Exploring a moderation analysis in the interaction between determinants of ITN use in Ghana. A multi-level analysis based on the DHS 2020 /2019 malaria indicator survey

Kelvin Edem Awoonor-Williams
edemwilliams@gmail.com

University of Bergen

Helga Bjørnøy Urke
University of Bergen

Research Article

Keywords: Insecticide-treated nets (ITNs), number of ITNs, household members, children under five years, moderation

Posted Date: February 22nd, 2024

DOI: https://doi.org/10.21203/rs.3.rs-3969816/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License. Read Full License

Additional Declarations: No competing interests reported.
Abstract

Background

Insecticide-treated mosquito net (ITN) use is considered a highly efficient vector-control strategy in reducing malaria transmission and while this tool is significantly available to vast malaria-endemic areas, there persists a gap in determining its effective use given households’ 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, determinants of ITN use are a result of the complex interplay of factors at the various socio-ecological levels (i.e., individual, household, community, and net level). These complexities are context-specific which shape the behavior choices of ITN use. This study explores the context-specific factors associated with ITN use that focus on the interactive relationship among 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 was drawn from the Ghana 2019 Demographic and Health Survey and the 2020 Malaria Indicator Survey to analyze an interactive relationship between 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), number of ITNs was negatively associated with ITN use (OR = -0.06, p < .05) and was positively associated with number of children under five years (OR = .23, p < .05). Gender was positively associated with ITN use and number of children under five years and negatively associated with number of ITNs. Increasing age was associated with decreased ITN use, number of children, and number of ITNs respectively. 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 number of households 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.

Background

Insecticide-treated mosquito nets (ITN) are commonly considered the most accessible and affordable vector control against malaria [1]. The effectiveness of ITNs as a malaria prevention intervention and a cost-effective vector control has over the years gained a strong desire among international and national malaria programs for rigorous evaluation and scaling up to tackle 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 3–52% and use 2–46% 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 [8] and Eisele et al., [9] have indicated that in high 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 up to 55%. Binka et al., [10] 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 non-users in the community.

Although ITNs are increasingly available in many malaria-endemic areas, there persists a gap in determining the 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 huge gaps in ITN use and ownership [ibid]. In accordance, malaria intervention analysis posits that despite 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 explored that these
Determinants can explain the health-related behavior choices of ITN use [14–16]. More so, studies by Scott et al., [15] indicate that the heterogeneity of determinants of ITN use in different settings is further compounded by the shifting epidemiology of malaria over time. They 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 ITN per household is high—80.7%, utilization was much lower 41.7% [20]; 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, 21].

Considering the multidimensionality between factors associated with ITN access and use, this study attempts to present a contextual understanding of determinants of ITN use by exploring how the number of children under five years influences household members’ ITN use in Ghana. It intends to provide an in-depth understanding of context-specific factors associated with ITN use to address the gap in ITN ownership and use at the household level. Much as several studies have analyzed the gap between ITN access, ITN ownership, and ITN use [16, 20, 22, 23]; 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’s ownership and household members ITN use.

**Methods**

**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, National Center for Biotechnology Information (NCBI), Biomed and PsycInfo. A search in 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 a selection of only published research articles that were peer reviewed. Academic articles not published in English were not selected and 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 level 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 analyzing the interplay between factors associated with ITN use.

**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 subsequent research to focus on net characteristics such as ITN ownership period among other net characteristics for analyzing ITN utilization. Others have focused on net characteristics in explaining why households with ITN ownership use fewer ITNs [12, 24–26]; as these factors interact with individual and household factors that can explain the trends in ITN use. Drawing from the synopsis of literature culminating this review, the study analysis is on the following level factors: 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).

**Study context**

The study is based on cross-sectional data from the 2019 Ghana Demographic and Health Survey (GDHS) which is developed from the Demographic and Health Survey that collects in-depth information on a wide range of topics from a representative sample of a population. The data thus involves 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, conducted in phases provide reliable and recent data on health topics, particularly malaria treatment, prevention, and prevalence among children and women.

The 2019 Ghana Malaria Indicator Survey (GMIS) is the second in the series of the GMIS—the first 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 collects 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].
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 was recorded on structures, names of the head of household, and the Global Positioning System (GPS) coordinates of clusters. The second stage involves interviews of households and eligible women aged 15–49, and children aged 6–59 months who are tested for anemia and malaria with consent from guardians or parents. The data collected is via computer-assisted personal interviewing [27].

Data sampling and sample

Data for this study was obtained from the Demographic and Health Survey which provided access to the dataset on the 2020 Ghana Demographic and Health Survey and 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. It included information about the enumeration areas (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 using a 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 is the household members which contains completed household and individual household members 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 slept under the previous night by household members [ibid].

Based on the surveyed data, a sample of 5,799 households from a selected 6,002 households were successfully selected and interviewed which yielded a 99% response rate. 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 chose the `de facto´ household members which describes the group of people that stayed in the household the previous night. The total number of the de facto household population interviewed in the GMIS 2019 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 on 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 categorical (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 respectively.

Possible biases included missing data values and estimation bias. Based on the data guide, missing data such as how values are labeled in the dataset could potentially lead to inconsistency with the total number of variables and types of variables. Also, this could influence estimation bias and statistical power of the model if not addressed. Missing data was handled by performing a descriptive analysis for the various continuous variables and 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 (see¹ 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 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 dropped. The final sample utilized after addressing missing values and outliers was 10,977 with complete observations, which was suitable for multilinear regression model and to decrease estimation errors [29].

A linear regression model was applied to determine the observations and detail the associations of factors to ITN use. Multiple linear regression was appropriate to estimate the parameters for a particular level of a set of exploratory variables by minimizing the sum squares of the differences between the observed outcome of ITN use (p < 0.05) [30]. This was 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]. It 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, the 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 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 and this provided corrective measures to the results for validity (Prob > chi2). All analyses were conducted using STATA/SE 16 (College Station, TX: Stata Corp LLC).

Results

The result of the outcome ITN use which reflects the number of persons that 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 a minimum and maximum value of one and four respectively. 22% of 10,977 households reported one person slept under an ITN the previous night. 40% reported two persons slept under an ITN the previous night. 28% reported three persons slept under an ITN the previous night and 10% reported four persons slept under an ITN the previous night. A significant difference was determined for households’ ITN use based on place of residence, with as much 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 measured 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, 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 with 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). 56% of the 10,977 households had ITNs that were less than a month old, 30% had owned ITNs for about 13 months, 7% obtained ITNs up to 25 months ago, and 7% of the sampled households had their ITNs for 37 months or more.

In the bivariate analysis, the number of children under five years and ITN use was positively correlated, and this association was statistically significant (r = .33, p < .05). The number of ITNs was negatively correlated to 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), 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 \( (r = -.03, p < .05) \). 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 \( (r = -.04, p < .05) \).

Region was not significant with ITN use \( (r = .02) \) but 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).

Model estimations and selection was used for identifying a moderating factor between ITN use and significant predictor variables (number of children under five years, number of ITNs in the household). Four models were estimated based on the hypotheses (see Awoonor-Williams, 2022)[1]. 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 a base 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 (OR = 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 number of ITNs in the household. Model 3, the final model is more complex as it introduces control variables. Thus, model 2 was replicated in model 3 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 = -0.04, \( p < .001 \)). 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 = -0.05, \( p < .001 \)). Model 3 was further utilized to make estimations on the data in a linear regression model (Table 3).

In the multivariate model, the number of children under five years is positively associated with ITN use \( (p < .001) \). Given that, for 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 is \( .29 \) times greater, holding other factors constant. Households with a higher number of children under five years are more likely to have an increased number of household members sleeping under an ITN compared to households with fewer number of children under five years (Table 3).

**Discussion**

The analysis examined the relationship between the number of children under five years and household members’ ITN use among households with ITN availability. The purpose was to determine an interactive effect among determinants of ITN use in analyzing the complex interplay among predictive determinants.
of ITN use given access. A moderating effect was determined given 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. 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 on targeted distribution based on intra-household factors (rooms available for sleeping, household size and composition, household relationship structure including other factors). Indeed, targeted distribution of ITNs has been shown to effectively increase ITN use especially among children under five years [23, 33, 34].

**Number of children under five years and ITN use**

The role children under five years play in ITN use is significant, as the analysis indicated this 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. Children under five years, 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, enable 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 found 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.

**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 (Fig. 6). This corroborates other studies that identified net-level factors as modifying ITN use [13, 14, 15, 24, 26]. Access to ITNs is a prerequisite for ITN 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 suggests that the number of ITNs was not associated with ITN use corresponding with previous studies [16, 42]. Contrarily, several studies have reported that the more 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 intra-household 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 the geographical location and climate compared to others [34]. As such, although ITNs are a major intervention tool in Ghana, it could be that they are 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 backed 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 likewise spatially dependent on several conditionalities such as region and place of residence [16].

An analysis of the number of ITNs in the households as a moderating factor posits the interplay with individual factors that proved a significant association 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 found that the number of ITNs is not significantly associated with ITN use in a direct-relationship effect, there is still a substantial impact of access to ITNs and availability of ITNs in the household in engaging ITN use [9, 12–16, 23].

Access to ITNs is fundamental to its use since it increases community-wide coverage of ITNs thereby improving the general socio-economic and environmental health conditions. This correlates to previous studies that explained that individuals not sleeping under ITNs but living in areas with high ITN coverage have been observed to be 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 have severe implications for malaria prevention. Singh et al., [45] 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. 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 sleep under ITNs. Korenromp et al., [48] and Eisele et al., [9] indicated that the more ITNs available in the household, the more likely a child under five years will sleep under an ITN. Nevertheless, Baume and Franca-Koh [25] and Ngondi et al., [14] mentioned that the more ITNs available in the household, the lower the likelihood of use for individual ITNs. It should be noted that both studies’ unit of analysis was 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 theorizing the findings of the number of ITNs relevant.

The role of covariates in 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 gender 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 ITN varies with sex. This contrasts with other studies that found no association between age and gender in 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 significant with ITN use when the net was less than 37 months or three years old. The age of ITNs was negatively associated with ITN use when ITNs owned 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, which found that ITN use was one-third as likely if all the ITNs in the household were more than a 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 corroborates findings from other studies [40, 46, 49, 57, 58]. Household size and sleeping rooms were positively and negatively associated with ITN use respectively. Age and gender of household heads were found to be significantly associated with ITN across different contexts [15, 37, 52, 59, 60]. Relationship to 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]. Household wealth index was significantly associated with ITN 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 explain 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 are similar to studies in other contexts [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 rural residents had higher odds of using ITNs compared to urban households [16]. Moreover, a significant association was determined across various studies [13, 16, 52, 54]. However, one study reported that people living in rural areas had lower odds of ITN use compared to urban areas [52]. A probable reason for no 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. Also, 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].

**Limitations**

There are several limitations to this study. The study 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 the variables analyzed 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 in the study data analysis. In addition, this study’s data was a cross-sectional design, which limits the opportunity for making causal inferences, and therefore, 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-reporting 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. Also, 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 ITN use measurement caused by social desirability bias, where households will probably overreport the number of household members sleeping under ITNs in the survey. Finally, the study analysis of ITN use and its determinants based on the theoretical model is not widely extensive as it excludes interactions at the broader levels (employment, education, social and community networks, and the general socio-economic, cultural, and environmental conditions) which have been explored in other studies [12, 13, 16, 22, 23].

**Conclusion**

Access to and the availability of ITNs in the household does not entirely affect health behavior in terms of sleeping under ITNs but instead influences 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 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 as to why certain household members with increased access to available ITNs in the household, do not consistently use them. This could be of great importance to reshaping thinking on malaria intervention strategies and help to effectively address malaria prevention efforts.
Declarations

Funding Declaration: Funding is not applicable to this study.

Author Contribution

K.E.A.W. wrote the main manuscript text and prepared figures H.B.J. supervised the research process and reviewed the research in its entirety.

References


Footnotes


2. Model 4 was a robustness check for final model estimation. The white test was estimated and reported as model 4. This was an estimate of standard errors and confidence intervals of model 3 estimates.
3. Regression coefficients and p-values were estimated based on model 3 to make inferences on the relationship between predictor variables and other explanatory variables on the dependent variable. The p-value in the analysis tests each predictor variable on the null hypotheses (Model 1) to determine the significance with ITN use.

**Tables**

Tables 1-3 are available in the Supplementary Files section.

**Figures**

*Figure 1*

*Research Model in the study of determinants of ITN use.*

Source: Adapted from Graves et al., 2011
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.*

Figure 4

Geographical variation of ITN use & access in Ghana.

U.S. President’s Malaria Initiative-PMI, (2020).

Figure 5

Number of ITNs

Number of children under five years

ITN use (number of persons who slept under an ITN)
Single-level Research Model

Figure 6

Figure 8: Average Marginal Effects of Number of Children Under Five years with 95% CIs

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Tables13.docx