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Prevalence of malaria infection and the impact of mosquito bed net distribution among children aged 6–59 months in Ghana: Evidence from the Ghana demographic health and malarial indicator surveys

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ABSTRACT

Objective: To assess the prevalence of malaria infection and further quantify the impact of mosquito bed net distribution on malaria infection among children aged 6–59 months in Ghana.
Methods: A cross-sectional study using Ghana Demographic Health (GDHS) and Malaria Indicator (GMIS) surveys (2014 GDHS, 2016 GMIS, and 2019 GMIS). The exposure and the main outcomes were mosquito bed net use (MBU) and malaria infection (MI). Relative percentage change (Δ) and prevalence ratio (PR) were estimated to assess the changes and the risk of MI by MBU respectively. The Propensity-score matching treatment effect model was employed to estimate the average treatment effect (ATE) of MBU on MI. All analyses were performed using Stata 16.1 and *p*-value<0.05 was deemed significant.
Results: The study involved 8781 children aged 6–59 months. MI ranged from 25.8%(22.3–29.7) in 2019 GMIS to 40.6%(37.0–44.2) in 2014 GDHS and the prevalence was significantly high among children who used mosquito bed net. The relative percentage change in MI prevalence showed a significant reduction rate and was high among non-MBU (*p*-value<0.05). In all, the adjusted PR of MI among children exposed to MBU was 1.21(1.08–1.35), 1.13(1.01–1.28), and 1.50(1.20–1.75) in 2014 GDHS, 2016 GMIS, and 2019 GMIS respectively. The average MI among participants who slept in mosquito bed net significantly increased by 8%(0.04 to 0.12), 4%(0.003 to 0.08), and 7%(0.03 to 0.11) in 2014 GDHS, 2016 GMIS, and 2019 GMIS respectively.
Conclusion: Even though malaria infection prevalence among children aged 6–59 months is decreasing, the reduction rate seems not to be directly linked with mosquito bed nets distribution and/or use in Ghana. For a continued distribution of mosquito bed nets, and for Ghana to achieve her *Malaria Strategic Plan (NMSP) 2021–2025,* program managers should ensure effective use of the distributed nets in addition to other preventive measures and nuanced consideration of community behaviours in Ghana. The effective use and care of bed nets should be emphasized as part of the distribution.

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1. Introduction

Malaria is a life-threatening disease caused by parasites that are transferred to humans by infected female Anopheles mosquito bites. Globally, about 229 million cases of malaria are reported and over 400,000 deaths occurred; particularly the World Health Organization (WHO) African Region continues to bear an inordinately large percentage of the global malaria burden accounting for 94% of malaria cases and deaths (WHO, 2021) as at 2021. In Ghana, impact of malaria is enormous. It remains a major public health problem where the burden is felt not only in the health institutions but also at community level (Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF International, 2015). Also, when compared to typical family wages in Ghana, the cost of treatment is expensive (Dalaba et al., 2021). Malaria Infection (MI) in Ghana accounts for 30% of outpatient attendances and 23% of inpatient admissions cases (Shretta et al., 2020). A community-based study conducted in the Upper East of Ghana estimated 73% of MI in households among participants who reported experiencing fever (Dalaba et al., 2021). The WHO has stated that children aged under 5 years are the most vulnerable group affected by malaria accounting for approximately 67% of all malaria deaths worldwide (WHO, 2021).

Large-scale implementation of high-impact interventions such as case management systems has been improved over the decade to detect and treat malaria infection. In Ghana, all patients with suspected malaria should have their parasitological confirmation by microscopy test or rapid diagnostic tests (RDTs) performed before treatment begins, according to the National Malaria Control Program (NMCP) guidelines (Ghana Statistical Service (GSS), and and ICF, 2020). As part of the interventions, prevention and control of malaria among pregnant women and children using intermittent preventive therapy, vector control strategies such as insecticide-treated bed nets (ITNs) or Long Lasting Insecticide Treated Nets (LLINs), and indoor residual spraying (IRS), have resulted in remarkable achievements in malaria control over the last decade (IRS) (Abeku et al., 2015; Eckert et al., 2017).

The core objective of the Ghana Demographic Health Survey (GDHS) and Ghana Malaria Indicator Survey (GMIS) is to provide current estimates of key malaria indicators by measuring the extent of ownership and use of mosquito bed nets and the corresponding malaria MI. One of the main strategies for avoiding MI in Ghana is the distribution and usage of ITNs/LLINs. Household ownership of at least one ITN has increased from 42% in 2008 GDHS to 74% in 2019 GMIS (Ghana Statistical Service (GSS), and and ICF, 2020). More than half (52%) of households have one ITN for every two people, while 26% do not own any ITNs. Among those who have access to ITNs, only 43% of the household population use them and the differences between access to and use of ITNs is larger in urban population (59% versus 28%) than in rural households (74% versus 57%) (Ghana Statistical Service (GSS), and and ICF, 2020). Skin irritation, individuals who perceive themselves as not likely to be beaten by mosquitoes or get malaria (Mensah and Anto, 2020), poor wealth index (Bawuah and Ampaw, 2021; Kanmiki et al., 2019), individual age (Konlan et al., 2019) among others are some factors that hamper mosquito bed net usage in Ghana.

What is lacking in Ghana currently is whether mosquito bed nets usage is reducing malaria infection among children aged 6–59 months. Lack of evidence for rational deployment of interventions, evaluation of their impact necessitates this current study to assess the impact of mosquito bed net use (either LLINs/ITNs) on MI among children aged 6–59 months in Ghana.

2. Methods

2.1. Study description

The study pooled data from the 2014 Ghana Demographic and Health Survey (GDHS) and the Ghana Malaria Indicator Survey (GMIS) conducted in 2016 and 2019. Both surveys were conducted across the then 10 regions of Ghana by adopting a nationally stratified sampling technique. The two separate surveys were appended as pooled data with the same codes identifying key variables of interest in all.

2.2. Study design

The GDHS and GMIS were based on a multi-stage cluster sampling involving a two-stage stratified (rural-urban differential) cluster sampling design across the countries' 10 administrative regions, giving 20 sampling strata. The sampling frame used for GDHS and GMIS was from the 2010 Population and Housing Census conducted in Ghana by Ghana Statistical Service. As of 2019, six new regions in Ghana were created, resulting in 16 administrative regions; however, during the 2019 GMIS, the new administrative boundaries were not available. The frame is a complete list of all census enumeration areas (EAs) created for the Population and Housing Census (PHC). During sampling, samples of EAs were selected independently in each stratum in two stages. In the first stage, EAs were selected with probability proportional to EA size and with independent selection in each sampling stratum. A household listing was conducted and was used as the list served as the sampling frame for the selection of households in the second stage. In the second stage of selection, a fixed number of households was selected from each cluster using systematic sampling from the list of households. Detailed sampling design for the GDHS and MIS can be found elsewhere (Ghana Statistical Service (GSS), and and ICF, 2020; Ghana Statistical Service (GSS), Ghana Health Service (GHS), and ICF International, 2015).

2.3. Study participants

In all the surveys, all women aged 15–49 who were either permanent residents of the selected households or visitors who stayed in the household the night preceding the survey were eligible. For ethical issues, parent or guardian consent to test for malaria infection was obtained for children aged 6–59 months. For GDHS, 9396 women in their reproductive years of 15–49 years were involved and the mother's response rate was 97.3%. The total number of children aged 6–59 months years eligible for malaria testing was 2781. For 2016 and 2019 GMIS, the study involved 5150 and 5181 women in their reproductive years of 15–49 respectively and the response rate was 99.3% and 98.8% respectively. The total number of children aged 6–59 months eligible for malaria testing for 2016 and 2019 GMIS was 3080 and 2920 respectively. In all, the current study involved 8781 children aged 6–59 months years.

2.4. Outcome measures

The main outcome variable considered in the study was malaria infection among children aged 6–59 months years. The study used secondary data from the GDHS, we defined the method that was used to assess malaria infection. Blood samples for malaria testing were collected via finger or heel pricks from children aged 6–59 months. Two approaches to blood sample testing were adopted; namely rapid diagnostic test (RDT) and blood smears.

For the RDT test, a drop of blood was tested for malaria with the SD BIOLINE Malaria Ag P.f rapid diagnostic test (RDT). The SD BIOLINE P.f RDT tests for one antigen, histidine-rich protein II (HRP-II) was appropriate since the major cause of malaria infectious parasite in Ghana is *Plasmodium falciparum (Pf)*. The diagnostic test includes a disposable sample applicator that comes in a standard package. A tiny volume of blood was collected with the applicator and placed in the sample well of the testing device, and then four drops of the buffer are added to the appropriate well.

For blood smear, thick blood smears were stained with 3% Giemsa solution and examined

under a microscope to determine the presence or absence of *malaria parasites* at the National Public Health and Reference Laboratory (NPHRL) at the Korle-Bu Teaching Hospital. All stained slides were read by two independent microscopists who were masked from the RDT results. Slides with discordant results between the first and second readers were re-examined by a third microscopist to determine the final result. The microscopic results were quality checked via internal and external quality control processes. As part of internal quality control, an independent microscopist read 5% of all slides. External quality control was conducted by the Noguchi Memorial Institute for Medical Research (NMIMR), which independently read 10% of the slides. The external quality control testing yielded 95% agreement between the NPHRL and NMIMR results. The detailed testing procedure can be found in (Ghana Statistical Service (GSS), and and ICF, 2020).

2.5. Exposure variable

The study considered mosquito bed net use among children aged 6–59 months as the exposure outcome of interest. Mosquito bed net use was a subjective response as measured by GDHS and GMIS by asking participants whether *children under 5 slept under mosquito bed net last night?* The response was categorized as 1 = no, 2 = all children, 3 = some children, and 4 = no net in the household. However, for this study, the variable was dichotomized as 1 = Yes (all children) and 0 = (no, some children and no net in the household).

2.6. Covariate

In this study, the authors adjusted for key covariates identified in the literature as a potential predictor of malaria infection among children between 6 and 59 months. Variables included; the age of the child (in months) in months (Abossie et al., 2020; Afoakwah et al., 2018; Lim et al., 2011; Morakinyo et al., 2018; Siri, 2014), sex of child (Abossie et al., 2020; Coulibaly et al., 2021; Lim et al., 2011), place of residence (Abossie et al., 2020; Beavogui et al., 2020; Lim et al., 2011; Morakinyo et al., 2018; Siri, 2014), sex of Household Head (HHH), and age of HHH, source of drinking water (Shayo et al., 2021; Yang et al., 2020), sanitation (Yang et al., 2020), wealth Index (Afoakwah et al., 2018; Lim et al., 2011; Siri, 2014; Tusting et al., 2016), number of mosquito bed nets (Abossie et al., 2020; Morakinyo et al., 2018), age of the mother/ caretaker (Lim et al., 2011; Siri, 2014) and education of the mother/caretaker (Beavogui et al., 2020; Lim et al., 2011).

2.7. Data analysis

Analysis controlled for the design effect of GDHS and GMIS by adjusting for the primary sampling units, stratification, and the sampling weights. The Rao-Scott χ^2 was used to evaluate the statistical difference of malaria infection by exposure outcome. The growth rate of malaria infection from 2014 GDHS to 2019 GMIS was estimated by adopting the formular $r = \left(\sqrt{n\frac{P_1}{P_0}}\right) - 1$; where r = growth rate, P_1 = the current malaria infection among children aged 6–59 months (2019 GMIS), and P_0 = past malaria infection among children aged 6–59 months (2014 GDHS). For comparative analysis, the growth rate was estimated for children who slept under a mosquito bed net the previous night and those who did not. In addition, the rate of percentage change within the periods was calculated by adopting the formula $\Delta = \left(\frac{x_2 - x_1}{x_1}\right) * 100$; where Δ represents the relative change x_2 and x_1 denote current and initial value respectively. Percentage change was assessed over three-point periods; 2014 GDHS-2016 GMIS, 2014 GDHS-2019 GMIS, and 2016 GMIS and 2019 GMIS.

Inferential analysis involving robust Poisson regression was adopted to assess the association between MBU and MI (independent analysis for RDT and blood smear and both). The analysis was adopted to assess the adjusted prevalence ratio (PR) of MI by MBU (x_1)

while controlling for k-1 covariates($x_2, x_3, x_4, \ldots, x_k$). The conditional probability of MI given that a child aged between 6 and 59 months would sleep in mosquito bed net and adjusting for other confounders is given by;

$$aPR = \frac{1 + exp\{-\beta_0 - \beta_2 X_2 - \ldots - \beta_k X_k\}}{1 + exp\{-\beta_0 - \beta_1 - \beta_2 X_2 - \ldots - \beta_k X_k\}}$$

In addition, the Propensity-score matching treatment effect model (the logistic treatment model) was employed to estimate the average treatment effect (ATE) of mosquito bed net use on malaria infection to evaluate the impact of bed net use on malaria infection. IPW corrects for missing data by using estimated probability weights which are based on the fact that each subject is only observed in one of the possible outcomes.

2.8. Ethical requirements

DHS procedures and questionnaires for standard DHS surveys were reviewed and approved by ICF Institutional Review Board (IRB). The ICF IRB ensures that the survey complies with the U.S. Department of Health and Human Services regulations for the protection of human subjects (45 CFR 46). The GDHS protocol was reviewed and approved by the Ghana Health Service Ethical Review Committee and the Institutional Review Board of ICF International. Individual women's written consent was obtained during the data collection process for all participants. Privacy and confidentiality were strictly adhered to. Data underlying the results in this study was requested and granted by the Monitoring and Evaluation to Assess and Use Results Demographic and Health Surveys (MEASURE DHS) department. Request can be obtained from DHS https://dhsprogram.com/data/dataset_admin/login_main.cfm

3. Results

The study involved 8781 children aged 6–59 months with a mean age of 32.4 (SD ± 15.5) months, with most of the children aged 36 months or more. Males and females were approximately equally represented in a ratio of 1:1. In all, mosquito bed net use over the previous night was below average in all the surveys (Supplementary Table 1). Among the children, the pooled malaria infection (either by RDT or blood smear) ranged from 25.8%(22.3–29.7) in 2019 GMIS to 40.6%(37.0–44.2) in 2014 GDHS. Between the exposure groups, the analysis showed that in all the survey years, malaria infection was significantly high among children who used mosquito bed net the previous night in all malaria tests (p-value<0.05). Over period, thus 2014, 2016 and 2019, the prevalence was 45.5%(95% CI = 41.1–50.0), 34.9%(95%CI = 29.4–40.7) and 31.6%(95%CI = 27.4–36.2) respectively among those who use bed net compared with 36.7%(32.4–41.2), 29.1%(25.1–33.5) and 20.1(16.8–24.8) among those who did not (Table 1).

Generally, malaria prevalence among the children showed a significant reduction rate over the years studied (14.0%). The pooled MI growth rate among those who use mosquito bed net the previous night and those who did were 11.4% and 18.2% respectively. The reduction rate was high for blood smear malaria infection (Table 2).

Percentage change in malaria prevalence showed that in all the change points, a significant reduction was observed (p-value<0.05). Meanwhile, the change as observed in 2016 and 2019 GMIS among children who slept under mosquito bed net use the previous night showed insignificant statistical change (p-value>0.05). In addition, the blood smear malaria infection change between 2014 GDHS and 2016 GMIS showed no significant change among those who did not use mosquito bed net (p-value>0.05) (Table 3).

As presented in Table 4 and 5, in all the survey years, it was observed that malaria infection was relatively high among children who slept in mosquito bed net the pervious night.

Table 1
Prevalence of positive malaria test by rapid diagnostic test and microscopy by mosquito bed net use among children under 5 in Ghana, evidence from GDHS and GMIS.

Type of test and Year	Overall	Mosquito bed net use		Roa-Scott Test of equality
		No	Yes	Test, p-value
	Prevalence[95%CI]	Prevalence[95%CI]	Prevalence[95%CI]	
RDT				
2014 GDHS	36.3[32.8–40.0]	32.4[28.2–37.0]	41.3[36.9–45.9]	10.31, 0.001
2016 MIS	27.9[23.6–32.6]	25.0[21.1–29.4]	30.9[25.3–37.2]	5.28, 0.022
2019 MIS	23.0[19.5–26.8]	18.6[15.1–22.7]	27.7[23.6–32.3]	16.61, <0.001
Microscopy				
2014 GDHS	26.7[23.8–29.9]	24.0[20.5–27.8]	30.3[26.6–34.3]	7.49, 0.006
2016 MIS	20.6[17.4–24.4]	20.0[16.5–24.2]	21.3[17.3–25.9]	0.34, 0.560
2019 MIS	14.1[11.9–16.9]	11.6[8.9–15.0]	16.9[13.9–20.3]	6.79, 0.009
Pooled				
2014 GDHS	40.6[37.0–44.2]	36.7[32.4–41.2]	45.5[41.1–50.0]	10.53, 0.001
2016 MIS	31.9[27.7–36.4]	29.1[25.1–33.5]	34.9[29.4–40.7]	5.06, 0.025
2019 MIS	25.8[22.3–29.7]	20.1[16.8–24.8]	31.6[27.4–36.2]	22.15, <0.001

NOTE: Abbreviation; RDT = Rapid Diagnostic Test, GDHS = Ghana Demographic Health Survey; GMIS = Ghana Malaria Indicator Survey.

Table 2
Growth rate of malaria infection by mosquito bed net use among children under 5 in Ghana, evidence from GDHS and MIS.

Exposure	RDT	Microscopy	Pooled
Mosquito bed net use			
Overall	(14.1%)	(19.2%)	(14.0%)
No	(17.8%)	(21.5%)	(18.2%)
Yes	(12.5%)	(17.7%)	(11.4%)

NOTE: Abbreviation; RDT = Rapid Diagnostic Test. () means a reduction rate.

Table 3
Percentage change in the prevalence of malaria diagnosed rapid diagnostic test and microscopy by mosquito bednet use among children under 5 in Ghana, evidence from GDHS and GMIS.

Malaria test	Exposure	2014 GDHS-2016 MIS	2015 GDHS-2019 MIS	2016 MIS-2019 MIS
		% Δ[95%CI]	%Δ[95%CI]	%Δ[95%CI]
RDT	Mosquito bed net use			
	No	−7.29[−13.70 to −0.89]*	−13.71[−19.81 to −7.62]***	−6.41[−11.40 to −1.43]*
	Yes	−10.24[−17.96 to −2.52]**	−13.65[−19.86 to −7.07]***	−3.22[−10.00 to 3.56]
	Overall	−8.47[−14.61 to −2.35]**	−13.38[−18.72 to −8.04]***	−4.90[−9.93 to 1.23]
Microscopy	Mosquito bed net use			
	No	−3.82[−9.28 to 1.64]	−12.20[−17.15 to −7.26]***	−8.38[−12.90 to −3.86]***
	Yes	−8.89[−14.86 to −2.91]**	−13.24[−18.37 to −8.12]***	−4.36[−9.26 to 0.54]
	Overall	−6.10[−10.95 to −1.25]***	−12.57[−16.70 to 8.45]***	−6.47[−10.21 to −2.74]***
Pooled	Mosquito bed net use			
	No	−7.49[−13.97 to 10.01]*	−16.07[−22.35 to −9.79]***	−8.58[−13.79 to −3.70]***
	Yes	−10.45[−17.97 to −2.87]**	−13.67[−20.13 to −7.22]***	−3.26[−9.83 to 3.32]
	Overall	−8.68[−14.79 to −2.57]**	−14.72[−20.21 to −9.22]***	−6.04[−11.03 to −1.05]**

NOTE: Abbreviation; RDT = Rapid Diagnostic Test, GDHS = Ghana Demographic Health Survey; GMIS = Ghana Malaria Indicator Survey, CI=Confidence Interval. %Δ symbolized percentage change. P-value: *p-value<0.05, ***p*-value<0.001, ***p-value<0.001.

4. Discussion

Malaria continues to be a major cause of illness and death in Ghana, especially for children under 5 years (USAID, 2022). Generally, malaria prevalence among the children showed a significant reduction rate over the years studied. This evidence could be attributed to some notable malaria prevention strategies in Ghana including; larval control, reducing man-vector contact with the use of ITNs, and adult mosquito control including indoor residual spray (WHO, 2022).

4.1. Impact of mosquito bed net use on malaria infection among children under 5 in Ghana

This study assessed the impact of WHO strategies for the elimination of malaria by enhancing and optimizing vector control. The core objective was to deploy LLINs/ITNs as a vector control intervention to eliminate malaria (Pryce et al., 2018; World Health Organization, 2021). Interestingly, the results of this study showed that within the different survey years studied, the use of mosquito bed nets among children aged 6–59 months falls below average even though the coverage of bed nets distribution in Ghana is very high and keeps increasing (Ghana Statistical Service (GSS), and and ICF, 2020; Ghana Statistical Service (GSS), Ghana Health Service (GHS), and

Table 4
Association between mosquito bednet use and malaria positive test among children under 5 in Ghana, evidence from GDHS and MIS.

Malaria test	Exposure	2014 GDHS	2016 MIS	2019 MIS
		aPR[95%CI]	aPR[95%CI]	aPR[95%CI]
RDT	Mosquito bed net use			
	No	ref	ref	ref
	Yes	1.24[1.09–1.41]***	1.14[0.99–1.31]	1.44[1.17–1.76]**
Microscopy	Mosquito bed net use			
	No	ref	ref	ref
	Yes	1.23[1.05–1.43]**	0.99[0.84–1.17]	1.41[1.05–1.88]*
Pooled	Mosquito bed net use			
	No	ref	ref	ref
	Yes	1.21[1.08–1.35]***	1.13[1.01–1.28]*	1.50[1.20–1.75]***

NOTE: Abbreviation; RDT = Rapid Diagnostic Test, GDHS = Ghana Demographic Health Survey; MIS = Malaria Indicator Survey, CI=Confidence Interval, ref. = Reference category used for inference. %Δ symbolized percentage change. *P*-value: *p-value<0.05, ***p*-value<0.001, ****p*-value<0.001.

Table 5
Influence of mosquito bednet use on rapid diagnostic and microscopy malaria positive among children under 5 in Ghana, evidence from GDHS and MIS.

Malaria test	Exposure	2014 GDHS	2016 MIS	2019 MIS
		ATE[95%CI]	ATE[95%CI]	ATE[95%CI]
	Mosquito bed net use			
RDT	No	ref	ref	ref
	Yes	0.08[0.03 to 0.12]***	0.0[−0.02 to 0.06]	0.04[−0.01 to 0.07]
	Mosquito bed net use			
Microscopy	No	ref	ref	ref
	Yes	0.05[0.01 to 0.09]**	0.01[−0.02 to 0.05]	0.03[0.003 to 0.06]*
	Mosquito bed net use			
Pooled	No	ref	ref	ref
	Yes	0.08[0.04 to 0.12]***	0.04[0.003 to 0.08]*	0.07[0.03 to 0.11]***

NOTE: Abbreviation; RDT = Rapid Diagnostic Test, GDHS = Ghana Demographic Health Survey; MIS = Malaria Indicator Survey, CI=Confidence Interval, ref. = Reference category used for inference. %Δ symbolized percentage change. *P*-value: *p-value<0.05, **p-value<0.001, ****p*-value<0.001.

ICF International, 2015). In addition, ITNs/LLINs are core interventions for lowering human mosquito biting rates and vector survival. It provides high protection against Anopheles mosquito bites by controlling vector mosquitoes, thus reducing transmission and the risk of MI (Pryce et al., 2018; World Health Organization, 2021).

A possible explanation could be that in Africa, the acceptability and utilization of LLINs/ITNs are inextricably linked to culturally accepted sleeping behaviours, with gender playing a key role as stated by WHO (WHO, 2007). It is normal for a mother to sleep with their young children and are therefore protected by her bed net if she has one. If a household has one bed net, the male head of the household may be given the preference to use the bed net because males are frequently the principal breadwinners in their families (WHO, 2007). This finding suggests that the Ghana Malaria Control programme should not only focus on the distribution of LLINs/ITNs, but the practice awareness should be keen to achieve malaria reduction rate in Ghana.

Further analysis showed that malaria infection was relatively high among children who slept in mosquito bed net the pervious night. The malaria reduction rate from 2014 GDHS to 2019 GMIS was highly significant among those who did not use mosquito bed nets rate among children aged 6–59 months in Ghana. This counter intuitive observation may have many potential explanations including; residing in malaria prone areas, and environment where the risk of infection is high, and that households in these areas may be more likely to use ITN compared to areas with low risk. Another potential explanation could be that MI among the children occurred before the use of bed nets since children especially those in rural areas and low socioeconomic/slum communities mostly stayed outside late at night (mostly from 18.00 to 23.00 h) socializing, night schooling, household chores, and small-scale economic activities (Monroe et al., 2015). In addition, most Ghanaian households are overcrowded and that a child would only be put under a mosquito bed net if a child showed any symptoms of malaria (Adjei and Gyimah, 2012). It has been suggested that mosquito bed net is mostly used as a treatment regimen in Ghana rather than as a preventive mechanism (Afoakwah et al., 2018). Furthermore, many buildings in Ghana have poorly built ventilation systems (Awuku and Wang, 2020), and that heat and lack of airflow in the sleeping space are associated with inconsistent ITN use among Ghanaians (Ahorlu et al., 2019). These factors lead to inconsistent use of mosquito bed net which predispose children to malaria infection. A research conducted by Lim and colleagues found that sleeping under mosquito bed net was significantly associated with a relative reduction in malaria parasitemia (Lim et al., 2011). In recent times, Siri also found that children who slept under insecticide-treated bed nets the previous night were 20% less likely to experience malaria infection (Siri, 2014). Thus, national effort should continue to provide ITNs and it's proper usage in high risk areas.

4.2. *Implication for public health practice*

The main lesson from this analysis is that, the key question from respondents in these surveys, "whether they used the ITNs the previous night", though may provide a useful gauge to population level usage of ITNs, has limitations. The indoor and outdoor behaviours, sleeping patterns, consistency of use and when families initiate the use of ITNs may need to be given important consideration, and that findings from such surveys should be interpreted in a more nuanced normative forms than just the positive assessment of the responses.

4.3. *Limitation*

The study observed a relatively higher prevalence of MI among children aged 6–59 months who used ITN the previous night. The study however did not consider the location/living areas of these children. Again, because of the cross-sectional design nature of GDHS and GMIS, the current finding does not allow for causal inferences. Impact evaluation analysis was adopted to address such limitations, a propensity score matching which allows for the construction of an artificial control group by matching children who slept under a bed net the previous night and those without with similar characteristics. In addition, due to the study participants involved, bed net use was assessed only among children which could have either been both mother and child. It has been suggested that mother and child use of bed net better explained malaria infection compared to when the child alone uses the net (Afoakwah et al., 2018).

5. Conclusion

Even though malaria infection prevalence among children aged 6–59 months is decreasing, the reduction rate seems not to be directly linked with the distribution of mosquito bed nets in Ghana. For a continued distribution of mosquito bed nets, and for Ghana to achieve her *Malaria Strategic Plan (NMSP) 2021–2025,* program managers should ensure effective use of the distributed nets in addition to other preventive measures and nuanced consideration of community behaviours among bed net users in Ghana (Abuaku et al., 2018; Coleman et al., 2021; Gogue et al., 2020; Hoke, 2015; Suuron et al., 2020) and Africa at large (Hamusse et al., 2012; Zhou et al., 2010; Zinszer et al., 2020). The effective use and care of bed nets should be emphasized as part of the distribution.

Author contributions

JT conceptualized the study and sought approval for access to the DHS data and undertook the statistical analysis. JT drafted the initial manuscript. EY, VB and AEY read and provided intellectual content revisions and suggestions. All authors read and approved the final review manuscript.

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Declaration of Competing Interest

The authors declared no potential conflicts of interest.

Data availability

The dataset used to support the findings of this study is available upon request through from DHS https://dhsprogram.com/data/dataset_admin/login_main.cfm

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.parepi.2023.e00302.

References

Abeku, T.A., Helinski, M.E., Kirby, M.J., Kefyalew, T., Awano, T., Batisso, E., Tesfaye, G., Ssekitooleko, J., Nicholas, S., Erdmanis, L., 2015. Monitoring changes in malaria epidemiology and effectiveness of interventions in Ethiopia and Uganda: beyond Garki project baseline survey. Malar. J. 14 (1), 1–15.

Abossie, A., Yohanes, T., Nedu, A., Tafesse, W., Damitie, M., 2020. <p>prevalence of malaria and associated risk factors among febrile children under five years: a cross-sectional study in Arba Minch Zuria District, South Ethiopia</p>. Infect. Drug Resist. 13, 363–372. https://doi.org/10.2147/IDR.S223873.

Abuaku, B., Ahorlu, C., Psychas, P., Ricks, P., Oppong, S., Mensah, S.K., Sackey, W., Koram, K., 2018. Impact of indoor residual spraying on malaria parasitaemia in the Bunkpurugu-Yunyoo District in northern Ghana. Parasit. Vectors. https://doi.org/10.1186/s13071-018-3130-z.

Adjei, J.K., Gyimah, S.O., 2012. Household bednet ownership and use in Ghana: implications for malaria control. Can. Stud. Popul. [Arch.] 39 (1–2), 1–2. https://doi.org/10.25336/P6ZS44.

Afoakwah, C., Deng, X., Onur, I., 2018. Malaria infection among children under-five: the use of large-scale interventions in Ghana. BMC Public Health 18 (1), 1. https://doi.org/10.1186/s12889-018-5428-3.

Ahorlu, C.S., Adongo, P., Koenker, H., Zigirumugabe, S., Sika-Bright, S., Koka, E., Tabong, P.T.-N., Piccinini, D., Segbaya, S., Olapeju, B., Monroe, A., 2019. Understanding the gap between access and use: a qualitative study on barriers and facilitators to insecticide-treated net use in Ghana. Malar. J. 18 (1), 417. https://doi.org/10.1186/s12936-019-3051-0.

Awuku, S.K., Wang, D., 2020. The effects of structural design on ventilation of buildings in Ghana and its effect on transmission of infectious diseases. *Open access*. Libr. J. 7 (10), 10. https://doi.org/10.4236/oalib.1106842.

Bawuah, A., Ampaw, S., 2021. Ownership and use of insecticide-treated nets under Ghana's National Malaria Control Program: what are the correlates? Trop. Med. Int. Health: TM & IH. https://doi.org/10.1111/tmi.13689.

Beavogui, A.H., Delamou, A., Camara, B.S., Camara, D., Kourouma, K., Camara, R., Sagara, I., Lama, E.K., Djimde, A., 2020. Prevalence of malaria and factors associated with infection in children aged 6 months to 9 years in Guinea: results from a national cross-sectional study. Parasite Epidemiol. Control 11, e00162. https://doi.org/10.1016/j.parepi.2020.e00162.

Coleman, S., Yihdego, Y., Sherrard-Smith, E., Thomas, C.S., Dengela, D., Oxborough, R.M., Dadzie, S.K., Boakye, D., Gyamfi, F., Obiri-Danso, K., Johns, B., Siems, L.V., Lucas, B., Tongren, J.E., Zigirumugabe, S., Dery, D., Fornadel, C., George, K., Belemvire, A., Seyoum, A., 2021. Partial indoor residual spraying with pirimiphos-methyl as an effective and cost-saving measure for the control of Anopheles gambiae s.l. in northern Ghana. Sci. Rep. 11 (1), 18055. https://doi.org/10.1038/s41598-021-97138-1.

Coulibaly, D., Guindo, B., Niangaly, A., Maiga, F., Konate, S., Kodio, A., Diallo, A., Antar, A.T.M., Kone, A.K., Traore, K., Travassos, M.A., Sagara, I., Doumbo, O.K., Thera, M.A., 2021. A decline and age shift in malaria incidence in rural Mali following implementation of seasonal malaria chemoprevention and indoor residual spraying. Am. J. Trop. Med. Hyg. 104 (4), 1342–1347. https://doi.org/10.4269/ajtmh.20-0622.

Dalaba, M.A., Welaga, P., Dalinjong, P.A., Chatio, S., Immurana, M., Alhassan, R.K., Klu, D., Manyeh, A.K., Agorinya, I., Oduro, A., Adongo, P.B., Akweongo, P., 2021. Health-seeking behaviour and cost of fever treatment to households in a malaria-endemic setting of northern Ghana: a cross-sectional study. BMJ Open 11 (9), e052224. https://doi.org/10.1136/bmjopen-2021-052224.

Eckert, E., Florey, L.S., Tongren, J.E., Salgado, S.R., Rukundo, A., Habimana, J.P., Hakizimana, E., Munguti, K., Umulisa, N., Mulindahabi, M., Karema, C., 2017. Impact evaluation of malaria control interventions on morbidity and all-cause child mortality in Rwanda, 2000–2010. Am. J. Trop. Med. Hyg. 97 (3 Suppl), 99–110. https://doi.org/10.4269/ajtmh.17-0281.

Ghana Statistical Service (GSS), & and ICF, 2020. Ghana Malaria Indicator Survey 2019. GSS and ICF.

Ghana Statistical Service (GSS), Ghana Health Service (GHS), & ICF International, 2015. Ghana Demographic and Health Survey 2014. GSS, GHS, and ICF International.

Gogue, C., Wagman, J., Tynuv, K., Saibu, A., Yihdego, Y., Malm, K., Mohamed, W., Akplu, W., Tagoe, T., Ofosu, A., Williams, I., Asiedu, S., Richardson, J., Fornadel, C., Slutsker, L., Robertson, M., 2020. An observational analysis of the impact of indoor residual spraying in northern, upper east, and upper west regions of Ghana: 2014 through 2017. Malar. J. 19 (1), 242. https://doi.org/10.1186/s12936-020-03318-1.

Hamusse, S., Balcha, TayeT, Belachew, T., 2012. The impact of indoor residual spraying on malaria incidence in east Shoa zone, Ethiopia. Glob. Health Action 5 (1), 11619. https://doi.org/10.3402/gha.v5i0.11619.

Hoke, J., 2015, August 4. President's Malaria Initiative Indoor Residual Spraying in Bunkpurugu Yunyoo Distict. PMI, Northern Region of Ghana. https://www.pmi.gov/presidents-malaria-initiative-indoor-residual-spraying-in-bunkpurugu-yunyoo-distict-northern-region-of-ghana/.

Kanmiki, E.W., Awoonor-Williams, J.K., Phillips, J.F., Kachur, S.P., Achana, S.F., Akazili, J., Bawah, A.A., 2019. Socio-economic and demographic disparities in ownership and use of insecticide-treated bed nets for preventing malaria among rural reproductive-aged women in northern Ghana. PLoS One 14 (1), e0211365. https://doi.org/10.1371/journal.pone.0211365.

Konlan, D.K., Japiong, M., Dodam Konlan, K., Afaya, A., Salia, S.M., Kombat, J.M., 2019. Utilization of insecticide treated bed nets (ITNs) among caregivers of children under five years in the ho municipality. Interdiscip. Perspect. Infect. Dis. 2019, e3693450 https://doi.org/10.1155/2019/3693450.

Lim, S.S., Fullman, N., Stokes, A., Ravishankar, N., Masiye, F., Murray, C.J.L., Gakidou, E., 2011. Net benefits: a multicountry analysis of observational data examining associations between insecticide-treated mosquito nets and health outcomes. PLoS Med. 8 (9), e1001091 https://doi.org/10.1371/journal.pmed.1001091.

Mensah, E.A., Anto, F., 2020. Individual and community factors associated with household insecticide-treated Bednet usage in the Sunyani West District of Ghana two years after mass distribution. J. Environ. Public Health 2020, e7054383. https://doi.org/10.1155/2020/7054383.

Monroe, A., Asamoah, O., Lam, Y., Koenker, H., Psychas, P., Lynch, M., Ricotta, E., Hornston, S., Berman, A., Harvey, S.A., 2015. Outdoor-sleeping and other night-time activities in northern Ghana: implications for residual transmission and malaria prevention. Malar. J. 14 (1), 35. https://doi.org/10.1186/s12936-015-0543-4.

Morakinyo, O.M., Balogun, F.M., Fagbamigbe, A.F., 2018. Housing type and risk of malaria among under-five children in Nigeria: evidence from the malaria indicator survey. Malar. J. 17 (1), 311. https://doi.org/10.1186/s12936-018-2463-6.

Pryce, J., Richardson, M., Lengeler, C., 2018. Insecticide-treated nets for preventing malaria. Cochrane Database Syst. Rev. 11.

Shayo, F.K., Nakamura, K., Al-Sobaihi, S., Seino, K., 2021. Is the source of domestic water associated with the risk of malaria infection? Spatial variability and a mixed-effects multilevel analysis. Int. J. Infect. Dis. 104, 224–231. https://doi.org/10.1016/j.ijid.2020.12.062.

Shretta, R., Silal, S.P., Malm, K., Mohammed, W., Narh, J., Piccinini, D., Bertram, K., Rockwood, J., Lynch, M., 2020. Estimating the risk of declining funding for malaria in Ghana: the case for continued investment in the malaria response. Malar. J. 19 (1), 196. https://doi.org/10.1186/s12936-020-03267-9.

Siri, J., 2014. Independent associations of maternal education and household wealth with malaria risk in children. Ecol. Soc. 19 (1) https://doi.org/10.5751/ES-06134-190133.

Suuron, V.M., Mwanri, L., Tsourtos, G., Owusu-Addo, E., 2020. An exploratory study of the acceptability of indoor residual spraying for malaria control in upper western Ghana. BMC Public Health 20 (1), 1–11.

Tusting, L.S., Rek, J.C., Arinaitwe, E., Staedke, S.G., Kamya, M.R., Bottomley, C., Johnston, D., Lines, J., Dorsey, G., Lindsay, S.W., 2016. Measuring socioeconomic inequalities in relation to malaria risk: a comparison of metrics in rural Uganda. Am. J. Trop. Med. Hyg. 94 (3), 650–658. https://doi.org/10.4269/ajtmh.15-0554.

USAID, 2022. U.S. President's Malaria Initiative Ghana Malaria Operational Plan FY 2022. Retrieved from. www.pmi.gov.

WHO, 2007. Gender, Health and Malaria. World Health Organization. https://www.who.int/gender/documents/gender_health_malaria.pdf.

WHO, 2021, October 28. Fact Sheet About Malaria. https://www.who.int/news-room/fact-sheets/detail/malaria.

WHO, 2022, January 1. Private sector support key in achieving Zero Malaria in Ghana. WHO, Regional Office for Africa. https://www.afro.who.int/news/private-sector-support-key-achieving-zero-malaria-ghana.

World Health Organization, 2021. Insecticide-Treated Nets for Malaria Transmission Control in Areas with Insecticide-Resistant Mosquito Populations: Preferred Product Characteristics. World Health Organization. https://apps.who.int/iris/handle/10665/339542.

Yang, D., He, Y., Wu, B., Deng, Y., Li, M., Yang, Q., Huang, L., Cao, Y., Liu, Y., 2020. Drinking water and sanitation conditions are associated with the risk of malaria among children under five years old in sub-Saharan Africa: a logistic regression model analysis of national survey data. J. Adv. Res. 21, 1–13. https://doi.org/10.1016/j.jare.2019.09.001.

Zhou, G., Githeko, A.K., Minakawa, N., Yan, G., 2010. Community-wide benefits of targeted indoor residual spray for malaria control in the Western Kenya Highland. Malar. J. 9 (1), 67. https://doi.org/10.1186/1475-2875-9-67.

Zinszer, K., Charland, K., Vahey, S., Jahagirdar, D., Rek, J.C., Arinaitwe, E., Nankabirwa, J., Morrison, K., Sadoine, M.L., Tutt-Guérette, M.-A., Staedke, S.G., Kamya, M.R., Greenhouse, B., Rodriguez-Barraquer, I., Dorsey, G., 2020. The impact of multiple rounds of indoor residual spraying on malaria incidence and hemoglobin levels in a high-transmission setting. J. Infect. Dis. 221 (2), 304–312. https://doi.org/10.1093/infdis/jiz453.