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Research Article

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Exploring a Moderation Analysis in the Interactive Relationship between the Determinants of ITN use in Ghana. A Multi-Level Analysis Based on the DHS 2019 Malaria Indicator Survey

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Abstract

Background: *Insecticide-treated mosquito net (ITN) use is considered a highly efficient vector-control strategy for reducing malaria transmission and while this tool is widely available in vast malaria-endemic areas, there is still a gap in determining its effective use given household access and ownership. Malaria analysis posits that although the availability of ITNs in a household is a prerequisite for use, it does not determine its effective use. Rather, the determinants of ITN use are a result of the complex interplay of factors at the various socioecological levels (i.e., the individual, household, community, and net levels). These complexities are context-specific and shape the behavioral choices of ITN users. This study explores the context-specific factors associated with ITN use and focuses on the interactive relationships among the individual determinants of ITN use. A conceptual approach is developed to test the interactive effect of ITNs in the household on the relationship between the number of children under five years and ITN use by household members in Ghana.*

Method: *Survey data with a sample size of 10,997 were drawn from the Ghana 2019 Demographic and Health Survey and the 2020 Malaria Indicator Survey to analyse the interactive relationship among individual, household, community, and net level variables. The relationship between these variables was assessed in a multivariate setting via a linear regression model. A further analysis involved a moderation effect of the number of ITNs on the relationship between the number of children under five years and household members' ITN use using a single moderation model.*

Results: *From the data analyses, the number of children under five years was positively associated with household members' ITN use (OR = 0.29, $p < .001$), and the number of ITNs was negatively associated with ITN use (OR = -06, $p < .05$) and was positively associated with the number of children under five years (OR = .23, $p < .05$). Gender was positively associated with ITN use and the number of children under five years and negatively associated with the number of ITNs. Increasing age was associated with decreased ITN use, number of children, and number of ITNs respectively. An increasing wealth index was associated with decreased ITN use, the number of children under five years, and the number of ITNs. The region was not significant with ITN use but associated with the number of children under five years. Place of residence was associated with ITN use, number of children under five years, and number of ITNs. A moderation effect of the number of ITNs (OR = -.05, $p < .001$) on the relationship between the number of children under five years and household members' ITN use was reported.*

Conclusion: *The number of children under five years influenced household members' ITN use but this relationship was moderated by the number of ITNs in the household. The proportion of the number of children under five years was moderately different for a high and low household ITN availability whereby ITN use decreased with higher ITN ownership and increased with lower ownership. Future research should focus on more moderation analysis to better understand the complexity of interactions between individual, household, community, and net-level factors that determine ITN use. This might help to better understand and engage better-targeted action in increasing effective ITN use in households relevant to their needs.*

Keywords: Insecticide-Treated Nets (ITNs), Number of ITNs, Household Members, Children Under Five Years, Moderation

1. Background

Insecticide-treated mosquito nets (ITNs) are commonly considered the most accessible and affordable vector for controlling malaria [1]. The effectiveness of ITNs as a malaria prevention intervention and a cost-effective vector control has strongly increased over the years among international and

national malaria programs for rigorous evaluation and scaling up to address malaria-related mortality and morbidity [2, 3]. This is supported by the World Health Organization´s recommendation for mass campaigns for ITN distribution to the general population, and regular distribution targeting pregnant women during antenatal care visits (ANC) and children under five years during immunizations to ensure that at least one for every two persons in each household [4].

Since 2000, it has been estimated that more than 2 billion ITNs have been delivered to malaria-endemic countries [1], and 69% of the 663 million cases averted in sub-Saharan Africa between 2000 and 2015 were attributed to ITNs [5]. Between 2000 and 2019, the percentage of the population with access to an ITN increased from 3% to 52% and use 2% to 46% in the same period [6, 7]. This has led to extensive impacts on the population especially among vulnerable groups such as children under the age of five years. Studies by Lengeler and Eisele et al., have indicated that in highly endemic areas which are characterized by stable malaria transmission all year round, ITNs have the potential to reduce severe malaria mortality by at least 45% and malaria-related mortality in children under five years by up to 55%. Binka et al., in his study suggested that when ITNs are easily accessible and available across the population, they not only provide effective protection from malaria infection for those who use them but also prevent malaria transmission to nonusers in the community [8- 10].

Although ITNs are increasingly available in many malaria-endemic areas, there is still a gap in determining their effective use given wide household access [11]. A survey on ITN use shows that only 50% of the population at risk in sub-Saharan Africa slept under an ITN the previous night, indicating large gaps in ITN use and ownership [ibid]. In accordance, malaria intervention analysis posits that although the availability of ITNs in the household is a prerequisite for use, it does not determine its use, particularly among household members [12]. Instead, determinants of ITN use are a result of the complex interplay of factors at the individual, household, community, and net levels [13, 14]. Studies have shown that these determinants can explain the health-related behavior choices related to ITN use [14- 16]. Moreover, studies by Scott et al. indicate that the heterogeneity of determinants of ITN use in different settings is further compounded by the shifting epidemiology of malaria over time [15]. These findings suggest the need to understand the context-specific factors associated with ITN use which is vital for achieving universal coverage and reducing the malaria burden [ibid].

In Ghana, ITN use determinants have empirically involved an understanding of malaria transmission dynamics which is based on the seasonal variability of malaria infections across the country [10, 17- 19]. In most cases, characterized by high malaria endemicity, even if ownership of the ITN per household is high—80.7%, utilization was much lower 41.7%; with some studies theorizing that ITN ownership does not equal an increase in ITN utilization even among high-risk groups particularly children under five years [18, 20, 21].

Considering the multidimensionality between factors associated with ITN access and use, this study attempts to present a contextual understanding of the determinants of ITN use by exploring how the number of children under five years influences household members´ ITN use in Ghana. This study intends to provide an in-depth understanding of context-specific factors associated with ITN use to address the gap in research on ITN ownership and use at the household level. Although, several studies have analyzed the gap between ITN access, ITN ownership, and ITN use these studies have often examined a general relationship among factors at various levels and not specifically the interaction among specific factors such as children under five years on household ownership and household members ITN use [16, 20, 22, 23].

2. Methods

2.1. Literature Search Strategy

The preferred method for the literature search involved an electronic examination of academic journals involving the terms "ITN utilization", "ITN access and ITN ownership", and "malaria intervention and prevention" from PubMed, the National Center for Biotechnology Information (NCBI), Biomed and PsycInfo. A search of these databases was performed through the authors´ university library system (Oria). Based on the scope of the study, exclusion, and inclusion criteria were established that involved the selection of only published research articles that were peer reviewed. Academic articles not published in English were not selected and were thus excluded. There were no year criteria for the published articles, allowing for a vast review of articles irrespective of the publication year.

In selecting the articles included for review, various criteria were followed. i. Keywords including "correlates of ITN use", "determinants of ITN use", and "factors associated with ITN use" were highlighted to address the study objectives and included ii. The articles included had to focus on the individual and household levels in terms of access to ITNs or households with ITN ownership; iii. The articles selected should contextually focus on malaria-endemic regions (e.g., Africa and Southeast Asia). These criteria allowed the search results to be filtered to identify the most relevant articles for the study in analysing the interplay between factors associated with ITN use.

2.2. Literature Review Synthesis (Study Characteristics)

The study analysis identified a fundamental aspect of the literature discourse as the gap between ITN ownership and ITN utilization. This is elicited from studies that have empirically explored the multidimensional interaction between factors associated with ITN use given the availability of ITNs [12, 13, 15, 22, 24]. For example, Graves et al., [13] indicated that subsequent research should focus on net characteristics such as the ITN ownership period, among other net characteristics when analyzing ITN utilization. Others have focused on net characteristics in explaining why households with ITN ownership use fewer ITNs as these factors interact with individual and household factors that can explain the trends in ITN use [12, 24- 26]. Drawing from the synopsis of literature culminating in this review, the following factors were studied: individual level (number of children under five years in the household), net level (number

of ITNs), household level (number of household members, age and gender of household head, number of rooms for sleeping, household wealth index, relationship to household head); and community-level (type of place of residence—rural vs. urban, region).

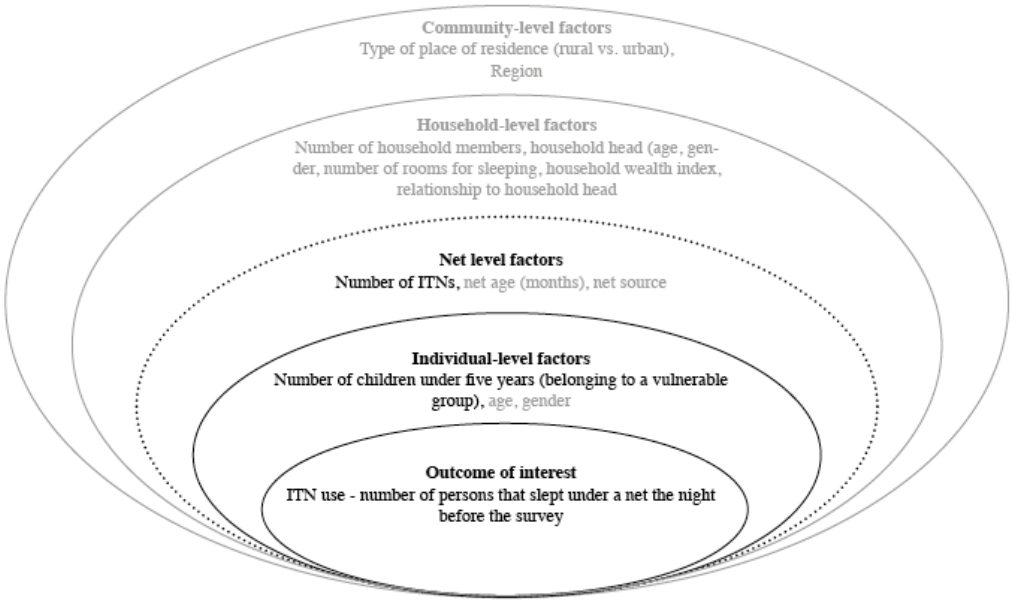

Figure 1: *Research Model for the Study of the Determinants of ITN use.*
Source: Adapted from Graves et al., 2011

2.3. Study Context

This study is based on cross-sectional data from the 2019 Ghana Malaria Indicator survey (GMIS) which was developed from the Demographic and Health Survey and collects in-depth information on a wide range of topics from a representative sample of a population. The data thus involve lengthy surveys that collect, process, tabulate, and publish a report describing the living conditions, demographics, and health situation in the country. The GDHS dataset is derived from the global DHS program established by the US Agency for International Development. The project thus measures public health topics such as malaria. It follows a nationally representative survey implemented by the Ghana Statistical Service (GSS), the Ghana Health Service (GHS), and the National Public Health Reference Laboratory (NPHRL), a division of the GHS. These surveys, which were conducted in phases provide reliable and recent data on health topics, particularly malaria treatment, prevention, and prevalence among children and women.

The 2019 GMIS is the second in the GMIS series—the first of which was conducted in 2016. The GMIS dataset is based on population estimates of malaria indicators used to inform strategic planning and evaluation of the Ghana Malaria Control Program. The dataset provides information on malaria prevention, treatment, and prevalence in Ghana. The survey collected data on global malaria measures such as ITN ownership, ITN utilization, assessed coverage of intermittent preventive treatment (IpT) to protect pregnant women against malaria, identified practices and specific medications used to treat malaria, and measured indicators of malaria knowledge and communication messages [27].

The GMIS data collection used in the study involved two phases. The first phase comprises the household listing exercise (200 cluster areas), which were visited, and the data were recorded on structures, names of the head of household, and the Global Positioning System (GPS) coordinates of clusters. The second stage involved interviews of households and eligible women aged 15-49 years, and children aged 6-59 months who were tested for anaemia and malaria with consent from guardians or parents. The data collected is via computer-assisted personal interviewing [27].

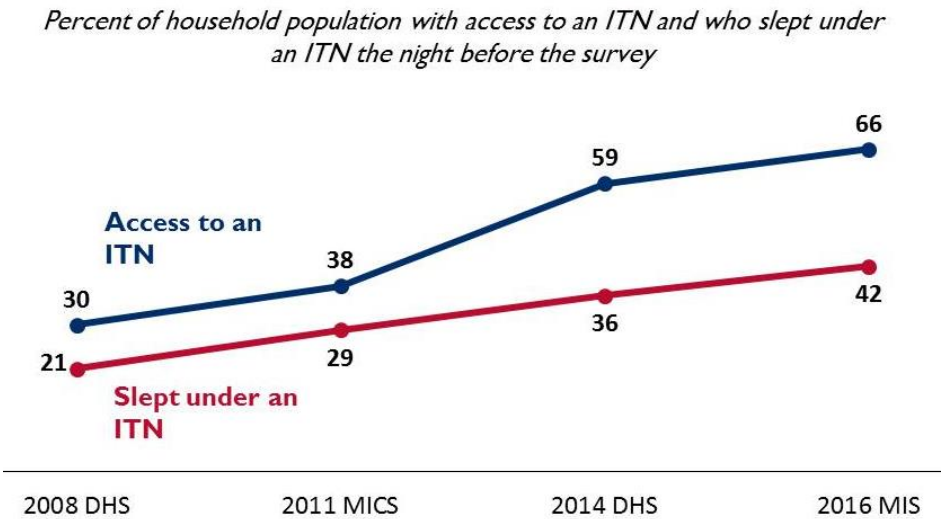

Figure 2: *Trends in ITN Access and Use in Ghana.*
Source: U.S. President´s Malaria Initiative-PMI., (2020).

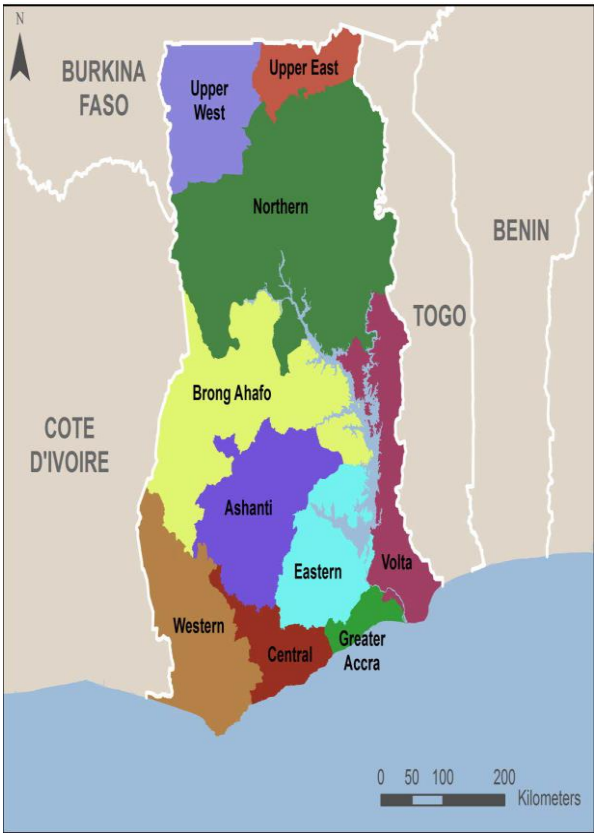

Figure 3: *Map of the Study Context.*
Source: Ghana Statistical Service-GSS & ICF (2020).

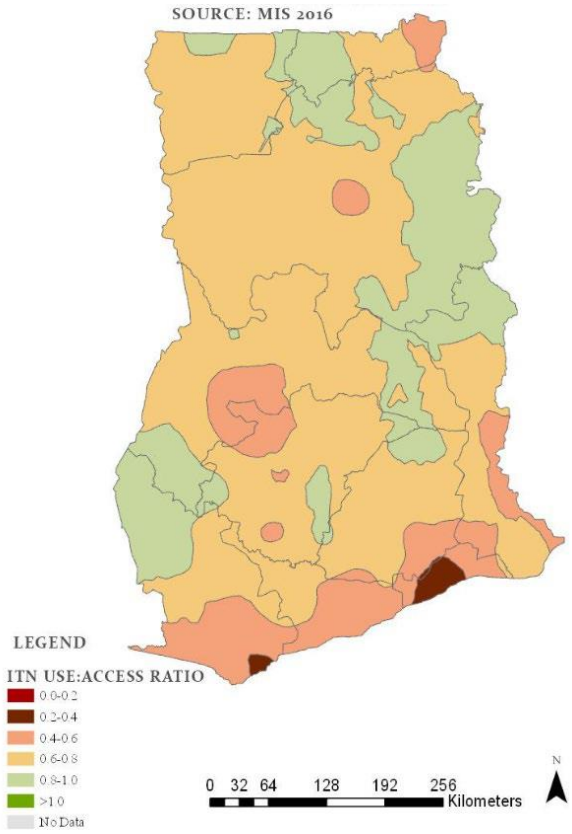

Figure 4: *Geographical variation in ITN use and access in Ghana.*
Source: U.S. President´s Malaria Initiative-PMI, (2020).

2.4. Data Sampling and Sample

The data for this study were obtained from the Demographic and Health Survey which provided access to the datasets from the 2019 Malaria Indicator Survey. The sampling strategy for the dataset follows a random sample of clusters based on the 10 administrative regions of Ghana. The data included information about the enumeration area (EA) location, type of residence (urban or rural), the estimated number of residential households, and the estimated population [27]. The sample was stratified and selected from the sampling frame in two phases—200 EAs (97 urban and 103 rural) were selected via random sampling selection in each sampling stratum. The survey for the dataset uses four questionnaires: household, women, biomarker, and fieldworker. The unit of analysis for this study was the household members which included completed household and individual household member interviews—household characteristics, individual men and women, and biomarker rosters [28]. Given the primary outcome of interest and indicators, the household questionnaire was assessed for the study. The household questionnaire indicators relevant for analysis involved all the usual members in the selected household including the characteristics of each household member such as age, sex, and the relationship to the household head [28]. Additionally, it provided household characteristics such as the number of sleeping rooms, the number of ITNs in the household, and the number of ITNs that slept under the previous night by household members were recorded [ibid].

Based on the surveyed data, a sample of 5,799 households from 6,002 selected households were successfully selected and interviewed which yielded a 99% response rate. A total of 5181 women out of 5,246 selected were successfully interviewed, yielding a response rate of 99% [27]. From the manuscript, the household members dataset that includes completed household and individual household members interviews—household characteristics, individual men and women, and biomarker rosters—was selected for the study. The dataset included the `de facto´ household members, which describes the group of people who stayed in the household the previous night. The total number of the de facto household population interviewed in the 2019 GMIS was 23,713. The dataset chosen for the study describes the household characteristics (household composition and structure) as well as the household members (women and men individually) that are relevant for analysis of the issue of malaria prevention.

The primary outcome variable of interest was ITN use by persons in the household. According to the DHS, this variable is on the household survey indicator regarding malaria control indicator four—i.e., the proportion of the household population that slept under an ITN the previous night. It is defined as the percentage of the household population who slept the night before under an ITN and among the population in the households with at least one ITN, the percentage who slept under an ITN the night before the survey [28]. Factors assessed for the association with the outcome variable were the number of children under five

years (*0,1,2,3,4,5,6,7,8, and 11*), number of insecticide-treated bed nets (*continuous*), age in range (15-49), gender (*male/female*), place of residence as categorical (*urban/rural*), region of residence as categorical (10 regions), net age in months as categorical (0, 13, 25 and 37+ months), source of ITNs recoded as binary (*campaign distribution(1), and other sources(0)*), number of household members as continuous, number of rooms for sleeping as continuous, relationship to household head recoded as categorial (*head, wife or husband, son or daughter and other relatives*), age of household head as continuous (0 > 95) gender of household head (*male/female*) and wealth index which measures the household wealth by residence. It involves the percent distribution of the ´de jure´ by wealth quintiles—poorest/lowest, poorer/second, middle, richer/fourth, richest/highest. The wealth index factor is calculated as the percentage of households possessing various household effects (radio, television, mobile phone, computer, refrigerator), means of transportation (bicycle, car, boat), agricultural land, and livestock/farm animals, according to the residence. The wealth index provides information that may be relevant for malaria control indicators regarding the proportion of household ITN ownership and the number of rooms for sleeping. The wealth index is categorized into wealth tertiles represented as poorest, poorer, middle, richer, and richest.

Possible biases included missing data values and estimation bias. Based on the data guide, missing data such as how values are labelled in the dataset could lead to inconsistency with the total number of variables and types of variables. Additionally, this could influence estimation bias and the statistical power of the model if not addressed. Missing data were handled by performing a descriptive analysis for the various continuous variables and a frequency distribution model for categorical variables. In this case, given the large dataset, an analysis of both descriptive statistics and graphic representation of variables was efficient in ensuring appropriate value ranges (e.g., possible minimum and maximum values). In the dataset, missing values were appropriately handled by coding and were assigned special responses (see for a comprehensive review of handling missing values and other exceptions).

Listwise deletion was applied to the missing values in the data analysis. For the study, missing values were determined to be random—i.e., not related to the missing data, but to some of the observed data—and did not pose any major concern to the data analysis. Listwise deletion was applied to the sample of 23,717 observations which resulted in 12,736 observations dropping. The final sample utilized after addressing missing values and outliers was 10,977 with complete observations, which was suitable for multilinear regression models and for decreasing estimation errors [29].

A linear regression model was applied to determine the observations and detail the associations of factors with ITN use. Multiple linear regression was appropriate for estimating the parameters for a particular level of a set of exploratory variables by minimizing the sum squares of the differences between the observed outcomes of ITN use ($p < 0.05$) [30]. This was based on the assumption that the smaller the differences in the outcome of ITN use of the sum of squared distances of the independent variables, the better the model fits the data [31]. This approach was appropriate since ITN use is continuous, thus minimizing bias. A moderation model was then used to test whether the outcome of ITN use among the predictor variable differed across levels of a third variable [32]. Thus, this study focused on the moderating effect of the *number of ITNs* on the relationship between the number of children under five years and household members´ ITN use. This test was performed on a single moderation model where both predictor variables and their relationship to the outcome variable are observed before the model estimation. Four models were estimated to measure ITN use at a single analytical level, excluding the null model. Each variable measured had a different intercept coefficient and different slope coefficients. A robustness check, such as the White test, was applied as a significant diagnostic check for model fit in the final model, which provided corrective measures for the validity of the results (prob > chi2). All analyses were conducted using STATA/SE 16 (College Station, TX: Stata Corp LLC.).

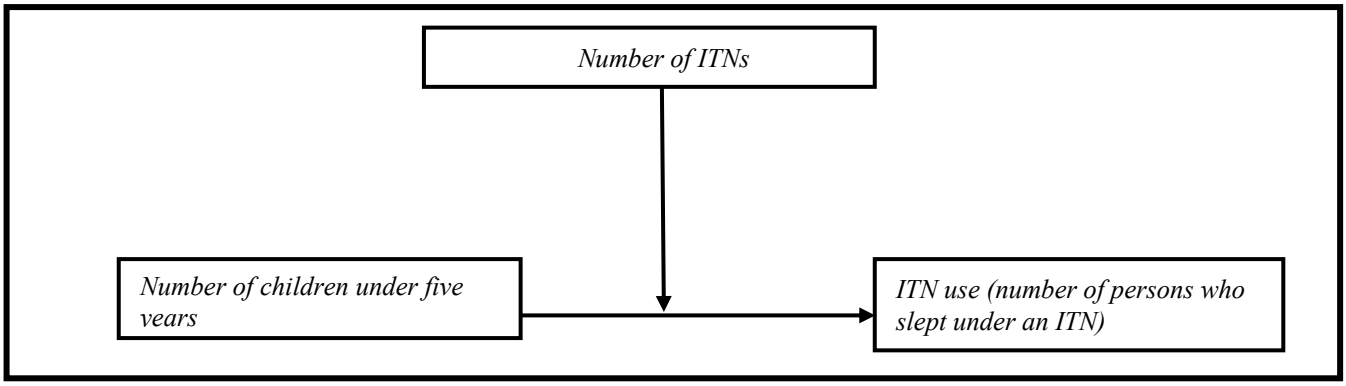

Figure 5: *Single-Level Research Model*

3. Results

The result of the outcome of ITN use, which reflects the number of persons who slept under a net the previous night before the survey, had a mean value of two persons per the number of persons who slept under a net per household, with minimum and maximum values of one and four, respectively. A total of 22% of the 10,977 households reported that one person slept under an ITN the previous night. 40% reported that two people slept under an ITN the previous night. 28% reported that three people slept under an ITN the previous night, and 10% reported that four people slept under an ITN the previous night. A significant difference was detected for household ITN use based on place of residence, with as many as 80% of the 10,977 households accounting for more persons sleeping under ITNs in rural households. The sample is thus unevenly distributed regarding ITN use based on the type of place of residence (Table 1). The number of children under five years in the household had a mean value of 1.20 (SD =1.21, range 1-11). 32% of the 10,977 households reported having no children under five years, 33.5% reported having a child under five years, 23% had two children under five years, 7% had three children under five years, 2% had four children under five years, and 1% had five children under five years, with 0.52% of the households having six children or more under five years. The mean score of the number of ITNs in the households was 3.14 (SD: 1.60, range 1-7). 12 % of 10,977 households owned at least one ITN, 28% owned two ITNs, and 24% reported owning three ITNs. 19% owned four ITNs, 8% reported owning five ITNs, 4% owned six ITNs, and 5% owned seven or more ITNs. 80% of the sampled households obtained ITNs from campaign distributions and the other 20% reported obtaining their ITNs from other sources (private health facilities, pharmacies, markets, religious institutions, NGOs, community-based agents, petrol stations, prior mass campaigns, and others). Net age (in months) had a mean value of 8.23 (SD: 11.10. range 0-37). A total of 56% of the 10,977 households had ITNs that were less than a month old, 30% had owned ITNs for approximately13 months, 7% had obtained ITNs up to 25 months ago, and 7% of the sampled households had their ITNs for 37 months or more.

From the bivariate analysis, the number of children under five years and ITN use were positively correlated, and this association was statistically significant ($r = .33$, $p < .05$). The number of ITNs was negatively correlated with ITN use ($r = -.06$, $p < .05$) and was positively associated with children under five years old ($r = .23$, $p < .05$). In terms of the various explanatory variables, gender was associated with ITN use ($r = .07$, $p < .05$) and the number of children under five years ($r = .03$, $p < .05$) and negatively associated with the number of ITNs ($r = -.02$, $p < .05$). Age was negatively associated with ITN use ($r = -.40$, $p < .05$), the number of children under five years ($r = -.24$, $p < .05$), and the number of ITNs ($r = -.03$, $p < .05$). The wealth index was negatively associated with ITN use ($r = -.10$, $p < .05$), the number of children under five years ($r = -.11$, $p < .05$) and the number of ITNs ($r = -.04$, $p < .05$).

Variable.	*Variable type*	*(%)*	*Obs.*	*Mean*	*Std. Dev.*	*Min*	*Max*
Age (years)	Continuous		10,977	24.67	21.51	0	95
Household members	Continuous		10,977	6.12	3.29	1	38
Children under five years	Continuous		10,977	1.20	1.21	0	11
Household Head (age)	Continuous		10,977	48.26	15.58	16	95
Number of rooms for sleeping	Continuous		10,977	2.46	1.71	1	24
Number of ITNs	Continuous		10,977	3.14	1.60	1	7
ITN use	Continuous		10,977	2.28	.92	1	4
Wealth index	Ordinal		10.977	2.19	1.25	1	5
Poorest		40.11					
Poorer		24.63					
Middle		18.38					
Richer		10.24					
Richest		6.63					
Gender	Nominal		10,977				
Male		46.10					
Female		53.90					
Household head (gender)	Nominal		10,977				
Male		73.39					
Female		26.61					

Net age (in months)	Nominal		10,977
0 months		55.89	
Up to 13 months		30.42	
Up to 25 months		6.53	
Up to 37 months (3 years+)		7.16	
Relationship to Household head	Nominal		10,977
Head		22.43	
Wife/husband		14.11	
Son/daughter		42.67	
Other relatives		20.79	
Type of place of residence	Nominal		10,977
Urban		26.97	
Rural		73.03	
Region	Nominal		10,977
Western		8.95	
Central		8.80	
Greater Accra		3.57	
Volta		10.39	
Eastern		6.77	
Ashanti		9.20	
Brong Ahafo		11.17	
Northern		15.07	
Upper East		14.21	
Upper West		11.87	
Net source	Nominal		10.977
Campaign distribution		80.01	
Other source		19.99	

N = 10,977

Table 1: ***Descriptive Characteristics of Study Variables for Household Members GMIS 2019/ Ghana DHS 2020***

Region was not significantly associated with ITN use (r = .02). but was significantly associated with number of children under five years (r = .12, p < .05) and number of ITNs(r = .10, p < .05). Place of residence was associated with ITN use (r = .10, p < .05), number of children under five years (r = .10, p < .05) and number of ITNs (r = .06, p < .05) (Table 2).

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
ITN use (1)	1														
Children under five years (2)	.33*	1													
Number of ITNs (3)	-.06*	.23*	1												
Gender of household members (4)	.07*	.03*	-.02*	1											
Age of household members (5)	-.40*	-.24*	-.03*	.08*	1										
Net source (6)	.02*	.08*	.06*	.01	-.03*	1									
Net age (in months) (7)	-.02*	-.04*	.0	-.01	.03*	-.40*	1								
Relationship to household head (8)	.22*	.20*	.20*	.10*	-.60*	.02*	-.10	1							
Gender of household head (9)	-.04*	-.11*	-.11*	.16*	.02*	.04*	-.06*	.10*	1						
Age of household head (10)	-.20*	-.10*	.23*	.01	.30*	-.02	.04*	.11*	.10*	1					
Number of household members (11)	.23*	.64*	.53*	-.0	-.15*	.03*	.01	.30*	-.20*	.21*	1				
Number of rooms for sleeping (12)	-.04*	.34*	.50*	-.03*	.02*	-.02	.02	.20*	-.20*	.31*	.70*	1			
Wealth index (13)	-.10*	-.11*	-.04*	.03*	.01	-.01	-.10*	-.10*	.12*	-.10*	-.20*	-.13*	1		
Region (14)	.02	.12*	.10*	-.02	-.02*	- .10*	.14*	.10*	-.20*	.03*	.22*	.24	-.44*	1	
Place of residence (15)	.10*	.10*	.06*	-.02*	-.0	.05*	.10*	.02*	-.12*	.05*	.10*	.10*	-.60*	.20*	1

Notes: * p < 0.05

Table 2: ***Bivariate Association of Potential Predictors with Reported Household ITN use. GMIS 2019/ Ghana DHS 2020***

Model estimations and selection were used to identify a moderating factor between ITN use and significant predictor variables (*number of children under five years, number of ITN IN in the household*). Four models were estimated based on the hypotheses (*see* Awoonor-Williams, 2022)[2]. In Model 1, only the main predictor variable (*number of children under five years*) was estimated with ITN use, and this showed a significant positive relationship (OR = 0.25, p < 0.001). No control variables were assessed in the analysis of Model 1 for comparison to subsequent models where the model complexity increases. In Model 2, an estimation of Model 1 was replicated, and a moderator variable, that is, the number of ITNs in the household, was introduced in the analysis. Model 2 estimated no significant relationship between the number of ITNs and ITN use (OR = 0.01). However, the number of children under five years was still significantly associated with ITN use (0R = 0.56, p < .001). The interaction between the number of children five years and the number of ITNs shows a significant moderating effect on ITN use (OR = -0.07, p < 0.001). The control variables were again not included in Model 2 to test the interaction between the number of children under five years and the number of ITNs in the household. In Model 3, the final model is more complex because it introduces control variables. Thus, Model 2 was replicated in Model 3 by introducing several control variables. The number of children

under five years was still significantly associated with ITN use (OR = 0.29, p < .001). The number of ITNs was significantly associated with ITN use (OR = -.04, p < .001). There was still a significant moderation effect of the number of ITNs on the relationship between the number of children under five years and ITN use (OR = -.05, p < .001). Model 3 was further utilized to draw estimations on the data in a linear regression model (Table 3).

Based on the multivariate model, the number of children under five years was positively associated with ITN use (p < .001). Given that, for a one-unit increase in the number of children under five years in each household, the odds of more household members sleeping under an ITN, compared with the middle and lower odds of ITN use are .29 times greater, holding other factors constant. Households with more children under five years of age are more likely to have more household members sleeping under an ITN than are households with fewer number of children under five years (Table 3).

Dependent variable: ITN use (number of persons who slept under an ITN the previous night before the survey)				
	Single-level linear regression			White test (Robustness check)
Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**
Number of Children under five years	0.25*** (37.11)	0.56*** (36.48)	0.29*** (19.01)	0.29*** [17.78]
Number of ITNs in household		0.01 (1.81)	-0.04*** (-6.16)	-0.04*** [-6.32]
Number of Children under five years x number of ITNs		-0.07*** (-20.49)	-0.05*** (-13.74)	-0.05*** [-13.14]
Relationship to household head				
Head (reference category)			-	
Wife/husband			0.26*** (9.10)	0.26*** [9.37]
Son/daughter			-0.02 (-0.57)	-0.02 [-0.56]
Other relatives			-0.08** (2.71)	-0.08** [-2.67]
Number of household members			0.10*** (23.53)	0.10*** [20.98]
Number of rooms for sleeping			-0.11*** (-16.43)	-0.11*** [-13.90]
Gender of household head				
Male (reference category)			-	
Female			0.04* (2.11)	0.04* [2.08]
Net age				
Less than 1 month (reference category)			-	
Up to 13months			0.01 (0.54)	0.01 [0.55]
Up to 25 months			-0.01 (-0.44)	-0.01 [-0.43]
Up to 37 months			-0.07* (-2.15)	-0.07* [-2.10]
Net source				
Other source (reference category)			-	
Campaign			-0.04 (-1.75)	-0.04 [-1.77]
Gender of household member				
Male (reference category)			-	
Female			0.08*** (4.75)	0.08*** [4.65]
Wealth index				
Poorest (reference category)			-	
Poorer			-0.05* (-2.50)	-0.05* [-2.48]
Middle			-0.06* (-2.50)	- 0.06* [-2.58]
Richer			-0.14*** (-4.47)	-0.14*** [-4.54]
Richest			-0.20*** (-5.09)	-0.20*** [-5.52]
Age of household members			-0.01*** (-27.10)	-0.01*** [-27.14]
Region			-0.02*** (-4.89)	-0.02*** [-4.94]
Place of residence				
Urban (reference category)			-	
Rural			0.02 (1.07)	0.02 [1.09]
_cons	1.975*** (169.65)	1.870*** (75.70)	2.286*** (41.87)	2.286*** [42.14]
N	10977	10977	10977	10977
t statistics in parentheses				
*** p < 0.05, ** p < 0.01, *** p < 0.001**				

Table 3: Results of single-level moderation: moderation effect of the number of ITNs on the association between the number of children under five years and household members' ITN use. Ghana DHS 2019

4. Discussion

The analysis examined the relationship between the number of children under five years and household members´ ITN use among households with available ITNs. The purpose of this study was to determine the interactive effect among the determinants of ITN use by analysing the complex interplay among the predictive determinants of ITN use given access. A moderating effect was determined given that the number of ITNs in the household influenced the relationship between the number of children under five years and household members´ ITN use. The analysis proved that the number of ITNs in the household is a significant moderator that impacts the predicted positive relationship between the number of children under five years and household members´ ITN use. The low availability and ownership of ITNs significantly influence ITN use since strategies for ITN access and ownership are mainly geared towards mass distributions of ITNs rather than towards targeted distributions based on intrahousehold factors (rooms available for sleeping, household size and composition, household relationship structure including other factors). Indeed, the targeted distribution of ITNs has been shown to effectively increase ITN use, especially among children under five years of age [23, 33, 34].

4.1. Number of Children under Five Years and ITN use

The role that children under five years play in ITN use is significant, as the analysis indicated that this factor was positively associated with household members´ ITN use. ITNs at the household level represent a primary factor in use patterns and are widely considered the most effective way to ensure malaria prevention [13, 35]. The number of children under five years in each household thus promotes the positive health behavior of sleeping under ITNs. Given their specific age group within the household and their associated risk as the most vulnerable group among household members to malaria infection and malaria mortality, children under five years represent the general trend of increased ITN use compared to other household members [33, 36- 40]. This is linked to increased household ITN ownership, which influences overall ITN use among household members, especially children under five years [34, 39]. Studies have supported the positive association between the number of children under five years and ITN use in households with ITN ownership [40, 41]. A previous study in Ghana also revealed that ITN use was positively associated with caregivers of children under five years by at least 49% [20]. The findings here support that ITN use in the household significantly increased due to the number of children under five years.

4.2. Moderating Factor of Number of ITNs in Household Members´ ITN use

The number of ITNs in the household as a moderating factor suggests that it has a changeable effect on the outcome of ITN use (Figure 6). This finding corroborates other studies that identified net-level factors as modifying ITN use [13, 14, 15, 24, 26]. Access to ITNs is a prerequisite for their use [12-16]. Given that access is an important determining factor in individual behavior regarding ITN use, the relationship with ITN use is not direct and conditional on other factors at the different levels of ITN use determinants. Our analysis suggested that the number of ITNs was not associated with ITN use, which is consistent with the findings of previous studies [16, 42]. In contrast, several studies have reported that a greater number of ITNs available in the household increases ITN use among household members, especially among certain age groups [15, 34, 40]. A possible explanation is the contextual differences in intrahousehold access to available ITNs, which significantly determine ITN use patterns. Another explanation could be the geographical differences in malaria vector control, such that ITNs are the primary malaria intervention in some contexts due to their geographical location and climate compared to others [34]. Although ITNs are a major intervention tool in Ghana, they could be used less in some areas of the country, particularly urban areas, due to other interventions, such as indoor spraying and mosquito coils, based on household preferences. This is further supported by a similar study in Ghana using DHS data, which reported that ITN ownership and use are influenced by a complexity of individual and household factors and are likewise spatially dependent on several conditions such as region and place of residence [16].

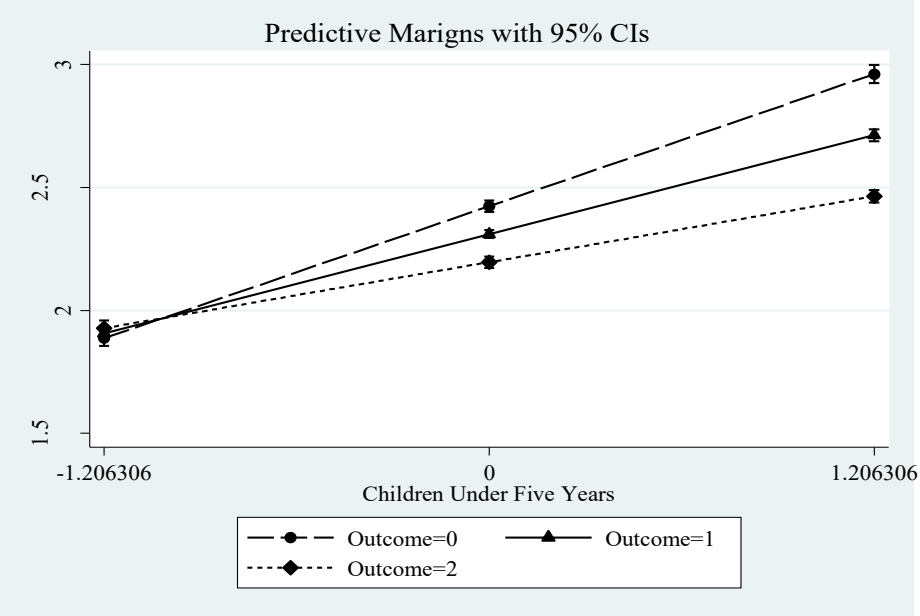

Figure 6: *Average Marginal Effects of the Number of Children Under Five Years with 95% CIs*

An analysis of the number of ITNs in the households as a moderating factor revealed interplay with individual factors that were significantly associated with ITN use. The moderation of the net-level factor on the relationship between individual-level factor(s) and health behavior outcome (ITN use) shows the influence of the number of ITNs on the predictive association between the number of children under five years and household members´ ITN use. The interplay of these factors is relevant, as it can provide insights into how various determinants of ITN use dynamically shape malaria intervention and the health behavioral implications underlying these conditions. Although this study revealed that the number of ITNs is not significantly associated with ITN use through a direct relationship effect, there is still a substantial impact of access to ITNs and the availability of ITNs in the household on engaging in ITN use [9, 12-16, 23].

Access to ITNs is fundamental to their use since it increases community-wide coverage of ITNs, thereby improving general socioeconomic and environmental health conditions. This findings is consistent with previous studies showing that individuals who do not sleep under ITNs but who live in areas with high ITN coverage are at decreased risk of infection due to the resulting reduction in overall malaria transmission [43, 44]. Moreover, the lack of access to ITNs in households creates a significant barrier to health action such that individuals are not exposed to malaria intervention strategies and are unable to adopt such interventions, which has severe implications for malaria prevention. Singh et al. explicitly state that the primary barrier to ITN use is the insufficient supply and availability of ITNs in the household. Increased access to ITNs can provide the necessary resources to influence ITN use by ensuring equitable distribution of ITNs based on household characteristics for optimal coverage [45]. This is relevant in addressing the differential access to ITNs for use among household members, as few studies have shown [41, 46, 47].

Additionally, ITN availability in the household is conditional on access that can influence health decision-making in the household concerning who sleeps under an ITN, what ITNs are been used, and how many individuals sleep under ITNs. Korenromp et al., [48] and Eisele et al. [9] indicated that the more ITNs are available in the household, the more likely it is that a child under five years will sleep under an ITN. Nevertheless, Baume and Franca-Koh [25] and Ngondi et al., [14] mentioned that the greater number of ITNs available in the household is, the lower the likelihood of use for individual ITNs. It should be noted that both studies' units of analysis were at the net level, which examined net characteristics such as shape, size, color, and net physical condition in predicting whether an ITN was used or not used. Although this study´s analysis included net-level factors, the unit of analysis was the household members, and of significance is the interplay between net-level factors and individual-level factors on household members' ITN use, suggesting that the findings of the number of ITNs are relevant.

4.3. The Role of Covariates in the Moderation Model

Covariates estimated for the study were essential to the moderation model since they accounted for several factors in the final model. Several control variables were introduced after the moderator, number of ITNs with the number of children under five years and ITN use, which still produced a significant result in the analysis. Age and sex were significantly associated with ITN use, as indicated in several studies [20, 34, 39, 47, 49]. As is the case in this study and backed by antecedent studies, gender as an individual-level factor is a strong predictor of ITN use such that women in the household are more likely to sleep under an ITN, and female caregivers have a greater likelihood of sleeping under an ITN with their infant children. Babalola et al. [47] in their study revealed that the relationship between age and the ITN varies with sex. This finding contrasts with other studies that found no association between age and gender in terms of ITN use [38, 50]. A probable interpretation of the difference in

findings is the contextual differences in factors associated with ITN use. Net age was only significantly associated with ITN use when the net was less than 37 months or three years. The age of the ITNs was negatively associated with their use when they were more than three years old, confirming similar results in previous studies [13, 14]. These studies analyzed net age as older than six months and older than 12 months and found that ITN use was one-third as likely if all the ITNs in the household were more than one year old.

Household-level variables used as covariates for the study, including household size, number of sleeping rooms, age and gender of household head, relationship to household head, and household wealth index, were significantly associated and corroborated findings from other studies [40, 46, 49, 57, 58]. Household size and number of sleeping rooms were positively and negatively associated with ITN use, respectively. The age and gender of household heads were found to be significantly associated with ITN across different contexts [15, 37, 52, 59, 60]. Relationship to the household head has been evidently significantly associated with ITN use, whereby household members closely related to the head of household are more likely to sleep under an ITN [54]. The household wealth index was significantly associated with the ITNs in the richer and richest categories, compared to the poorer and middle categories, consistent with a previous study in Ghana [16]. They found that increasing wealth was associated with decreased ITN use compared to the poorest categories among households with ITN access. They further explained that in urban households, there is an increased use of alternative malaria interventions such as indoor spraying, mosquito coils, and window screens (over 80% of urban households in Ghana have window screens [16]. These findings are similar to those of other studies [14, 42, 52].

The place of residence was not associated with ITN use in the study, which differs from a previous study in Ghana that found that rural residents had greater odds of using ITNs than did urban households [16]. Moreover, a significant association was detected across various studies [13, 16, 52, 54]. However, one study reported that people living in rural areas had lower odds of ITN use than did people living in urban areas [52]. A probable reason for the lack of association in this study is the increased coverage of ITNs in rural households in Ghana, which increases ITN access and thus is not affected by place of residence. Additionally, rural households are not affected by the cost and affordability of ITNs since they are generally mass distributed. Region of residence was significantly associated with ITN use in this study, which supports evidence from past studies [47, 52].

4.4. Limitations

There are several limitations to this study. The analysis of secondary data suggests that the main objectives and hypotheses are extracted from the available data, and as such, no consideration is given to the design of the DHS, which is a primary concern in utilizing the existing dataset [51]. Several explanatory variables estimated as possible predictors in previous studies were omitted. The study inclusion and exclusion of variables for analysis was limited in the scope of the analysis. In addition, given that the variables analysed are significant predictors of ITN use, few other relevant variables, including educational level, degree of control over household decision-making, occupation/livelihood, social and cultural norms, behavioral change communications, and malaria knowledge explored in ITN studies [16, 49, 52-55] are excluded from the data analysis. This study's data were cross-sectional in design, which limits the opportunity for making causal inferences; the same results might not be estimated, given that they did not capture households with similar characteristics [56].

Additionally, the variable outcome of "How many people slept under an ITN?" is based on self-reports and may have validity issues, as cross-sectional surveys are periodic and have the potential to influence the reported ITN use behavior depending on the perceived malaria risk of the surveyed respondents. Additionally, the study´s dependent outcome, "How many people slept under an ITN the previous night?", is self-reported with responses drawn from a cross-sectional survey of ITN use at a specific night and does not estimate an accurate measure of ITN use consistently over time. This might lead to errors in the measurement of ITN use caused by social desirability bias, where households will probably overreport the number of household members sleeping under ITNs in the survey. Finally, the analysis of ITN use and its determinants based on the theoretical model is not widely extensive, as it excludes interactions at broader levels (employment, education, social and community networks, and the general socioeconomic, cultural, and environmental conditions), which have been explored in other studies [12, 13, 16, 22, 23].

5. Conclusion

Access to and the availability of ITNs in the household do not entirely affect health behavior in terms of sleeping under ITNs but instead influence other factors in predicting ITN use. Addressing the gap between ITN access and use requires a contextual understanding of conceptual approaches, that determine the interplay of the determinants of ITN use. It is essential to focus on the interactive relationship among various other determinants of ITN use, particularly at the household level, that could predict ITN use within a comprehensive outlook, which could further help improve our understanding of why certain household members with increased access to available ITNs in the household, do not consistently use them. This could be of great importance for reshaping malaria intervention strategies and helping to effectively address malaria prevention efforts.

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