# Linking insecticide-treated mosquito nets to malaria: The roles of malaria Knowledge and household-income

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**Research**

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# Abstract

Background: Drawing on the theory of the health belief model, this study examined the interplay between insecticide-treated mosquito nets, malaria-knowledge, household income, and malaria. The study was premised on the notion that insecticide-treated mosquito nets are positively related to malaria prevalence; and that knowledge mediates the relationship between insecticide-treated mosquito nets and malaria. Furthermore, household-income was hypothesised to have a moderating effect on the direct and indirect relationships (through malaria knowledge) between insecticide-treated mosquito nets and the prevalence of malaria.

Methods: The hypothesised relationships were examined using panel data collected from ten regions of Ethiopia during 2011 – 2015. Structural equation modelling and the random effect model were used to test the hypotheses. Statistical analyses were performed using Stata version 13.0.

Results: The results were consistent with our proposed hypotheses, showing a significant relationship between the research variables. Accordingly, our findings suggest that malaria knowledge contributes to improving the relationship between insecticide-treated mosquito nets and malaria prevalence. The results revealed a positively significant indirect effect ($\beta = 0.47$, $p = 0.003$) as well as a positively significant direct effect ($\beta = 0.28$, $p = 0.001$). Further, the study showed a positive impact of household-income in strengthening the relationship between insecticide-treated mosquito nets and malaria through knowledge, with a considerable value ($\beta = 0.13$, $p = 0.000$).

Conclusion: The findings are potentially useful for the health sector to ensure success in infectious disease prevention and control, particularly malaria, and to explain how various factors contribute to the relationship.

# Background

While everyone has the right to live healthily throughout their lifetime, providing adequate health care is a serious challenge [1]. Malaria is a global health concern, with 214 million cases reported in 2015. Approximately 438,000 of the cases resulted in death, 88% of which occurred in African [2]. The other report showed 212 million cases of malaria with 429,000 deaths [3], where 92% of the deaths were reported to have occurred in African, followed by South-East Asia (6%) and Eastern Mediterranean Region (2%). Further, an estimated 216 million global malaria cases were reported, of which 90% were in Africa [4]. Every year, many international travellers fall ill with malaria while visiting endemic regions, and more than 10,000 visitors have confirmed to have fallen sick with the disease after returning home; however, the cases are underreported, which means that the real number of illness cases is much higher [5]. A recent estimate shows a significant burden of malaria on health systems and the broader economy, particularly in Africa, which places a significant economic burden on households in paying for prevention and treatment [6]. Insecticide-treated mosquito nets (ITNs) were identified as the most effective malaria prevention approach [7] and have decreased malaria incidences by 50% in various settings and malaria mortality rates by 55% in children under five years old in Sub-Saharan Africa [4]. African heads of government set a target of 60% coverage of bed nets for use by pregnant women and children under five years by 2005 following the Abuja summit in 2000 [8]. Since the introduction of the intervention strategy, there has been significant success in the malaria programme. Between 2000 and 2015, malaria cases decreased by 48% worldwide [2]. However, the disease remains the leading cause of maternal and child morbidity and mortality in low-resource countries; for example, Ethiopia accounts for 6% of malaria cases worldwide and about 12% of global concerns and deaths from Plasmodium vivax [9]. The general coverage of mosquito nets for households in malaria-prone areas is one of Ethiopia's primary vector control and prevention initiatives to ensure unlimited access to ITNs and the spraying of households with indoor residual spray (IRS) in targeted areas [5,10]. Thus, the cumulative number of ITNs exceeded 65 million, and about six million households in malaria-prone areas sprayed yearly with IRS [11]. However, malaria continues to be a serious public health challenge in Ethiopia [12]. Further, Ethiopia set an objective to have a community with appropriate knowledge and health-seeking behaviours regarding malaria prevention and control by 2020 [13]. In addition, ownership and utilisation, net care and repair through demand creation, and familiarity are the critical points to be implemented. More than 50 million Ethiopian people are at risk of contracting malaria, representing nearly two-thirds of the total population, and 75% of the land is malaria-prone [14,15]. In 2010, the Ethiopian health minister, in line with the Millennium Development Goals and the Roll-Back Malaria Initiative, planned to cut malaria morbidity and mortality by 50% by 2015; however, although good progress was made in the fight against malaria during the period, the goal was not achieved [16]. Peter [17] indicated general improvements in malaria prevention and control, but a low level of knowledge and use of malaria intervention tools was reported. Further, the study reported weak public awareness and practice towards malaria prevention and control alternatives, persistent misunderstandings about malaria, and unsatisfactory malaria control practices [18]. Previous studies investigated knowledge, attitudes, and practices related to malaria prevention options such as ITNs [7,18–21] — these studies provide information on the prevention of malaria, but they did not explore the in-context socio-economic aspects and knowledge of households to explain the relationship. Additionally, most of these studies relied on the assessment of knowledge about malaria with specific study populations. Studies indicate that Ethiopian communities are not well aware of the multi-dimensional challenges of the disease despite the acrimonious facts, misuse of ITN, and unsatisfactory malaria control methods reported [22–26]. Therefore, it is pertinent to consider the impact of knowledge on strategic interventions to prevent the spread of the disease. To the best of our knowledge, none of the previous studies considers the role of malaria knowledge in the relationship between ITNs and malaria. In addition, no previous study tested the moderating role of household_income in strengthening the relationship between strategic interventions and malaria based on malaria_knowledge. Our study, therefore, measured the influence of malaria knowledge and household_income in the relationship intending to investigate the effect of ITNs on malaria prevalence, with knowledge and household_income playing a mediating and moderating role, respectively.

Apart from this fundamental contribution, this study contributes to the existing literature in numerous ways. First, we observed the changes in the outcome of the direct relationship between ITN and malaria, besides the moderation-mediation effect. Second, we considered national-level aggregate panel data with a significant number of observations for study. Third, this is the first study in Ethiopia to evaluate the ITN_malaria relationship in the context of malaria knowledge and household income as a mediating-moderating effect. Finally, we conducted our analyses using structural equation modelling and the random effect model of the panel data estimation technique. The rest of the paper is organised as follows. Section 2 explains the theoretical background. Section 3 discusses the hypothesis development. Section 4 presents the analysis and results. Finally Section 5 focuses on the discussion and implications of the findings.

## Theoretical Background

### *The Health Belief Model*

Theory of the health belief model (HBM) was first introduced by a group of U.S_public health service social psychologists in the 1950s seeking to understand and explain why most people fail to participate in preventive and detective health measures [27]. The model remains the most widely employed theories of health behaviour [28] and the most commonly recognised approach in the health field [29]. The HBM hypothesises that health-related action depends upon the simultaneous occurrence of three classes of factors: (1) The existence of sufficient motivation (or health concern) to make health issues salient or relevant. (2) The belief that one is susceptible (vulnerable) to a severe health problem or to the sequelae of that illness or condition, which is often viewed as a perceived threat. (3) The belief that following a particular health recommendation would be beneficial in reducing the perceived threat at a subjectively-acceptable cost. Furthermore, the theory is based on the understanding that a person will take health-related action if that person believes they are susceptible to the condition (perceived susceptibility); the condition has serious consequences (perceived severity); taking action would reduce their vulnerability to the condition or its severity (perceived benefits); and these benefits outweigh the cost of taking action (perceived barriers) [30]. The response is accepted more easily if the person is exposed to factors that prompt measures (cues to action) and is confident in their ability to act successfully (self- efficacy) [31]. This study employed the theory of the HBM, holding that the independent variable (ITNs) should influence the dependent variable (malaria prevalence) through mediating variables (malaria knowledge) and moderating variables (household income). If a person has a good level of knowledge and a positive attitudes towards malaria prevention strategies, and if intervention tools are accessible to a vulnerable group at risk, they are more likely to practice preventive measures, thus reducing their risk of contracting malaria, and treat malaria patients effectively. Furthermore, a person who has more income and is knowledgeable about the programme, is more likely to access ITN to protect themselves from malaria. Thus, mediation as an indirect effect occurs when the causal effect of an independent variable (X) on a dependent variable (Y) is transmitted by a mediator (M) [32] while the moderating variable is the interaction terms at which the strength of the relationship between two variables is dependent on a third variable. The HBM is a tool to explore the perceptions and beliefs about malaria and the use of strategic interventions such as ITN [33]. The theory guided this study in establishing the relationship between the explanatory variable (ITNs) and the outcome variable (malaria prevalence), and we examined whether household income has a moderating effect on the direct and indirect relationship (through malaria knowledge). **Figure 1 illustrates the proposed relationship.**

## Hypothesis Development

### Insecticide-treated mosquito nets (ITNs) and malaria prevalence

Net distribution is an integral part of a selective vector control strategy for malaria protection, and ITNs have been identified as having a significant impact on malaria (3,13,26). Regular use of ITNs has been reported to reduce the overall death risk by 20% and the number of clinical malaria episodes in young children by 50% [35]. Insecticide-treated mosquito nets were reported to be used as a preventive measures against malaria [36]. For malaria control, ITN and IRS are recommended as the cornerstone of the strategy by the World Health Organization (WHO) [2,38]. Ethiopia implemented selective vector control methods, such as ITNs, IRS, and environmental management to fight against malaria [39]. The impressive decline in child mortality has been attributed to the implementation of vector control methods, such as ITN and IRS [37]. Another study also reveals the decline in malaria morbidity and mortality due to the introduction of vector control intervention methods [40]. However, malaria remains a major health problem in Ethiopia [41]. In addition, the government is working towards eradicating malaria by providing technical and material support; however, malaria still prevalent every rainy season, especially in the lowland areas of Ethiopia [42]. Inadequate knowledge about malaria and lack of ITNs were observed in some areas [43], which challenged the programme's success in prevention and control. Regular use of ITNs was reported to prevent malaria [44], and it was also believed that ITN prevents mosquito bites if used regularly.

Therefore, we hypothesised the following:

Hypothesis 1: Insecticide-treated mosquito nets reduces malaria prevalence.

### Insecticide-treated mosquito nets and malaria knowledge

Effective preventive action is the outcome of public health programmes, which resulted in the implementation of community-based health education. Awareness creation about the programme on prevention and control measures is critical [45], which occurred through iterative actions to strengthen the awareness of the population about malaria prevention. Lack of knowledge about malaria has been reported to be hindering any measures of personal protection [46]. According to the HBM of health and illness, it is not only the participants' belief that matters but also their knowledge and attitude [47]; hence, the perception of seriousness is based on medical knowledge people own. Better utilisation of ITNs existed among the communities who understand malaria infection and transmission methods [48]. Differences in malaria knowledge have been shown to cause discrepancies in tackling malaria [49] due to differences in strategic utilisation. Similarly, respondents who were knowledgeable about strategic interventions to prevent malaria, such as IRS, were less likely to accept the spray, compared to those who were not knowledgeable, but gaps in knowledge and fears about the effects on health were identified as challenges [50]. Another study reported the influence of knowledge gaps and a wrong perception on the use of insecticide-treated nets to protect oneself from malaria [51], which shows the influence of knowledge on the relationship. Similarly, the study reported better ownership and use of ITN by the communities with good knowledge than by those without the same [52]. Knowledge about malaria transmission and prevention methods was identified as a significant factor in combatting the disease [34]. Furthermore, another study revealed a high level of knowledge among study participants about mosquito vectors and their ability to kill [26]; however, the access and use did not correlate with the practice for protection. The association between age, educational status, and household income were reported to affect the relationship [53]. Moreover, yet another study reported respondents' familiarity with malaria, where 99% had heard of malaria and control methods, with 97% of the participants owning bed nets [7], but only 58.2% of ITNs owned by households were used in the previous night. This may be attributed to the improper delivery of health education in specific communities. The study found that mothers had sufficient awareness and appropriate attitudes towards malaria and ITNs, with a favourable attitude of 74.3% and 51.1% [19], but only 15.6%  associated mosquitoes with malaria, and most of them (65.6%) replied that the disease was transmitted due to poor personal hygiene and environmental sanitation. Additionally, another study reported gaps in communities’ understanding of malaria transmission and lack of malaria vector knowledge and malaria transmission patterns [54,55]. Health motivation is the central focus of the health belief model (HBM) to evoke health concerns, forexample, living in a malaria-prone area and the possibility of contracting the disease [31,56].  Thus, we hypothesized the following:

Hypothesis 2: Insecticide-treated mosquito nets are positively associated with knowledge about malaria prevalence.

### Knowledge and malaria prevalence

Lack of malaria knowledge is the most critical factor that contributes to several malaria deaths in many communities [57]. Therefore, there is a need for practical health education to improve knowledge about health programmes among the public to control infectious diseases such as malaria. Due to differences in malaria prevention and control practices, the adopted strategy should be tailored according to the environment [25]. The study revealed the achievements of malaria intervention planning based on local knowledge about malaria transmission [58]. In addition, the study found that communities with advanced information about malaria and its burden were interested in prevention and making personnel decisions on how to protect themselves from the disease [59]. Apart from the evidence from various channels, witnessing the death and sufferings of others due to a particular health problem contributes to positive health behaviour [47,60]. To design and implement effective interventions, local knowledge about the prevalence, distribution, and influencing factors were given paramount importance [61]. In addition, similar use of malaria intervention tools was observed in communities with reasonable knowledge about malaria and its consequences [62]. Low willingness to accept IRS was reported because of the lack of communityies awareness of the severity and seriousness of the disease when infected [50]. The individuals belief about the severity of the problem is mostly based on medical information and knowledge, which may motivate one's decision to act towards self protection [63]. The barriers to the use of the intervention method are not about the cost or access; instead, they are linked to fear of the interventions and limited knowledge about malaria [64]. To achieve optimal health-seeking behaviors in endemic settings, malaria prevention and control programmes should consider local misconceptions and wrong perceptions [65]. Insecticide-treated mosquito nets are an effective method of malaria control; however, school-age children have reported less frequent use of them [66], probably due to the lack of proper knowledge and inadequate education in line with health programmes. Therefore, we formulated our next set of hypotheses:

**Hypothesis** $_{3:}$ Knowledge is positively related to malaria prevalence, and

**Hypothesis** $_{4:}$ Knowledge links Insecticide-treated nets to malaria prevalence.

### The Moderating effect of household-income

Malaria remains the leading cause of morbidity and mortality in low and middle-income countries [67,68]. The burden of chronic diseases is increasing in low and middle-income countries, where it constitutes multiple burdens along with infectious diseases [11]. The study reported a positive association between household income and the use of ITN to protect people from malaria [69]. Further, the study revealed that quality of life and health status are linked to economic, income, and educational status of residents [70]. In addition, the report indicates malaria elimination from high-income countries, while it is a challenge for low and middle-income countries [64]. Similarly, the study revealed the association between income and the practice of malaria preventive actions, where higher income groups are two times more likely to practice the actions than low-income groups [71]. Moreover, the report shows that access to intervention is influenced by household income [8]. Similarly, the study reported that, although ITN was suggested as a means of malaria reduction, the communities with large families and low-incomes are more affected by malaria disease [72]. another study showed that income level, age, educational level, and occupation are significant predictor variable for knowledge on malaria and to use IRS as a control tool [73]. Therefore, we hypothesised the following:

**Hypothesis** $_{5:}$ Household income moderates the relationship between insecticide-treated mosquito nets and malaria through knowledge. Thus, the mediated relationship will be stronger for those societies that have a higher income.

**Hypothesis** $_{6:}$ Household income moderates the strength of the direct relationship between insecticide-treated nets and malaria. Thus, the relationship will be stronger for an advanced community than for those with lower_incomes.

## Methods

### Data source

We investigated the moderated mediation role of malaria knowledge and household income on the relationship between ITN and malaria prevalence in Ethiopia. The study used data from the national malaria indicator survey (EMIS) and health-related indicators that were obtained from the Federal Ministry of Health, Ethiopia fielded from 2011 to 2015. The data are collected by the Ethiopian Public Health Institute/Ministry of Health in collaboration with Central Statistics Agency (CSA), U.S. President's Malaria Initiative (PMI), United Nations Children's Fund (UNICEF), Malaria Control and Elimination Partnership in Africa (MACEPA/PATH), Malaria Consortium (MC)-Ethiopia, WHO, and Columbia University Mailman School of Public Health (ICAP). The data produced annually, contains extensive details about malaria and related indicators. All malaria epidemic regions in the country are included in the study, and the data are secondary panel data containing 50 observations for the final review after condensing the suitable ones. All relevant variables for this study were identified. Accordingly, malaria prevalence (outcome variable), ITNs (independent variable), household income (moderating variable), and knowledge (mediating variable) were selected for the study.

## Measures

### Malaria prevalence

We measured malaria by the sum of malaria prevalence according to rapid diagnostic tests (RDT) and microscopy tests in all age groups [41,74].

### Insecticide-treated mosquito nets

The percentage of households with at least one insecticide-treated bed nets of any type was used to measure the 'insecticide-treated mosquito net' variable [11,41].

### Malaria knowledge

Malaria knowledge was measured using the percentage of respondents who have heard of malaria, recognized fever as a symptom of malaria, indicated mosquito bites as the cause of malaria, and indicated having mosquito nets (treated or untreated) as a prevention method [41,74]. Subsequently, we condensed these indicators using principal component analysis to obtain general knowledge.

### Household income

We measured household income using five indicators-the lowest income category, the second category, the middle category, the fourth category, and the highest category, and subsequently condensed them using principal component analysis to obtain the total household income for this study [75].

## Analysis

All analyses were performed using Stata software version 13.0. The ITNs were used as an intervention strategy for malaria protection, and malaria knowledge was found to mediate the relationship. Household income played a moderating role, and we evaluated malaria prevalence as an outcome effect. We followed a two-step approach to conduct the analysis and deduce the results — the principal component analysis was used to condense variables given by multiple indicators. The theoretical framework provided two steps. First, the linear relationship between the study's variables was estimated using the random-effect model. Second, we used structural equation modelling to test all of the conditional direct and indirect hypothesised relationships. The significance of the study and corresponding 95% confidence interval was determined using Wilson's test. We used a z-test to verify the statistical significance of the study's variables for the outcome variables and the mediating and moderating effect of malaria knowledge and household income on the relationship. The coefficients used to see ITNs and malaria prevalence were mediated by malaria knowledge and moderated by household income through malaria knowledge. All variables and correlations were found to be significant if ($p<0.05$).

### Empirical models

We designed various equations to find out the overall impact of the study variables. Accordingly, Equation (1) was designed to test the relationship between ITNs and malaria prevalence. Equation (2) was used to test ITNs and malaria knowledge relationships. We tested the influence of knowledge on malaria using Equation (3). Equation (4) was designed to test the mediating effect of knowledge on the relationship between ITNs and malaria prevalence. Equation (5) was employed to assess the effect of household income on malaria prevalence, while Equation (6) was designed to test the relationship between household income and malaria knowledge. Finally, Equation (7) was developed to investigate the moderating role of household income in the relationship between ITNs and malaria through knowledge. The model used a log of dependent and independent variables to reduce data variances and capture the mediating and moderating factors of malaria knowledge and household income given by multiple indicators through principal component analysis. The following seven equation models were used to test the results of the research hypotheses:

*[Please see the supplementary files section to view the equations 1-7]*

where MP represents a dependent variable, measured by the sum of confirmed malaria cases for both Plasmodium species using an RDT kit and microscopy tests [14,41,74]. ITN is an independent variable measured for all regions; malaria knowledge (Knm) represents a mediating variable with different indicators but condensed using principal component analysis. Household income (Income) is the moderating variable with various indicators and is summarised using principal component analysis, while β represents an estimate of the effect, and  represents the error term of the equation [76]. We used structural equation modelling and the random effect model to solve endogeneity and serial correlation. This has the advantage of higher efficiency relative to fixed effect model (FEM), leading to smaller standard errors of coefficients and higher statistical power to detect effects [77,78]. The moderation and mediation were assessed by disintegrating paths into direct and indirect impact to identify the immediate effect of the variables under the structural equation model [79].

# Results

### Descriptive statistics

The means (M), standard deviations (SD), minimum, maximum, and number of observations of the study's variables are shown in **Table 1**.

**Table 1**. Descriptive statistics of research variables

### Direct relationship

The direct relationships among the study variables tested simultaneously. The results are presented in **Table 2**, which show a positive relationship between ITNs and malaria prevalence ($\beta = 0.28$, $p < 0.01$). Further, a positive coefficient ($\beta$) was found in our analysis for all study variables, suggesting a positive relationship between ITNs, knowledge, household income, and malaria prevalence. The findings are consistent with those of previous studies [43,55,80], which showed the benefit of ITNs for malaria protection.

**Table 2**. Results of a direct relationship

### Testing the direct and indirect relationship (Hypotheses 1-6)

The proposed direct and indirect relationships for all hypotheses were simultaneously tested using structural equation modelling. The results, shown in **Table 3**, revealed a significant and direct relationship between ITNs and malaria prevalence, indicating changes in malaria prevalence as the access and use of ITN varies ($\beta = 0.28$, $p = 0.001$), thus supporting Hypotheses 1. Additionally, ITNs are significantly related to malaria knowledge ($\beta = 0.053$, $p = 0.049$), and malaria knowledge is significantly related to malaria prevalence ($\beta = 65$, $p = 0.118$), thus confirming Hypothesis 2 and 3. Further, our result supports the partial mediation of Judd and Kenny [81]. The findings were corroborated by the study's report, which showed that ITNs were the most preferred strategy for malaria prevention [7]. Other studies also indicate the use of ITNs for protection against malaria among the study communities [20]. Similarly, Odoko et al. [8] suggest that the proper use of ITNs could cut the transmission of malaria by at least 60% and child mortality by 20%. To further confirm mediation, we used Judd and Kenny Difference of Coefficients Approach, which involves subtractions of the partial regression coefficient obtained [81]. The result showed that the indirect effect of ITNs on malaria prevalence through knowledge of malaria ($\beta = 0.47$, $p = 0.003$) was significantly different from zero, with a 95% confidence interval. Thus, Hypothesis 4 regarding the mediation effect of malaria knowledge was supported.

As seen in **Table 3**, the effect of the interaction between ITNs and household income on malaria was positively significant (β = 0.13, p = 0.000), indicating a moderating effect. Thus, the results supported our Hypothesis 5. Regarding the moderated mediation effect, we checked for conditions suggested by Preacher et al. (2007) that needed to be satisfied for the existence of a moderation mediation effect [32]. To establish moderated-mediation, 1) the relationship between the independent variable and the outcome variable should be significant; 2) the interaction of the moderator variable and the mediator variable with the outcome variable should be significant; 3) the interaction effect of the moderator variable and the independent variable with the outcome variable should be significant; and 4) the mediator variable should be positively related to the outcome variable. The analysis showed that ITNs were significantly related to malaria (β = 0.28, $p < .001$), thus satisfying condition 1. The interaction between malaria knowledge and household income had a significant effect on malaria (β = 0.35, p = 000), thus meeting condition 2. The interaction between ITNs and household income had a significant effect on malaria (β = 0.13, P = .000), thus fulfilling requirement 3. Malaria knowledge was positively related to malaria (β = 0.65, p = 0.118), thus meeting condition 4, as shown in Table 3. These results were consistent with our Hypothesis 6. Further, our study revealed a positive association between the interaction of ITN and household income and malaria knowledge (β = 0.04, p = 0.000). Figure 2 shows the structural model of path analysis.

**Table 3**. Results of structural equation model path analysis

# Discussion

This study aimed to examine the interplay between ITNs, malaria knowledge, household income, and malaria in the context of public health. Programmes must consider local values and emphasise the role of vectors in transmission of disease to ensure protection from malaria [22,23,82]. Our results revealed a positive and direct relationship between ITNs and malaria prevalence. The findings imply that ITNs are an action-based mechanism designed in response to malaria. This result is consistent with previous findings, which reported ITN as a malaria prevention method [19]. Further, this finding promotes a contextualised understanding of the possible causes of malaria by providing a set of antecedents rooted in public health, which may inspire cerebral rationalisations. Moreover, we found thatITNs were positively related to malaria knowledge and that knowledge was positively related to malaria. In addition, malaria knowledge mediated the positive relationship between ITNs and malaria. The findings regarding malaria knowledge are consistent with its previous conceptualisation as perceived severity, benefit, and self-efficacy, reflecting a reaction to practice [33]. Furthermore, the present findings suggest a positively significant relationship between ITN and malaria prevalence when the outcome variable is linked with explanatory factors such as malaria knowledge as a mediating role. The role of malaria knowledge in this study is consistent with people's behaviour in response to the threat influenced by their current perception and conceptualisation of the diseases [43].

Additionally, both the direct and the indirect relationship (via malaria knowledge) between ITNs and malaria was stronger with the existence of household income as a moderating factor. This finding is consistent with a previous study, which reported that a low-income earning community might not have access to effective preventive strategies such as ITN [83]. Similarly, household income was reported among the factors that influence awareness regarding malaria and possible malaria prevention access such as vaccines [84]. Moreover, this study will help to develop an in-depth understanding of the relationship between malaria and household income and the relationship between strategic interventions and the prevalence of malaria in order to achieve malaria elimination. This study has empirically proven its role in evaluating situational factors as moderators and mediators in the relationships when umpiring the ethicality of an action. Generally, our study concludes that there is a positive relationship between ITNs and malaria, and household income and knowledge about malaria play a moderating and mediating role.

# Conclusions

Malaria imposes a heavy burden on people, particularly, Ethiopia. Nevertheless, many studies on malaria prevention and control have not studied the effect of household income and knowledge about malaria on strategic interventions and malaria in general, and the prevalence of malaria in particular. As reported in different studies, access to interventions cannot solve the challenges of its utilisation for infectious disease prevention and control, primarily malaria. Therefore, the provision of proper health education programmes has to be given due focus to improve awareness about malaria and its prevention. In addition, various studies reported associations between household income and access to and use of intervention methods [52]. Our findings support the active moderating and mediating roles of malaria knowledge and household income in the relationship. This study offers concrete and practical information to policymakers and health planners on the invaluable advantage of malaria knowledge and household income to ensure the programme's optimum performance. Malaria threatens mostly pregnant women and children, and achieving malaria elimination goals is possible only through awareness creation backed by proper education of vulnerable groups. Therefore, the study recommends that policymakers should strengthen the provision of health education. Further, the findings demonstrate the incorporation of health-related subjects in education curricula from primary school level, in line with community-based health literacy for adults. Moreover, it would be significant to discover the cumulative effect of malaria knowledge and household income in fighting against malaria on the relationship between explanatory and outcome variables. Furthermore, the report suggests that health planners should ensure that the programme is understood particularly in relation to the prevention and control of communicable disease such as malaria, to strengthen the usage culture of prevention interventions.

# Abbreviations

ITN: insecticide-treated mosquito nets; WHO: World Health Organization; RDT: rapid diagnostic test; HHI: health and health-related indicators; EMIS: Ethiopian malaria indicator survey; HBM: health belief model

# Declarations

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Not applicable

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Availability of data

The datasets used and analysed during this study are available from the corresponding author upon reasonable request.

Authors' contributions

This work was conducted collaboratively. Author M.A. is the first author in this study right from conception, execution, data analysis, and work review. Authors T.H. supported the supervision, manuscript writing and revision, and reading and confirmation of the final manuscript. Each author was involved in the manuscript preparation and approval of the final version submitted.

Ethical approval

'Not applicable'. The research is exempt from ethical approval because of the utilisation of secondary data.

Consent for publication

Not applicable

Competing interests

The authors declare that they have no competing interests.

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# References

1. Dalgleish, T.; Williams, J.M.G..; Golden, A.-M.J.; Perkins, N.; Barrett, L.F.; Barnard, P.J.; Au Yeung, C.; Murphy, V.; Elward, R.; Tchanturia, K.; et al. Sustainable Development Goals. *Journal of Experimental Psychology: General* **2007**, *136*, 23–42.

2. World Health Organization WORLD MALARIA REPORT WHO GLOBAL MALARIA PROGRAMME 2015. *WHO* **2015**.
3. Africa, S. Country trends in selected indicators Annex 4 - Data tables. *World malaria repor* **2016**.
4. World Health Organization *World malaria report: Geneva*; 2017; ISBN 9789241565523.
5. World Health Organization Chapter 7 Malaria. *Technical Report* **2010**.
6. DFID Malaria Burden and Interventions Evidence Overview. **2010**.
7. Animut, A.; Negash, Y.; Kebede, N. Distribution and utilization of vector control strategies in a malarious village of Jabi Tehnan District, north-western Ethiopia. *Malaria Journal* **2014**, *13*.
8. Odoko, J.O.; Nwose, E.U.; Igumbor, E.O. Utilization of insecticide treated nets against malaria among pregnant women in Southern Nigeria. *International Journal of Research in Medical Sciences* **2017**, *5*.
9. Alzate, N.G. Effectiveness of Pyriproxyfen and Olyset Duo in Controlling Insecticide Resistant Mosquito Populations in Burkina Faso. **2016**.
10. Turgeman *WHO global malaria programme*; 2011;
11. Federal Minstry of Health *Health Sector transformation plan*; 2015;
12. Watiro1, A.H.; Awoke2, W. Insecticide-treated net ownership and utilization and factors that influence their use in Itang , Gambella region , Ethiopia : cross-sectional study. *Risk Management and Healthcare Policy* **2016**, 101–112.
13. Prevention, D.; Directorate, C.; Control, N.M.; Program, E.; Ababa, A. NATIONAL MALARIA STRATEGIC PLAN : National Malaria Strategic Plan. **2020**, 2017–2020.
14. Ababa, A. Disease Prevention and Control Directorate , Malaria Control Programme. *guide lineline* **2014**.
15. World health organisation global malaria programme; world malaria report. **2013**, *b*.
16. President's Malaria Initiative Ethiopia: Malaria Operational Plan. **2016**.
17. OSSAI, P.O. AWARENESS , ACCESSIBILITY AND USE OF MALARIA CONTROL INTERVENTIONS AMONG AT-RISK GROUPS IN LAGOS METROPOLIS , NIGERIA. **2014**.
18. Molla Gedefaw, Z.A. Knowledge, Attitude and Practice of the Community towards Malaria Prevention and Control Options in Anti-Malaria Association Intervention Zones of Amahara National Regional State, Ethiopia. *Journal of Tropical Diseases* **2013**, *01*.
19. Fuge, T.G.; Ayanto, S.Y.; Gurmamo, F.L. Assessment of knowledge, attitude and practice about malaria and ITNs utilization among pregnant women in Shashogo District, Southern Ethiopia. *Malaria Journal* **2015**, *14*, 1–9.
20. Forero, D.A.; Chaparro, P.E.; Vallejo, A.F.; Benavides, Y.; Gutiérrez, J.B.; Arévalo-Herrera, M.; Herrera, S. Knowledge, attitudes and practices of malaria in Colombia. *Malaria Journal* **2014**, *13*.
21. Simon Alain Inah, Jimmy Ebi Eko, Z.U. and J.A.I. Knowledge of Malaria among Adult Residents in Abi Local Government Area, Cross River State, Nigeria. *Asian Journal of Research in Medical and Pharmaceutical Sciences* **2017**, *1*, 1–9.

22. Amaechi, E.; Ukpai, O. Knowledge , attitude and practices about malaria among mothers and care-givers in Aba South Local Government Area , Abia state , Nigeria. *Animal Research International* **2013**, *10*, 1786 – 1791.
23. Ruberto, I.; Camara, S.; Banek, K.; Loua, M.K. Knowledge, attitudes and practices of malaria control among communities from the health district of Forécariah in the Republic of Guinea, West Africa. *Journal of Vector Borne Diseases* **2014**, *51*, 119–127.
24. Taffese, H.S.; Hemming-schroeder, E.; Koepfli, C.; Tesfaye, G.; Lee, M.; Kazura, J.; Yan, G.; Zhou, G. Malaria epidemiology and interventions in Ethiopia from 2001 to 2016. *Infectious Diseases of Poverty* **2018**, *7*.
25. Seth, R.K.; Agarwal, A. Awareness About Malaria And its Prevention Amongst Rural Population of western Uttar Pradesh. *IOSR Journal of Dental and Medical Sciences (IOSR-JDMS)* **2017**, *16*, 28–31.
26. Shimaponda-Mataa, N.M.; Tembo-Mwase, E.; Gebreslasie, M.; Mukaratirwa, S. Knowledge, attitudes and practices in the control and prevention of malaria in four endemic provinces of Zambia. *Southern African Journal of Infectious Diseases* **2017**, *32*, 29–39.
27. Orji, R.; Vassileva, J.; Mandryk, R. Towards an Effective Health Interventions Design : An Extension of the Health Belief Model. **2012**, *4*.
28. Hounton, S.H.; Carabin, H.; Henderson, N.J. Towards an understanding of barriers to condom use in rural Benin using the Health Belief Model : A cross sectional survey. *BioMed Central* **2005**, *8*, 1–8.
29. Cecilia Van Zyl-Schalekamp, A.S. Perceived Threat of Malaria and the Use of Insecticide Treated Bed Nets in Nigeria. *African Socilogical Review* **2013**, *17*, 25–44.
30. Michielsen, K.; Chersich, M.; Michielsen, K.; Chersich, M.; Temmerman, M.; Dooms, T.; Rossem, R. Van Nothing as Practical as a Good Theory ? The Theoretical Basis of HIV Prevention Interventions for Young People in ... Nothing as Practical as a Good Theory ? The Theoretical Basis of HIV Prevention Interventions for Young People in Sub-Saharan Africa : A. *AIDS Research and Treatment* **2016**, *2012*.
31. Robert T. Croyle, P.D. *Teory at a Glance*; 2005;
32. Preacher, K.J.; Rucker, D.D.; Hayes, A.F.; Preacher, K.J.; Rucker, D.D.; Hayes, A.F.; Rucker, D.D.; Hayes, A.F. Addressing Moderated Mediation Hypotheses : Theory , Methods , and Prescriptions Addressing Moderated Mediation Hypotheses : Theory , Methods , and Prescriptions. *Multivariate Behavioral Research* **2017**, *42*, 185–227.
33. Watanabe, N.; Kaneko, A.; Yamar, S.; Leodoro, H.; Taleo, G.; Tanihata, T.; Koji Lum, J.; Larson, P.S. Determinants of the use of insecticide-Treated bed nets on islands of pre-and post-malaria elimination: An application of the health belief model in Vanuatu. *Malaria Journal* **2014**, *13*, 1–12.
34. Kumar, M.; Raghavendra, K.; Kleinschmidt, I.; Bhatt, R.M.; Kumar, D.; Bellamy, T.; Valecha, N. Impact of long-lasting insecticidal nets on prevalence of subclinical malaria among children in the presence of pyrethroid resistance in Anopheles culicifacies in Central India. *International Journal of Infectious Diseases* **2017**.
35. World health organisation Strategic orientation paper on prevention and control of malaria. *Strategic orientation paper on prevention and control of malaria* **2005**, *First Edit*.

36. Taremwa, I.M.; Ashaba, S.; Adrama, H.O.; Ayebazibwe, C.; Omoding, D.; Kemeza, I.; Yatuha, J.; Turuho, T.; Macdonald, N.E.; Hilliard, R. Knowledge , attitude and behaviour towards the use of insecticide treated mosquito nets among pregnant women and children in rural Southwestern Uganda. *BMC Public Health* **2017**, 4–11.
37. Eckert, E.; Florey, L.S.; Tongren, J.E.; Ren, S.; Rukundo, A.; Habimana, J.P.; Hakizimana, E.; Munguti, K.; Umulisa, N.; Mulindahabi, M.; et al. Impact Evaluation of Malaria Control Interventions on Morbidity and All-Cause Child Mortality in Rwanda , 2000 – 2010. *Am, J, Trop.Med.Hyg* **2017**, *97*, 99–110.
38. World health organisation Indoor Residual Spraying, policy and strategy. *Operational Manual for IRS* **2015**, *Second Edi*.
39. PMI President ' S Malaria Initiative Technical. *Cdc* **2016**, 9–11.
40. Alemu, A.; Muluye, D.; Mihret, M.; Adugna, M.; Gebeyaw, M. Ten year trend analysis of malaria prevalence in Kola Diba, North Gondar, Northwest Ethiopia. *Parasites and Vectors* **2012**, *5*, 1–6.
41. EHNRI/EPHI *Ethiopia National Malaria Indicator Survey*; 2015;
42. Dejene, A.A. and T. Current Status of Malaria in Ethiopia : Evaluation of the Burden , Factors for Transmission and Prevention Methods. *Acta Parasitologica Globalis* **2016**, *7*, 01-6.
43. State, T.; Vol, J.; Page, I. Awareness about Mosquito Borne Diseases and Practice about Preventive Methods Against Mosquito Bite in Rural Field Practice Area of a Tertiary. *Journal of Medical Science And cCinical Research* **2018**, *06*, 512–518.
44. Alexander Suuk Laar, Amos Kankponang Laar, P.A.D. Community perception of malaria and its influence on health-seeking behaviour in rural Ghana: a descriptive study. *MalariaWorld Journal* **2013**, *4*.
45. Gorgui Diouf Department, Yihua Xu, P.N.K. Evaluation of the Effectiveness of Intervention for Malaria Control in Rural Areas in China. *Global Journal of Health Science Vol.* **2010**, *2*.
46. Nitin Joseph, Maria Nelliyanil, Shashidhar M Kotian, Mohammed Omar, R. Srikanth Aswin, Saiteja Donkena, Smita Jugnu, P.C. Awareness, practices and expenditure towards mosquito bite prevention methods in urban and semi-urban areas of South India. *International Journal of Mosquito Research* **2015**, *2*, 53–59.
47. Constructs, T.; Concept, T. *Health Belief Model*; 2003;
48. Alemu, M.B.; Asnake, M.A.; Lemma, M.Y.; Melak, M.F. Utilization of insecticide treated bed net and associated factors among households of Kola Diba town , North Gondar , Amhara region , Ethiopia. *BMC Research Notes* **2018**, 1–5.
49. Tokponnon, F.T.; Ogouyémi, A.H.; Sissinto, Y.; Sovi, A.; Gnanguenon, V.; Cornélie, S.; Adéothy, A.A.; Ossè, R.; Wakpo, A.; Gbénou, D.; et al. Impact of long-lasting, insecticidal nets on anaemia and prevalence of Plasmodium falciparum among children under five years in areas with highly resistant malaria vectors. *Malaria Journal* **2014**, *13*, 1–11.
50. Wadunde, I.; Mpimbaza, A.; Musoke, D.; Ssempebwa, J.C.; Ediau, M.; Tuhebwe, D.; Adoke, Y.; Wanyenze, R.K. Factors associated with willingness to take up indoor residual spraying to prevent malaria in Tororo district, Uganda: a cross-sectional study. *Malaria Journal* **2018**, *17*.

51. Doda, Z.; Solomon, T.; Loha, E.; Gari, T.; Lindtjørn, B. A qualitative study of use of long - lasting insecticidal nets ( LLINs ) for intended and unintended purposes in Adami Tullu , East Shewa Zone , Ethiopia. *Malaria Journal* **2018**, 1–14.
52. Tassew, A.; Hopkins, R.; Deressa, W. Factors influencing the ownership and utilization of long - lasting insecticidal nets for malaria prevention in Ethiopia. *Malaria Journal* **2017**, 1–9.
53. Adebayo, A.M.; Akinyemi, O.O.; Cadmus, E.O. Knowledge of malaria prevention among pregnant women and female caregivers of under-five children in rural southwest Nigeria. *PeerJ* **2015**, *3*, e792.
54. Birhanu, Z.; Yihdego, Y.Y. ebiyo; Yewhalaw, D. Caretakers' understanding of malaria, use of insecticide treated net and care seeking-behavior for febrile illness of their children in Ethiopia. *BMC Infectious Diseases* **2017**, *17*, 1–16.
55. Getachew, D. Ecology and Distribution Pattern of Anopheles Mosquitoes and Malaria Transmission in Ghibe River Basin , southwestern Ethiopia. *thesis-PhD* **2017**.
56. *HEALTH COMMUNICATION FROM THEORY TO PRACTICE Second Edition*; 2014; ISBN 9781118122198.
57. Karunamoorthi, K.; Bekele, M. Changes in Malaria Indices in an Ethiopian Health Centre : A Five Year Retrospective Analysis. *Health Scope* **2012**, *1*, 118–126.
58. Pinchoff, J.; Larsen, D.A.; Renn, S.; Pollard, D.; Fornadel, C.; Maire, M.; Sikaala, C.; Sinyangwe, C.; Winters, B.; Bridges, D.J.; et al. Targeting indoor residual spraying for malaria using epidemiological data : a case study of the Zambia experience. *Malaria Journal* **2016**, 1–6.
59. Domina Asingizwe, P. Marijn Poortvliet, Constantianus J.M. Koenraadt, Arnold J.H. Van Vliet, Marilyn M. Murindahabi, Chantal Ingabire, Leon Mutesa, P.H.F. Applying citizen science for malaria prevention in Rwanda: An integrated conceptual framework. *NJAS - Wageningen Journal of Life Sciences* **2018**.
60. Sylvester, G. Technologies for agricultural information sharing - Part II. **2013**, 51–105.
61. Alemu, A.; Tsegaye, W.; Golassa, L.; Abebe, G. Urban malaria and associated risk factors in Jimma town, south-west Ethiopia. *Malaria Journal* **2011**, *10*, 1–10.
62. Nkoka, O.; Chuang, T.W.; Chuang, K.Y.; Chen, Y.H. Factors associated with insecticide - treated net usage among women of childbearing age in Malawi : a multilevel analysis. *Malaria Journal* **2018**, 1–16.
63. Matthew Asare, Manoj Sharma, Amy L. Bernard, Liliana Rojas-Guyler, L.L.W. Using the Health Belief Model to Determine Safer Sexual Behavior among African Immigrants. *Journal of Health Care for the Poor and Underserved* **2013**, *24*, 120–134.
64. Salam, R.A.; Das, J.K.; Lassi, Z.S.; Bhutta, Z.A. Impact of community-based interventions for the prevention and control of malaria on intervention coverage and health outcomes for the prevention and control of malaria. *Infectious Diseases of Poverty* **2014**, *3*, 1–15.
65. Birhanu, Z.; Abebe, L.; Sudhakar, M.; Dissanayake, G. Malaria Related Perceptions , Care Seeking after Onset of Fever and Anti-Malarial Drug Use in Malaria Endemic Settings of Southwest Ethiopia. *PLoS ONE* **2016**, *7*, 1–20.

66. Nankabirwa, J.; Brooker, S.J.; Clarke, S.E.; Fernando, D.; Gitonga, C.W.; Schellenberg, D.; Greenwood, B. Malaria in school-age children in Africa: An increasingly important challenge. *Tropical Medicine and International Health* **2014**, *19*, 1294–1309.
67. Rugnao, S.; Gonahasa, S.; Sebuguzi, C.M.; Opigo, J.; Yeka, A.; Katureebe, A.; Kyohere, M.; Lynd, A.; Hemingway, J.; Donnelly, M.J.; et al. LLIN Evaluation in Uganda Project ( LLINEUP ): factors associated with childhood parasitaemia and anaemia 3 years after a national long - lasting insecticidal net distribution campaign : a cross - sectional survey. *Malaria Journal* **2019**, 1–12.
68. Wangroongsarb, P.; Hwang, J.; Thwing, J.; Karuchit, S.; Kumpetch, S.; Rand, A.; Drakeley, C.; MacArthur, J.R.; Kachur, S.P.; Satimai, W.; et al. Using respondent driven sampling to identify malaria risks and occupational networks among migrant workers in Ranong, Thailand. *PLoS ONE* **2016**, *11*.
69. Balami, A.D.; Said, S.; Afiah, N.; Zulkefli, M.; Norsa, B.; Audu, B. Knowledge , motivation , self - efficacy , and their association with insecticidal net use among pregnant women in a secondary health centre in Maiduguri , Nigeria. *Malaria Journal* **2018**, 1–17.
70. Knight, E.K. *Health Equity Guide for Public Health Practitioners and Partners*; 2015;
71. Tayseir T. M. Masaad, Yousif M. Elmosaad, Abd Elbasit Elawad Mohammed, Ahmed Elnadif Elmanssury, Mahmoud Jaber, Mustafa M. Mustafa, H.E. Knowledge, Attitude and Practices Among Mothers Towards Insecticide-Treated Nets in Abuharira Village -Um Remta Locality- The White Nile State -2015. *Science Journal of Clinical Medicine* **2017**, *6*, 24–31.
72. Ayele, D.G.; Zewotir, T.T.; Mwambi, H.G. The risk factor indicators of malaria in Ethiopia. *International Journal of Medicine and Medical Sciences* **2013**, *5*, 335–347.
73. Munga, S.; Kimwetich, Z.; Atieli, F.; Vulule, J.; Kweka, E.J. Knowledge and perceptions about indoor residual spray for malaria prevention in mumberes division, Nandi county in central province of Kenya. *Tanzania Journal of Health Research* **2017**, *19*, 1–9.
74. EHNRI/EPHI Ethiopian National Malaria Indicator Survey. **2011**.
75. EHNRI/EPHA Ethiopian National Malaria Indicators Survey. **2015**.
76. Bell, A. Explaining Fixed Effects: Random Effects Modeling of Time-Series Cross-Sectional and Panel Data*. *European political science association* **2015**, *3*, 133–153.
77. Schmidheiny, K. *Short Guides to Microeconometrics. Panel Data: Fixed and Random Effects*; 2018; Vol. 2;.
78. Bollen, K.A.; Odum, H.W. A GENERAL PANEL MODEL WITH RANDOM AND FIXED EFFECTS: A STRUCTURAL EQUATIONS APPROACH. *NIH Public Access* **2011**, *1*, 1–34.
79. Breen, R.; Karlson, K.B.; Holm, A. Total, Direct, and Indirect Effects in Logit and Probit Models. *Sociological Methods and Research* **2013**, *42*, 164–191.
80. Sovi, A.; Azondékon, R.; Aïkpon, R.Y.; Govoétchan, R.; Tokponnon, F.; Agossa, F.; Salako, A.S.; Oké-Agbo, F.; Aholoukpè, B.; Okè, M.; et al. Impact of operational effectiveness of long-lasting insecticidal nets (LLINs) on malaria transmission in pyrethroid-resistant areas. *Parasites and Vectors* **2013**, *6*, 1–13.

81. Mackinnon, D.P.; Fairchild, A.J.; Fritz, M.S. *Mediation Analysis*; 2007;
82. Ukpai, O.M.; Irole-Eze, O.P.; Amaechi, E.C.; Ejike, B.U.; Ejike, E.N.; Okorocha, N.A. A Study of Knowledge, Attitude, and Practices Regarding Malaria Among Inhabitants of Ezinihite Local Government Area, Imo State, Eastern Nigeria. *Manila Journal of Science* **2017**, *10*, 65–74.
83. Attu, H.; Adjei, J.K. Local knowledge and practices towards malaria in an irrigated farming community in Ghana. *Malaria Journal* **2018**, 1–8.
84. Chukwuocha, U.M.; Okorie, P.C.; Iwuoha, G.N.; Ibe, S.N.; Dozie, I.N.; Nwoke, B.E. Awareness , perceptions and intent to comply with the prospective malaria vaccine in parts of South Eastern Nigeria. *Malaria Journal* **2018**, 1–7.

# Tables

**Table 1**. Descriptive statistics of research variables

| Variables | | Mean | Std. Dev. | Min | Max | Observation | | |
|---|---|---|---|---|---|---|---|---|
| Malaria pr | overall | 9.328151 | 2.553441 | 2.3979 | 13.7181 | N | = | 50 |
| | between | | 2.04277 | 5.566182 | 11.48004 | n | = | 10 |
| | within | | 1.639451 | 6.159869 | 12.62001 | T | = | 5 |
| ITN | overall | 11.39936 | 3.790337 | 0 | 15.3455 | N | = | 50 |
| | between | | 2.938286 | 5.91212 | 14.39478 | n | = | 10 |
| | within | | 2.537303 | 5.122061 | 16.25176 | T | = | 5 |
| Knowledge | overall | 3 | 1 | .739625 | 4.29885 | N | = | 50 |
| | between | | .954039 | 1.441853 | 4.098688 | n | = | 10 |
| | within | | .4051063 | 1.533178 | 3.689393 | T | = | 5 |
| Income | overall | 2 | 1.000002 | .227062 | 3.351187 | N | = | 50 |
| | between | | 1.005721 | .565118 | 3.086802 | n | = | 10 |
| | within | | .2666422 | 1.475116 | 2.48946 | T | = | 5 |
| ITN*Income | overall | 24.96946 | 15.17194 | 0 | 49.36902 | N | = | 50 |
| | between | | 15.26644 | 3.361229 | 43.80043 | n | = | 10 |
| | within | | 4.018591 | 17.97984 | 35.93472 | T | = | 5 |

**Note:**Overall represents ordinary statistics that are based on 50 observations, Between statistics are calculated on the basis of summary statistics of ten regions (entities) regardless of a time period, Within statistics are calculated using summary statistics of five time periods regardless of regions. N stands for the number of observations in the panel data, n represents the numbers of regions (entities), and T represents the period of the study.

**Table 2**. Results of a direct relationship

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| | Malaria pr. | Malaria knowledge | Malaria pr. | Malaria knowledge | Malaria pr. |
| Insecticide mosquito nets | 0.278** | 0.0523* | | | |
| | (0.0866) | (0.0288) | | | |
| Malaria knowledge | | | 0.651 | | |
| | | | (0.417) | | |
| Household income | | | | 0.628*** | 1.655*** |
| | | | | (0.132) | (0.340) |
| _cons | 6.165*** | 2.403*** | 7.374*** | 1.744*** | 6.018*** |
| | (1.083) | (0.372) | (1.335) | (0.301) | (0.762) |
| *N* | 50 | 50 | 50 | 50 | 50 |

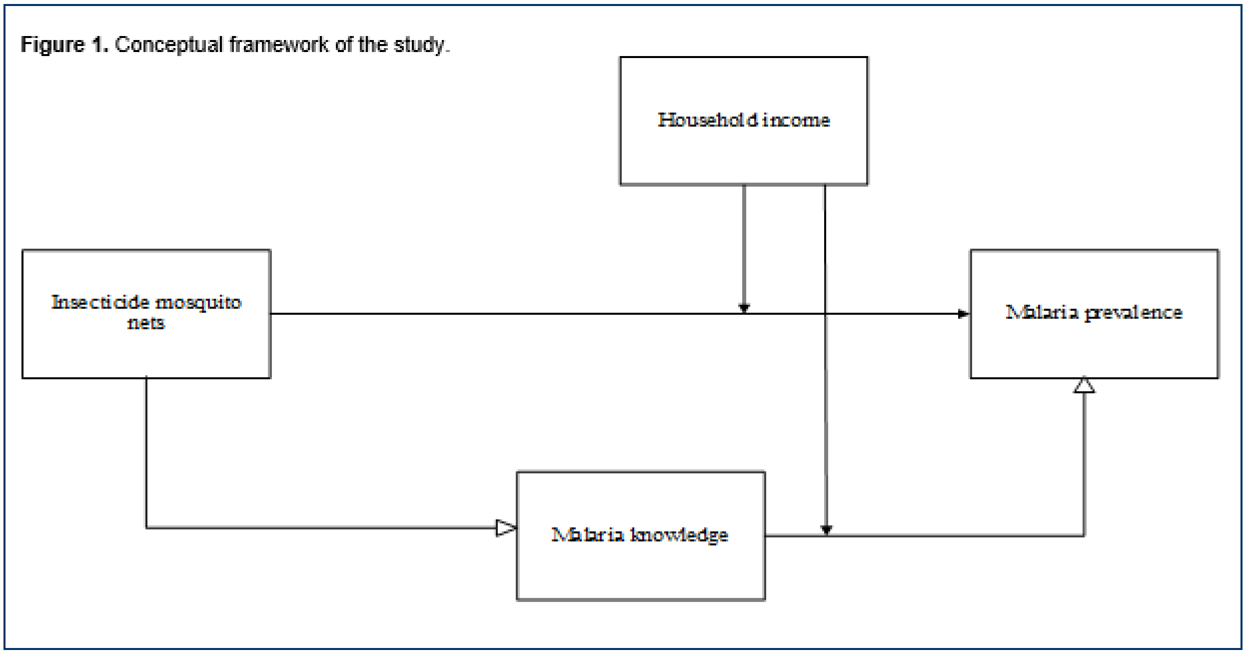
Standard errors in brackets

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

**Table 3**. Results of structural equation model path analysis

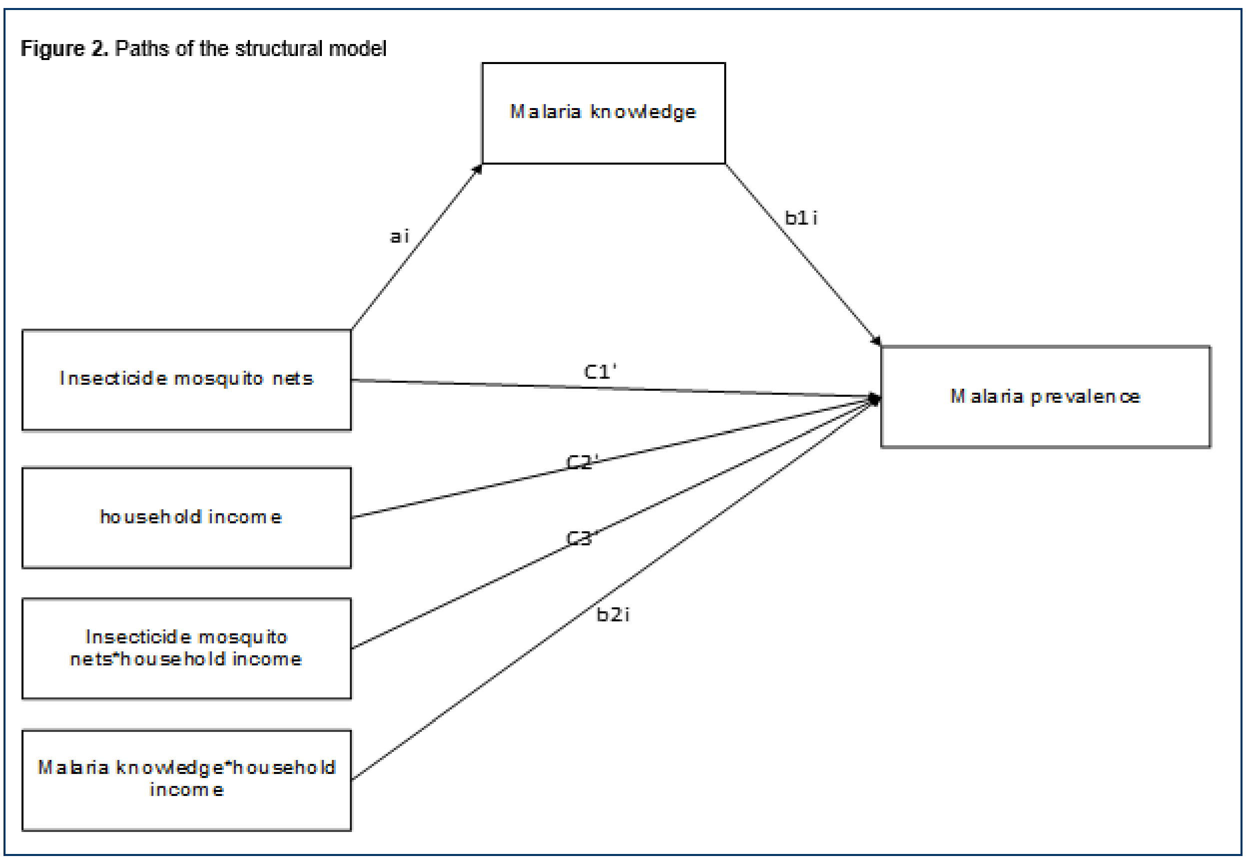
| Structural Path | Coef. | Std.Er. | Z | p>Z | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| Insecticide-treated mosquito nets → Malaria pr | 0.28 | 0.086 | 3.21 | 0.001 | .1078217 | .4472075 |
| Insecticide mosquito nets → Knowledge | 0.05 | 0.029 | 1.82 | 0.049 | -.0041617 | .4472075 |
| Malaria Knowledge → Malaria pr | 0.65 | 0.416 | 1.56 | 0118 | -.1651322 | 1.467698 |
| Household income → Malaria pr | 1.65 | 0.339 | 4.87 | 0.000 | .9894127 | 2.320555 |
| ITN*household income → Malaria pr. | 0.13 | 0.023 | 5.53 | 0.000 | .0819049 | .1717884 |
| Knowledge*Household income → Malaria pr | 0.35 | 0.082 | 4.33 | 0.000 | .1940172 | .5145745 |
| ITN → Knowledge → Malaria pr | 0.47 | 0.096 | 2.94 | 0.003 | .0935075 | .4694023 |

# Figures




## Figure 1

Conceptual framework of the study.




## Figure 2

Paths of the structural model