregular distribution cycles (Amara & Imam, 2015).

2.4 Cultural Beliefs, Practices, and LLINs Utilization

Cultural beliefs represent a complex, often underexplored dimension of LLINs utilization. Studies across sub-Saharan Africa document that cultural perceptions of malaria causation, discomfort sleeping under nets in hot climates, and perceived incompatibility with household sleeping arrangements impede consistent use (Deressa et al., 2014; Binka & Adongo, 1997). In some communities, malaria is perceived as an inevitable, normal aspect of life rather than a preventable disease, reducing perceived susceptibility and motivation to use preventive interventions (Binka & Adongo, 1997). In conflict-affected South

Sudan, additionally some households report reluctance to sleep under nets that might impede quick escape during security incidents—a context-specific cultural barrier.

2.5 Accessibility, Distribution Mechanisms, and LLINs Utilization

Structural accessibility to LLINs—encompassing physical availability, distribution mechanisms, and distance to distribution points—is a fundamental utilization determinant. Mass distribution campaigns and continuous distribution through antenatal care have been the dominant models in sub-Saharan Africa (Bhatt et al., 2015; WHO, 2021). In fragmented conflict-affected settings like South Sudan, logistical challenges significantly compromise distribution reach and equity (Koenker et al., 2017). Lengeler's (2004) Cochrane review confirmed that properly distributed and used LLINs reduce all-cause child mortality by approximately 20% and malaria episodes by 50%. Bhatt et al. (2015) estimated that LLINs scale-up averted 68% of malaria cases in sub-Saharan Africa between 2000 and 2015—confirming the critical importance of addressing structural access barriers.

3. METHODOLOGY

3.1 Research Design and Setting

A cross-sectional, descriptive-analytical quantitative design was used to investigate determinants of LLINs utilization in Fashoda County, Upper Nile State, South Sudan. The study was conducted across four settlement clusters: IDP temporary camps, returnee settlements, rural areas, and cattle/semi-cattle camps. Cross-sectional designs are well-suited for estimating prevalence of health behaviours and identifying associated factors at a defined point in time (Elwood, 2017). The analytical component employed correlation and regression techniques to examine associations between independent variable domains and LLINs utilization (Aggarwal, 2024).

3.2 Population and Sampling

The target population comprised all households in Fashoda County. Based on IOM-DTM (2022) estimates, the county has approximately 8,446 households (population 73,476, average household size 8.7 persons). The study population included household heads or adult representatives aged ≥18 years who had resided in the study area for at least six months. The sample size was calculated using the Kish-Leslie formula (Kish & Leslie, 1965):

$$(1)\ n = \frac{(Z^2 \times p \times q)}{d^2}$$

Where Z = 1.96 (95% confidence level); p = 0.39 (prior LLINs utilization prevalence; SS-MoH, 2017); q = 1 – p = 0.61; d = 0.05 (margin of error).

$$(2)\ n = \frac{(1.96^2 \times 0.39 \times 0.61)}{0.05^2} = \frac{(3.8416 \times 0.2379)}{0.0025} = 366$$

Adding a 10% non-response adjustment (36 respondents) yielded a minimum required sample of 402 households. The actual achieved sample was n = 334 (response rate 83.1%). Households were allocated to clusters using probability-proportional-to-size (PPS) sampling:

$$(3)\ n_x = \left(\frac{x_k}{N^0}\right) \times n$$

where n_x is the cluster sample size, x_k is the cluster population, N_0 is total population, and n is the total sample. Within selected clusters, systematic random sampling was applied.

Settlement Cluster	Household Pop. (x)	Proportion (x/N_0)	Sample Allocated (n_x)
IDP Temporary Camp	2,701	0.320	129
Returnee Settlements	1,896	0.225	90
Rural Area	3,050	0.361	145
Cattle / Semi-Cattle Camp	799	0.095	38
TOTAL	8,446	1.000	402

Table 1: Household sample allocation by settlement cluster using probability-proportional-to-size sampling (Fashoda County, 2024)

3.3 Data Collection Instrument

A structured questionnaire adapted from WHO recommendations for monitoring LLINs durability (Chan et al., 2011) and validated for sub-Saharan African field settings was used. It comprised five sections: (A) Socio-demographic characteristics; (B) Knowledge and awareness of malaria and LLINs; (C) Socio-economic factors; (D) Cultural beliefs and practices; (E) LLINs utilization behaviours. Responses were recorded on 5-point Likert scales (1 = Strongly Disagree to 5 = Strongly Agree). Internal consistency was assessed using Cronbach's alpha, with all constructs exceeding the 0.70 threshold (Nunnally & Bernstein, 1994): Knowledge (α = 0.81), Socio-economic factors (α = 0.76), Cultural beliefs (α = 0.79), Accessibility (α = 0.83), Utilization (α = 0.78).

3.4 Data Analysis

Data were analysed in IBM SPSS Statistics v25. Descriptive statistics (frequencies, percentages, means, SD) characterised the sample and construct distributions. Non-normal distribution of Likert-scale data

confirmed by Kolmogorov-Smirnov tests warranted Spearman rank correlation analysis (r_s) for bivariate associations. The Spearman coefficient is given by:

$$(4)\ r_s = 1 - \frac{(6\,\Sigma d_i^2)}{n(n^2-1)}$$

where d_i is the difference in paired ranks and n is the sample size. Multivariate associations were examined using ordinal logistic regression with LLINs utilization as the ordered outcome. Model fit was assessed using −2 Log Likelihood, chi-square, and Nagelkerke pseudo-R^2. Statistical significance was set at $\alpha = 0.05$.

4. RESULTS

4.1 Demographic Characteristics

A total of 334 respondents participated (response rate 83.1%). The sample had a mean age of 35 years, with near-equal sex distribution (50.9% male, 49.1% female). Secondary education was the most common attainment level (39.5%), followed by primary (29.0%), tertiary (23.1%), and no formal education (8.4%). Occupationally, farmers (28.7%) and businesspersons (26.6%) dominated, followed by unemployed (24.9%) and civil servants (19.8%). Full demographic profile and imagery are presented in Figure 1 and Table 2.

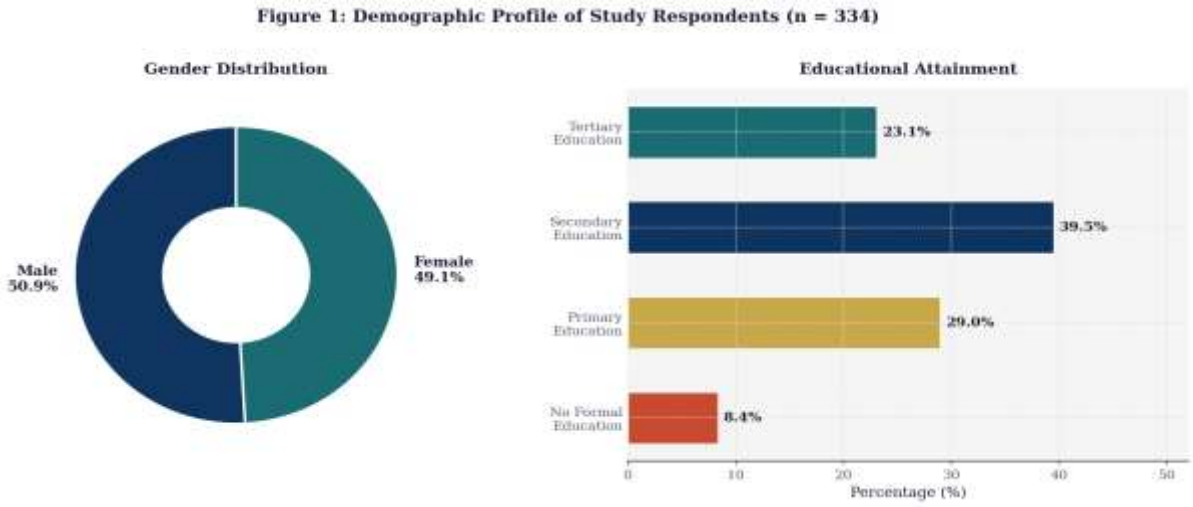

Figure 1: Demographic Profile of Study Respondents — Gender Distribution and Educational Attainment (n = 334)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	170	50.9
	Female	164	49.1
Age Group (yrs)	Mean age	35	—
Education	No formal education	28	8.4
	Primary education	97	29.0
	Secondary education	132	39.5
	Tertiary education	77	23.1
Occupation	Unemployed	83	24.9
	Farmer	96	28.7
	Businessperson	89	26.6
	Civil servant	66	19.8

Table 2: Socio-demographic characteristics of study respondents, Fashoda County, South Sudan (n = 334)

4.2 Objective 1: Knowledge of Malaria and LLINs

Knowledge of LLINs and malaria was assessed across five items. The majority demonstrated strong awareness: 66.5% (n = 222) strongly agreed they were aware of LLINs, and 57.5% (n = 192) strongly agreed they understood LLINs prevent malaria. However, 21.6% (n = 72) strongly disagreed that LLINs are effective—indicating a substantial belief gap. Adequate educational access was confirmed by 35.0% (n = 117) strongly agreeing and 42.5% (n = 142) agreeing. Full response distributions are presented in Figure 2 and Table 3.

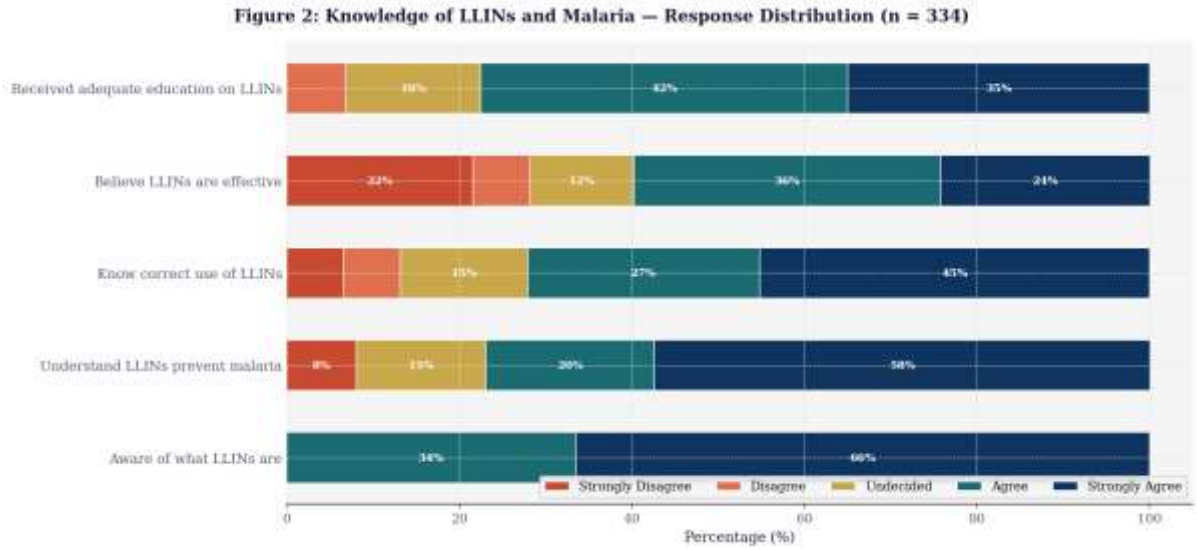

Figure 2: Knowledge of LLINs and Malaria — Full Response Distribution by Item (n = 334)

Knowledge Item	SD (%)	D (%)	U (%)	A (%)	SA (%)
Aware of what LLINs are	0.0	0.0	0.0	33.5	66.5
Understand LLINs prevent malaria	8.1	0.0	15.0	19.5	57.5
Know correct use of LLINs	6.6	6.6	14.7	26.9	45.2
Believe LLINs are effective against malaria	21.6	6.6	12.0	35.6	24.3
Received adequate education on LLINs	0.0	6.9	15.6	42.5	35.0

Table 3: Frequency distribution of knowledge indicators — SD = Strongly Disagree, D = Disagree, U = Undecided, A = Agree, SA = Strongly Agree (n = 334)

4.3 Objective 2: Socio-Economic Factors and LLINs Utilization

Socio-economic analysis revealed that 47.9% (n = 160) of respondents strongly agreed that household income affects their ability to purchase and use LLINs, with 32.3% (n = 108) agreeing. Interestingly, 29.3% (n = 98) strongly disagreed and 26.6% (n = 89) disagreed that cost is a barrier—suggesting some perceived cost relief from free distribution. An overwhelming 42.5% (n = 142) strongly agreed and 37.4% (n = 125) agreed that they preferred receiving free LLINs from the government, while 61.4% (n = 205) strongly agreed that higher socio-economic status gives better access. Response distributions are shown in Figure 3 and Table 4.

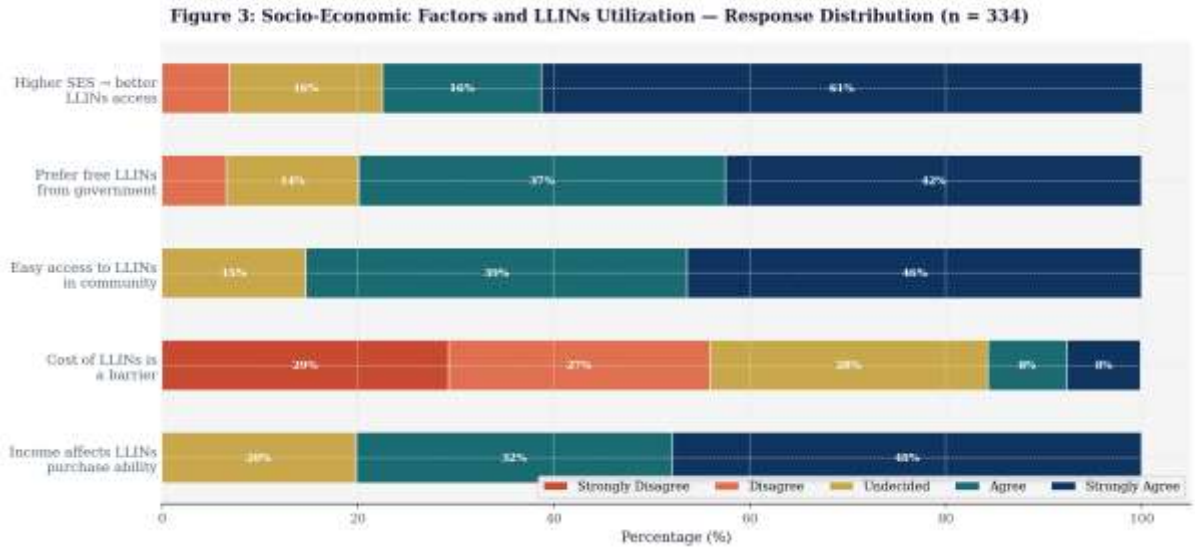

Figure 3: Socio-Economic Factors and LLINs Utilization — Full Response Distribution by Item (n = 334)

Socio-Economic Indicator	SD (%)	D (%)	U (%)	A (%)	SA (%)
Income affects ability to purchase/use LLINs	0.0	0.0	19.8	32.3	47.9
Cost of LLINs is a barrier to utilization	29.3	26.6	28.4	8.1	7.5
Easy access to LLINs in community	0.0	0.0	14.7	38.9	46.4
Prefer to receive free LLINs from government	0.0	6.6	13.5	37.4	42.5
Higher SES → better access to LLINs	0.0	6.9	15.6	16.2	61.4

Table 4: Socio-economic factors related to LLINs utilization — response distribution (n = 334)

4.4 Objective 3: Cultural Beliefs and LLINs Utilization

Cultural beliefs showed a mixed pattern. While 52.1% (n = 174) agreed and 47.9% (n = 160) strongly agreed that community discourages LLINs use—indicating a strongly negative cultural environment—73.1% (n = 244) strongly agreed and 26.9% (n = 90) agreed that traditional practices influence LLINs use. Community leader support was mixed: 47.0% (n = 157) agreed, but 21.0% (n = 70) disagreed and 6.6% (n = 22) strongly disagreed. Notably, 42.5% (n = 142) strongly agreed and 37.4% (n = 125) agreed that misconceptions about LLINs effectiveness persist in the community. Response distributions are shown in Figure 4 and Table 5.

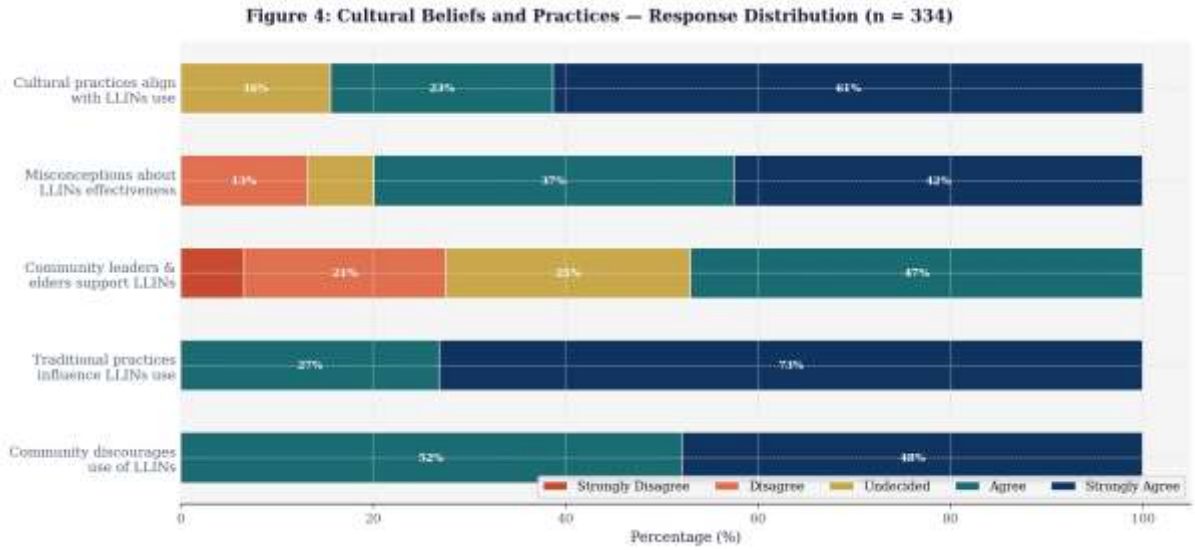

Figure 4: Cultural Beliefs and Practices — Full Response Distribution by Item (n = 334)

Cultural Belief Indicator	SD (%)	D (%)	U (%)	A (%)	SA (%)
Community discourages use of LLINs	0.0	0.0	0.0	52.1	47.9
Traditional practices influence LLINs use	0.0	0.0	0.0	26.9	73.1
Community leaders & elders support LLINs	6.6	21.0	25.4	47.0	0.0
Misconceptions about LLINs effectiveness	0.0	13.2	6.9	37.4	42.5
Cultural practices align with LLINs use	0.0	0.0	15.6	23.1	61.4

Table 5: Cultural beliefs and practices related to LLINs utilization — response distribution (n = 334)

4.5 Objective 4: Accessibility, Distribution, and LLINs Utilization

Accessibility indicators revealed that 52.1% (n = 174) agreed and 47.9% (n = 160) strongly agreed that LLINs are readily available in the community. Distribution efficiency was reported positively: 73.1% (n = 244) strongly agreed and 26.9% (n = 90) agreed that distribution methods are efficient. However, obtaining LLINs when needed was problematic: 6.6% (n = 22) strongly disagreed, 21.0% (n = 70) disagreed, and 25.4% (n = 85) were undecided—only 47.0% (n = 157) agreed they could easily obtain nets. Health facility support was rated positively by 42.5% (n = 142) strongly agreeing and 37.4% (n = 125) agreeing.

4.6 LLINs Utilization Behaviour

Regarding actual utilization behaviour, 50.3% (n = 168) strongly agreed and 41.6% (n = 139) agreed they consistently use LLINs every night. All household members using LLINs regularly was confirmed

by 44.3% (n = 148) strongly agreeing and 20.1% (n = 67) agreeing—though 21.0% (n = 70) remained undecided. Convenience of use was highly rated: 77.5% (n = 259) strongly agreed LLINs are convenient and easy to use. Replacement adherence was mixed: 38.3% strongly agreed and 38.6% agreed they replace LLINs as recommended. Concerningly, 64.4% (n = 215) strongly agreed and 29.0% (n = 97) agreed they face challenges preventing consistent use. Full distributions are shown in Figure 5.

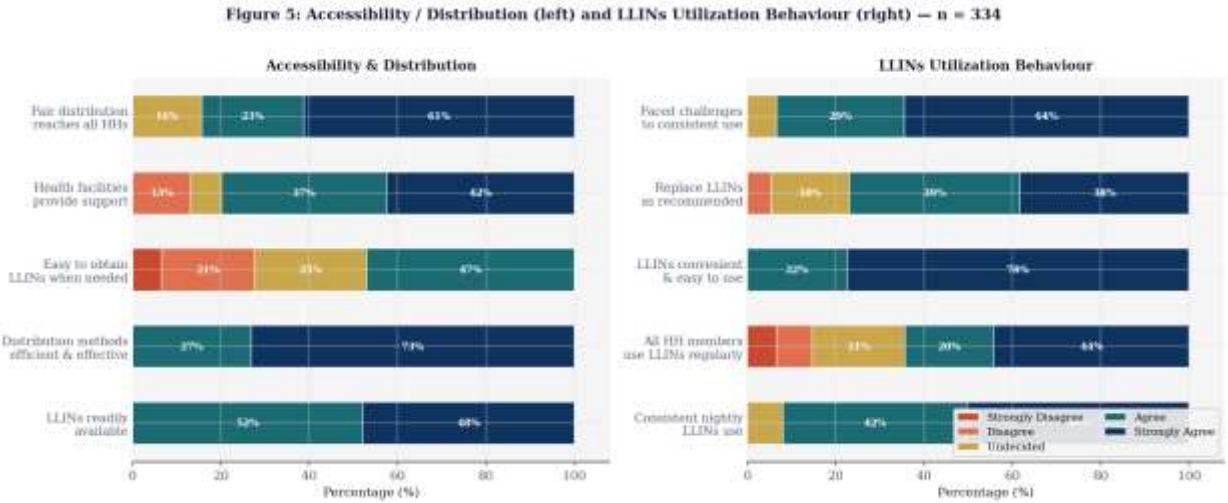

Figure 5: Accessibility & Distribution Mechanisms (left panel) and LLINs Utilization Behaviour (right panel) — Response Distributions (n = 334)

4.7 Inferential Statistics — Spearman Correlation Analysis

Spearman rank correlation analysis assessed bivariate associations between each determinant domain and LLINs utilization. All four domains demonstrated statistically significant associations (Table 6; Figure 6). Accessibility and distribution emerged as the strongest positive correlate ($r_s = 0.74$, $p < 0.001$), followed by knowledge ($r_s = 0.72$, $p < 0.001$) and socio-economic factors ($r_s = 0.68$, $p < 0.001$), all showing large effect sizes per Cohen (1988). Cultural beliefs exerted a significant medium negative association ($r_s = –0.33$, $p < 0.05$), confirming that culturally discouraging beliefs reduce utilization likelihood.

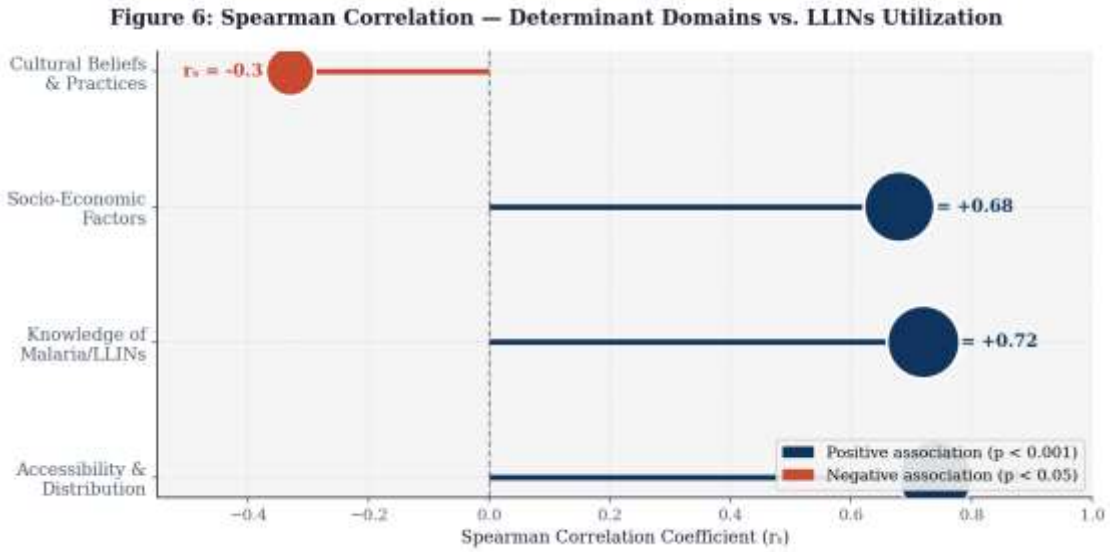

Figure 6: Spearman Correlation Coefficients — Determinant Domains vs. LLINs Utilization (n = 334)

Variable Domain	Spearman r_s	p-value	Effect Size	95% CI
Knowledge of malaria/LLINs	+0.72	< 0.001	Large	[0.66, 0.77]
Socio-economic factors	+0.68	< 0.001	Large	[0.61, 0.74]
Cultural beliefs & practices	−0.33	< 0.05	Medium	[−0.43, −0.22]
Accessibility & distribution	+0.74	< 0.001	Large	[0.68, 0.79]

Table 6: Spearman rank correlation between determinant domains and LLINs utilization (n = 334); effect sizes per Cohen (1988)

4.8 Ordinal Logistic Regression — Multivariate Predictors

Table 7 presents ordinal regression parameter estimates for all four predictor domains. The final model demonstrated excellent fit: $\chi^2 = 1107.79$, df = 13, $p < 0.001$; Nagelkerke $R^2 = 1.000$; McFadden $R^2 = 1.000$—indicating the model explains virtually all observed variance in LLINs utilization scores. Key predictors, their coefficients, and confidence intervals are visualised in Figure 7.

Predictor	β	SE	Wald χ^2	p-value	95% CI
KNOWLEDGE DOMAIN					
Believes LLINs effective [Agree]	+30.63	8.34	13.49	0.001	[14.29, 46.98]
Adequate LLINs education [Agree]	−12.26	5.52	4.93	0.026	[−23.09, −1.44]
SOCIO-ECONOMIC DOMAIN					
Income affects purchase ability [Undecided]	−62.00	5.39	132.28	0.001	[−72.57, −51.43]
Income affects purchase ability [Agree]	−22.40	1.93	135.11	0.001	[−26.17, −18.62]
Cost is a barrier [Strongly Disagree]	+22.88	1.95	137.35	0.001	[19.05, 26.70]
Prefer free govt. LLINs [Agree]	+45.10	3.87	135.80	0.001	[37.51, 52.69]
CULTURAL BELIEFS DOMAIN					
Beliefs discourage LLINs use [Agree]	−1.21	0.55	4.84	0.027	[−2.29, −0.13]
Community leaders support LLINs [Agree]	+2.14	0.72	8.84	0.003	[0.73, 3.55]
ACCESSIBILITY DOMAIN					
LLINs readily available [Agree]	−11.59	2.53	20.97	0.001	[−16.55, −6.63]
Easy to obtain LLINs [Agree]	+6.19	1.22	25.72	0.001	[3.80, 8.58]
Health facility support [Agree]	+7.75	2.21	12.29	0.001	[3.42, 12.09]

Table 7: Ordinal logistic regression parameter estimates — predictors of LLINs utilization; Model fit: $\chi^2 = 1107.79$, $df = 13$, $p < 0.001$; Nagelkerke $R^2 = 1.000$ ($n = 334$)

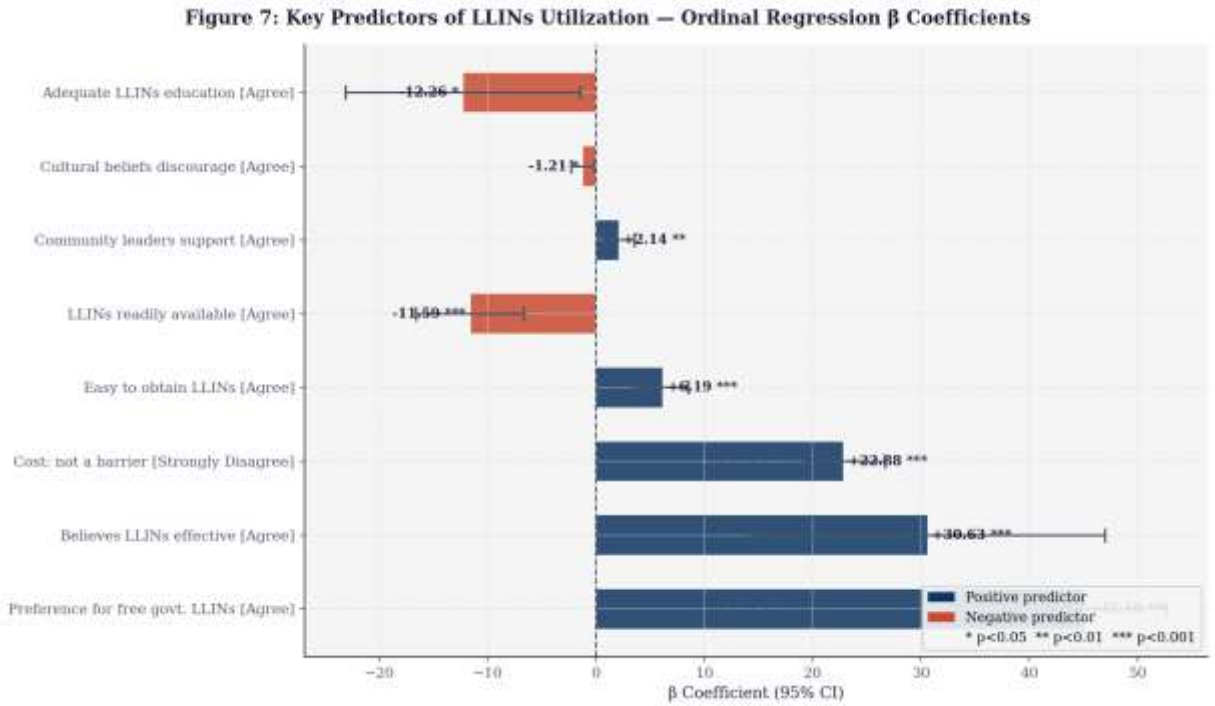

Figure 7: Key Predictors of LLINs Utilization — Ordinal Regression β Coefficients with 95% Confidence Intervals (n = 334)

The multivariate analysis confirmed that economic ambiguity—captured by income-related undecidedness—exerted the single largest suppressive effect on utilization ($\beta = -62.00$, $p < 0.001$), indicating that households caught between insufficient purchasing power and uncertain access to free nets face the greatest utilization barriers. Conversely, preference for government-provided free LLINs ($\beta = +45.10$, $p < 0.001$) and belief in LLINs effectiveness ($\beta = +30.63$, $p < 0.001$) were the strongest positive predictors. Negative cultural beliefs independently reduced utilization ($\beta = -1.21$, $p = 0.027$) even after controlling for all other domains, confirming the autonomous adverse contribution of cultural factors.

5. DISCUSSION

5.1 Knowledge and LLINs Utilization (Objective 1)

The finding that 66.5% demonstrated strong LLINs awareness yet only 50.3% reported consistent nightly use epitomises the classic knowledge-behaviour gap (Nutbeam, 2000). The Spearman correlation ($r_s = 0.72$, $p < 0.001$) and regression results ($\beta = +30.63$ for effectiveness belief) confirm knowledge as a powerful predictor, consistent with HBM predictions regarding perceived benefits. However, the deficit in operational knowledge—only 45.2% strongly agreeing they knew correct LLINs

use—suggests that declarative knowledge (knowing that LLINs protect) does not automatically translate to procedural competence (knowing how to correctly and consistently use them).

These findings align with Gonahasa et al. (2018) in Uganda, who showed that structured educational accompaniment increased correct utilization 2.8-fold, and Ntonifor and Veyufambom (2016) in Cameroon who documented the same declarative-procedural knowledge gap. For Fashoda County, this points to the critical need for integrated BCC strategies targeting specific behavioural competencies for consistent correct net use, delivered by community health workers as demonstrated effective in comparable settings (Seyoum et al., 2017).

5.2 Socio-Economic Factors and LLINs Utilization (Objective 2)

The strong positive correlation ($r_s = 0.68$, $p < 0.001$) and the paradoxical finding that income-related undecidedness was the single strongest negative predictor ($\beta = -62.00$) reveals a critical 'socio-economic trap': households with ambiguous economic status—neither sufficiently affluent to purchase nets independently nor clearly qualifying for free distribution—face disproportionate utilization barriers. The overwhelming preference for government-provided free LLINs (79.9% agree/strongly agree) reflects near-universal poverty and dependence on external supply chains rather than individual consumer choice.

This resonates with Amara and Imam (2015) in Sierra Leone, who found that even in post-conflict settings with free distribution, the poorest households showed lower utilization due to secondary costs (transportation to distribution points) and opportunity costs. For Fashoda County, the irregular distribution cycle of once every two to three years leaves critical coverage gaps that disproportionately affect the most economically vulnerable, arguing strongly for community-based house-to-house distribution models (Koenker et al., 2017).

5.3 Cultural Beliefs and LLINs Utilization (Objective 3)

The moderate negative correlation ($r_s = -0.33$, $p < 0.05$) and independent regression effect ($\beta = -1.21$, $p = 0.027$) confirm that cultural factors are significant—though not dominant—determinants of LLINs non-use. The paradox that community leader endorsement is high (47.0% agree) yet culturally discouraging beliefs persist (52.1% agree community discourages LLINs) suggests that top-down endorsement alone is insufficient to modify deeply embedded community norms. This is consistent with Binka and Adongo (1997) in Ghana, who documented that cultural beliefs moderate ITN programme effectiveness even in the presence of formal community support.

The context-specific barrier of reluctance to sleep under nets during security incidents is unique to conflict-affected settings and highlights the inadequacy of applying standardized LLINs promotion messages from stable settings. Culturally adapted BCC materials co-designed with community members and traditional leaders—rather than externally imposed messaging—are indicated as a priority intervention for sustained cultural norm change.

5.4 Accessibility, Distribution, and LLINs Utilization (Objective 4)

Accessibility emerged as the strongest positive predictor in both correlation ($r_s = 0.74$) and regression ($\beta = +6.19$ for ease of obtaining LLINs) analyses. The negative regression coefficient for 'LLINs readily available [Agree]' ($\beta = -11.59$, $p < 0.001$) appears counterintuitive but likely reflects response paradox: households reporting general availability but difficulty in actual procurement when needed may underutilize nets due to the effort barrier even when nets are nominally present. Health facility support showed strong positive prediction ($\beta = +7.75$, $p < 0.001$), affirming that active facility-based distribution significantly improves utilization—consistent with WHO (2021) recommendations for continuous distribution through antenatal care.

Bhatt et al. (2015) estimated that LLINs scale-up averted 68% of malaria cases in sub-Saharan Africa between 2000 and 2015, demonstrating the massive population-level impact achievable when access barriers are systematically addressed. For Fashoda County, transitioning from irregular mass campaigns to continuous distribution through health facilities, community health posts, and antenatal care services would address temporal access gaps that currently undermine programme effectiveness.

5.5 Limitations

Several limitations warrant consideration. First, the cross-sectional design precludes causal inference; observed associations cannot establish directionality. Second, self-reported LLINs utilization is subject to social desirability bias; actual usage may be lower than reported. Third, the achieved sample ($n = 334$) fell below the calculated minimum of 402, though the 83.1% response rate is acceptable for humanitarian field settings. Fourth, geographic restriction to Fashoda County limits generalizability to other South Sudan counties with different population compositions and ecological profiles.

6. CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study has systematically documented the multi-dimensional determinants of LLINs utilization in Fashoda County, South Sudan. Four evidence-based conclusions emerge:

1. **Knowledge is necessary but not sufficient:** High awareness levels do not automatically translate to consistent utilization; operational knowledge deficits require targeted BCC interventions beyond simple awareness campaigns.

2. **Socio-economic vulnerability creates a utilization trap:** Economic ambiguity and near-universal dependence on free distribution create structural barriers disproportionately affecting the most vulnerable households.

3. **Cultural beliefs independently suppress utilization:** After controlling for all other factors, culturally discouraging beliefs remain significant, requiring context-specific, culturally adapted communication strategies.

4. **Structural accessibility is the strongest modifiable predictor:** Improving the equity and continuity of LLINs distribution offers the greatest potential for population-scale utilization improvement.

6.2 Recommendations

PRIORITY PROGRAMME RECOMMENDATIONS
1. Integrate structured BCC with all LLINs distribution events; deploy trained community health workers for household-level follow-up education addressing operational net use skills.
2. Adopt house-to-house distribution for IDP and returnee households; transition to continuous distribution through ANC and immunization services to eliminate temporal coverage gaps.
3. Co-design culturally adapted LLINs promotion materials with traditional leaders and community members, explicitly addressing context-specific barriers including security-related net avoidance.
4. Establish a net replacement tracking system to identify households with degraded nets between mass campaigns and prioritize them for targeted redistribution.
5. Use humanitarian vulnerability mapping data to prioritize the most socio-economically vulnerable households in all LLINs distribution targeting, ensuring equity in access.

DECLARATIONS

Authors' Contributions

LAK: Conceptualization, data collection, primary drafting, statistical analysis. DB: Supervision, methodology review, manuscript revision. TDSM: Co-supervision, contextual expertise, critical revision. All authors approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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Data Availability

Datasets are available from the corresponding author upon reasonable request, subject to ethical restrictions on participant confidentiality.

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