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RISK FACTORS INFLUENCING MALARIA INFECTION IN COMMUNITIES OF THE BONO REGION, GHANA: INDIVIDUAL AND ENVIRONMENTAL PERSPECTIVES

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Abstract

Malaria is a potentially fatal infectious disease caused by parasitic organisms transmitted to humans through the bites of mosquitoes carrying the infection. This study examined individual and environmental perspectives on the risk factors of malaria infection in Bono Region, Ghana. An analytical cross-sectional study design was used in this study. A structured questionnaire was used to collect data, and a data extraction form was used to collect malaria data from repositories of the Ghana Health Service, Bono Regional Health Directorate. Descriptive statistics, such as frequency distributions and percentages of variables in each objective, were performed, and an inferential analysis was performed using binary logistic regression to determine environmental factors associated with malaria infection or endemicity in communities in the Bono Region. Findings showed that there was a statistically significant association between the use of insecticide-treated nets rarely and the prevalence of malaria in the bivariate model (p=0.0001) (OR=17.70, 95% CI: 3.885-12.820). Participants who traveled to a malaria-endemic area in the last 3-6 months had a statistically significant association with prevalence of malaria in the bivariate model at (p=0.0001) (OR=382.08, 95% CI: 51.821-2817.203). Similarly, having control measures of breeding sites of mosquitoes was statistically significantly associated with prevalence of malaria in the bivariate model at (p=0.0001) (OR=8.049, 95% CI: 4.734-13.683). In the 2020–2024 period, malaria trends in Bono showed sharp fluctuations, with notable spikes in mid-year months,

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indicating the need for intensified interventions during those periods. Seasonal variation in malaria prevalence was evident, with peaks observed predominantly during the rainy and humid months, suggesting a strong link between climatic conditions and disease transmission. The persistence of malaria in Bono is largely driven by preventable environmental and behavioral risk factors. This study highlighted that the persistence of malaria in Bono Island is largely driven by preventable environmental and behavioral risk factors. Thus, it was recommended that healthcare workers should collaborate with community leaders to organize a health education programme that will focus on improving preventive measures against malaria in communities.

Introduction

Malaria remains a persistent public health challenge in Ghana, and its prevalence fluctuates in response to seasonal variations. In 2019, the disease affected approximately 25.8% of children aged 6–59 months (Tetteh et al., 2023). Malaria is responsible for more than 20,000 child fatalities annually (Aheto, 2022). According to the 2022 Ghana Demographic and Health Survey (DHS), the prevalence of malaria among children in this age group was 8.6% (Ozigbu et al., 2022), with incidence rates notably higher in rural areas (12.8%) compared with urban locations (4.3%) (Ozigbu et al., 2022). A recent study estimated the overall prevalence of malaria in the general population to be 20.9% (Tetteh et al., 2023). The same research highlighted a progressive increase in malaria rates, ranging from 6.7% to 55.4% throughout the months, largely influenced by seasonal fluctuations (Tetteh et al., 2023). Additionally, the rising prevalence of malaria has been linked to decreased productivity, increased poverty levels among affected populations, and a significant financial burden on families and the national economy (Aheto, 2022). Approximately 16% of the predicted national prevalence of malaria in Ghana (Aheto, 2022).

Findings showed that there are variations in the prevalence of malaria in different locations, ranging from (2.0%) in Accra to (4.4%) in the Western North and (6.4%) in Volta. According to the Ghana Statistical Service [GSS], 2023, a 15% prevalence of malaria in the Oti Region was recorded to be the highest based on the microscopy results, followed by 13.4% prevalence in the Upper West and 12.2% prevalence in the Upper East regions. Additionally, half of the 16 regions recorded a prevalence of malaria of >10% (Ghana Statistical Service [GSS], 2023). Malaria transmission in Africa is influenced by several factors, including the household economic index, maternal education, knowledge about malaria prevention, cultural practices, and proximity to swamps and forests (Dawaki et al., 2016). The disparity in malaria prevalence in Ghana has been linked to environmental and climatic factors, coverage of insecticide-treated nets (ITNs) (i.e., percentage of the population protected by ITNs), time of travel (time needed to reach a high-density urban center), aridity (ranging from most arid to most wet), enhanced vegetation (ranging from least vegetation to most vegetation), annual temperature (average temperature), and precipitation (average precipitation in a month) (Aheto, 2022). Findings showed that some of these factors influence the prevalence of malaria by affecting the growth and development of mosquitoes in the country (Aheto, 2022).

Human variables, including age, gender, pregnancy, blood type, and rhesus status, have also contributed to malaria's endemicity in Ghana (Awosolu et al., 2021). Malaria may also spread when needles and syringes are shared, blood is transfused between people, or organs are transplanted (Pierrotti et al., 2018). The adult parasites move through the circulatory system and begin infecting erythrocytes after a delay of many days. Within 48–72 hours of infection, the parasites within red blood cells grow, causing the infected cells to rupture (Bassey, 2017). Symptoms of malaria occur in cycles lasting 2–3 days due to the persistent infection of red blood cells by the parasites. People with malaria often experience high body temperature, chills, rigors, fever, chills, and flu-like illness (WHO, 2021). Most cases of severe malaria occur in children and may cause various symptoms, including severe anemia, respiratory distress, convulsions, hypoglycemia, and coma (Taylor et al., 2021). Severe cases of malaria are linked to minor developmental and cognitive abnormalities in children, even after the illness resolves. Another recognized consequence of malaria infections is anemia, which contributes significantly to morbidity and death in children younger than five years (Morakinyo et al., 2018).

Statement of the Problem

Despite several control measures, malaria mortality still occurs more frequently in African countries such as Ghana than in other developing countries (Dabbagh et al., 2017). The World Health Organization (WHO) established the Roll Back Malaria (RBM) Initiative to reduce the prevalence of malaria and associated deaths (World Health Organization [WHO], 2020). This approach is targeted toward the improvement of early diagnosis, effective antimalarial treatment, and the use of insecticide-treated nets (ITNs) in developing countries, including Ghana (Kanmiki et al., 2019). This is acknowledged by the World Health Organization as a success story that contributed to the decrease in the prevalence of malaria 15 years after the era of the Millennium Development Goals (MDGs) (Aheto, 2022). Sufficient efforts have been made to provide and distribute LLINs and ITNs to targeted populations. Additionally, control and preventive methods for reducing malaria-related morbidity and mortality involve presumptive treatment of fever with anti-malarial medications in children aged below 5 years in malaria-endemic regions such as Ghana (Birhanu et al., 2016). This approach is consistent with the World Health Organization (WHO) recommendations for malaria-stricken and low- and middle-income countries where diagnostic facilities are few (Nadeem & Bilal, 2023). Hence, understanding the prevalence and associated factors would help to devise measures to reduce the incidence of malaria in Bono (Aheto, 2022).

In Ghana, there are numerous national policies and interventions such as National Health Insurance, the 2014–2020 Ghana Strategic Plan for Malaria Control, Community-based Health Planning and Services (CHPS), and Child Health Policy 2007–2015 have been established to improve and promote the health of residents against cases of malaria (Sacks et al., 2022). Additionally, the 2014–2020 Ghana Strategic Plan for Malaria Control was established to improve preventive interventions, thereby decreasing the morbidity and mortality burden of malaria by 75% before the end of the year 2020 (Aheto, 2022). However, the prevalence and malaria-related deaths remain high in the country after the target year. A study conducted on mapping the risk of under-five children with malaria in Ghana reported high cases of malaria with a significant geographical difference in the risk (Aheto, 2022). Based on the literature review, there is a dearth of knowledge on the localized geospatial distribution of incidences of malaria and factors that influence malaria risk in Ghana. Similarly, the malaria burden remains persistent and requires high-quality surveillance data to guide malaria control policies and approaches. Therefore, this study aimed to fill these gaps by predicting and modeling the prevalence (communities at high risk of cases of malaria) and associated factors in the Bono region of Ghana.

Aim and Objectives of the Study

This study aimed to determine individual and environmental perspectives on the risk factors of malaria infection in communities in the Bono Region, Ghana. The objectives of this study are as follows:

1. To identify risk factors for malaria infection among residents of the Bono Region of Ghana.
2. To identify risk factors for malaria infection in communities in the Bono Region of Ghana.
3. To determine individual-level factors associated with malaria infection among residents of the Bono Region of Ghana.
4. To determine environmental factors associated with malaria infection in communities in the Bono Region of Ghana.

Research Questions

The following research questions were used to guide this study:

1. Risk factors for malaria infection among residents of the Bono Region of Ghana
2. Risk factors for malaria infection in communities in the Bono Region of Ghana
3. Individual-level factors associated with malaria infection among residents of the Bono Region of Ghana
4. What environmental factors are associated with malaria infection in communities in the Bono Region of Ghana?

Hypotheses

The following four research questions were developed to guide this study:

1. H_0**:** There are no individual-level factors significantly associated with malaria infection among residents in the Bono Region of Ghana.
2. H_0: There are no significant environmental factors associated with malaria infection in the Bono Region of Ghana.
3. H_A: Individual-level factors significantly associated with malaria infection among residents in the Bono Region of Ghana.
4. H_A: Environmental factors significantly associated with malaria infection in communities in the Bono Region of Ghana.

The significance of the Study

This study will be of immense benefit to the following areas:

1. **Improved Public Health Strategies**: By identifying key individual and environmental risk factors, the study will help health authorities in Bono Region, Ghana, develop targeted malaria prevention and intervention programs in affected communities.

2. Enhanced Disease Control Measures: Understanding the factors contributing to malaria infection in the study area will lead to improved vector control strategies, such as better sanitation, insecticide-treated bed nets, and community-based health initiatives.

3. Policy Development and Implementation–Findings from the study will inform policymakers in Bono Region, Ghana, to create evidence-based guidelines that address both personal and environmental risks, leading to stronger malaria control policies.

4. Community awareness and engagement: This study will help raise awareness among residents of Bono Region, Ghana, about the behaviors and environmental conditions that increase malaria risk, encouraging proactive measures to reduce infection rates.

Materials and Methods

This study adopted an analytical cross-sectional design to determine the trend of malaria infection, as well as individual-level factors associated with malaria infection and environmental factors associated with malaria infection in communities in the Bono region of Ghana. The study was conducted in the Bono Region of Ghana. The study population comprised all residents of Bono, Ghana. The study was conducted using malaria data collected from all individuals of different ages, that is, all available records from the 2019 Demographic Health Survey. This study used data from the 2019 GMIS of the DHS program (Aheto, 2022). The first 2019 GMIS is the second phase of the survey after the first phase was conducted in 2016 and offers estimates of population-based malaria indicators as a complement to the regular administrative data obtained in the country used for strategic planning and evaluation of the Ghana Malaria Control Programme (Ghana Statistical Service GSS, National Malaria Control Programme, National Public Health Reference Laboratory, ICF, 2020). Individuals aged 18 years and above and residents of the Bono Region of Ghana were included in the study, whereas the critically ill were excluded. A sample of 664 participants was recruited for this study. A multi-stage sampling method was employed, and the sample size was obtained using the descriptive studies' sample size determination formula by Cochran. The instrument for data collection was a structured questionnaire that was pre-tested in the Bono East Region (BER) among randomly selected residents. The questionnaire consisted of both open-ended and closed-ended questions written in English. The questionnaire was adapted from Kawaguchi et al. (2022). Primary data were collected from the participants who participated in this study. Data were collected using a structured questionnaire over eight weeks. Four research assistants were recruited and trained for a total of seven working days. The training was based on the objectives of the study, the administration of the questionnaire, and how to respond to questions from the participants. The aim of the study was explained to the eligible participants during data collection, and a questionnaire was administered. Secondary data were extracted from the records of the Ghana Health Service Bono Regional Health Directorate repositories. This was performed by completing the DHS form following the instructions provided for data extraction. Data were extracted from the demographic health survey spreadsheet and then exported to the Statistical Package for Social Sciences (SPSS) version 25. Data collected was analysed using the Statistical Package for Social Sciences (SPSS) version 25. Descriptive statistics of frequency distributions and percentages of variables were used to answer research questions, while further analysis was done using Autoregressive Integrated Moving Average (ARIMA) modelling.

Results and Findings

Table 1: Socio-demographic characteristics of participants with malaria infection in the Bono Region of Ghana

Parameter	Response Category	Odds Ratio	p-value	95% C.I. of Odds Ratios Lower	Upper
Sex	Male	ref	**0.011***		
	Female	0.301		0.120	0.758
Age	20-29	ref			
	30-39	1.000	1.000	0.212	4.709
	40-49	0.417	0.228	0.100	1.732
	≥50	0.467	0.296	0.112	1.945
Education	No formal education	ref			
	Primary education	190056051.786	0.996	0.000	.
	Secondary education	55706084.144	0.996	0.000	.
	Tertiary education (university, polytechnic, etc.)	2277237873.506	0.995	0.000	.
Occupation	Business (trading)	ref			
	Unskilled (eg. farming)	0.057	**0.0001***	0.026	0.127
	Skilled (eg. mechanic, tailoring)	0.044	**0.0001***	0.021	0.091
	Professional (eg. doctor)	0.279	**0.0001***	0.143	0.544
Under-five age	Yes	ref			
	No	0.704	0.335	0.344	1.437
Being pregnant	Yes	ref			
	No	0.450	**0.001***	0.245	0.828

(P≤0.05 = statistically significant); (ref=reference)

Table 1 shows that covariates, sex of the participants, were statistically significantly associated with the prevalence of malaria in the bivariate model (p=0.011) (OR=0.301, 95% CI: 0.120-0.758). Occupational status was statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.0001) (OR=0.057, 95% CI: 0.026-0.127). The results showed that females were more susceptible to malaria than males. In addition, being pregnant was statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.001) (OR=0.450, 95% CI: 0.245-0.828). However, the age of the participants did not show a statistically significant association with the prevalence of malaria in the bivariate model. The level of completed education of the participants did not show a statistically significant association with the prevalence of malaria in the bivariate model. No statistically significant association was observed between age under 5 years and the prevalence of malaria in the bivariate model (p=0.335).

Table 2: Social lifestyle associated with the prevalence of malaria among the participants

Parameter	Response Category	Odds Ratio	p-value	95% C.I. of Odds Ratios	
				Lower	**Upper**
Consume alcohol	Yes	ref			
	No	0.554	**0.029***	0.326	0.942
Ever being drunk?	Yes	ref			
	No	0.000	0.998	0.00	-
Consume tobacco	Yes	ref			
	No	0.060	**0.001***	0.018	0.195
Ever being under the influence of tobacco	Yes	ref			
	No	0.755	0.822	0.065	8.789

(P≤0.05 = statistically significant); (ref=reference)

Table 2 shows that consumption of alcohol had a statistically significant association with prevalence of malaria in the bivariate model (p=0.029) (OR=0.554, 95% CI: 0.326-0.942). The table reveals that tobacco consumption had a statistically significant association with the prevalence of malaria in the bivariate model at (p=0.001) (OR=0.554, 95% CI: 0.326-0.942). Ever being drunk had no statistically significant association with malaria prevalence in the bivariate model, and ever being under the influence of tobacco did not have a statistically significant association with malaria prevalence in the bivariate model.

Table 3 Behavioral risk factors associated with malaria infection among the participants

Parameter	Response Category	Odds Ratio	p-value	95% C.I. of Odds Ratios	
				Lower	**Upper**
Use of ITN	Yes	ref	**0.0001***		
	No	17.700		1.360	3.841
How often do you use ITN?	Every night	ref			
	Sometimes	0.000	0.998	0.000	-
	Rarely	7.057	**0.0001***	3.885	12.820
	Never	.000	0.997	0.000	-
Other methods for mosquito control (e.g., coils, sprays, repellents)	Yes	ref			
	No	0.000	0.999	0.000	-
Staying outside in evening or night hours (e.g., 6 pm–6 am)	Yes	ref			
	No	0.862	0.142	0.707	1.051
Traveled to a malaria-endemic area within the last 3-6 months	Yes	ref			
	No	382.085	**0.0001***	51.821	2817.203
Access to health care facility for treatment of malaria	Yes	ref			
	No	0.731	0.464	0.315	1.693
Control measures at breeding sites of mosquitoes	Yes	ref			
	No	8.049	**0.0001***	4.734	13.683

(P≤0.05 = statistically significant); (ref=reference)

Table 3 shows that the covariates of the use of insecticide-treated nets by the participants were statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.0001) (OR=17.7, 95% CI: 1.360-3.841). The results showed that there was a statistically significant association between the use of insecticide-treated nets rarely and the prevalence of malaria in the bivariate model (p=0.0001**)** (OR=17.70, 95% CI: 3.885-12.820). Participants who traveled to a malaria-endemic area in the last 3-6 months had a statistically significant association with prevalence of malaria in the bivariate model (p=0.0001) (OR=382.08, 95% CI: 51.821-2817.203). Similarly, having control measures of breeding sites of mosquitoes was statistically significantly associated with prevalence of malaria in the bivariate model at (p=0.0001) (OR=8.049, 95% CI: 4.734-13.683)**.** This indicates that participants who rarely use insecticide-treated nets have malaria than others. The results showed that use of other methods for mosquito control (e.g., coils, sprays, repellents etc) by the participants did not show statistically significant association with prevalence of malaria in the bivariate model at (p=0.999). Also, staying outside during evening or night hours (e.g., 6 pm–6 am) by the participants had no statistically significant association with prevalence of malaria in the bivariate model at (p=0.999). This implies that participants who traveled to a malaria-endemic area in the last 3-6 months had more chances of having malaria than others. The result showed that having access to a health care facility for treatment of malaria had no statistically significant association with prevalence of malaria in the bivariate model (p=0.464).

Table 4: Environmental risk factors associated with malaria infection among the participants

Parameter	**Response Category**	**Odds Ratio**	**p-value**	**95% C.I. of Odds Ratios Lower**	**Upper**
Have bushes around the houses.	Yes	ref	**0.002***		
	No	2.286		1.360	3.841
The presence of stagnant water around homes	Yes	ref			
	No	0.239	**0.0001***	0.149	0.382
Slow-flowing water nearby	Yes	ref			
	No	3.405	**0.0001***	2.011	5.764
Presence of gutters close to houses	Yes	ref			
	No	0.057	**0.0001***	0.026	0.127
Open water storage tank (left)	Yes	ref			
	No	2.672	**0.0001**	1.703	4.191
Poor drainage	Yes	ref			
	No	1.148	0.566	0.717	1.836
Heavy rainfall	Yes	ref			
	No	1.130	0.644	0.674	1.894
A long humid period	Yes	ref			
	No	0.388	**0.007***	0.194	0.775

(P≤0.05 = statistically significant (*); (ref=reference)

Table 4 shows that the covariates of having bushes around the houses were statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.002) (OR 2.286, 95% CI: 1.360-3.841). The results showed a statistically significant association between the presence of stagnant water around the homes and the prevalence of malaria in the bivariate model (p=0.0001) (OR 0.239, 95% CI: 0.149-0.382). The result showed that having slow-flowing water nearby homes was statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.001) (OR 3.405, 95% CI: 2.011-5.764). The presence of gutters close to houses had a statistically significant association with the prevalence of malaria in the bivariate model at (p=0.0001) (OR 0.057, 95% CI: 0.026-0.127). Participants in the open water storage tanks had a statistically significant association with the prevalence of malaria in the bivariate model at (p= 0.0001) (OR 2.672, 95% CI: 1.703-4.191). The result showed that a long humid period had a statistically significant association with the prevalence of malaria in the bivariate model at (p=0.007) (OR 0.388, 95% CI: 0.194-0.775). The results indicated that poor drainage around the surroundings had no statistically significant association with the prevalence of malaria in the bivariate model (p=0.566). The table reveals that heavy rainfall did not have a statistically significant association with the prevalence of malaria in the bivariate model (p=0.644).

Table 4. Housing-related risk factors associated with malaria infection among the participants

Parameter	Response Category	Odds Ratio	p-value	95% C.I. of Odds Ratios Lower	Upper
Poorly built houses	Yes	ref	**0.0001**		
	No	2.441		1.562	3.816
Open houses	Yes	ref			
	No	0.417	**0.0001**	0.256	0.678
Broken walls	Yes	ref			
	No	0.773	**0.249**	0.499	1.198
Open windows/without nets	Yes	ref			
	No	2.470	**0.0001**	1.572	3.882

(P≤0.05 = statistically significant); (ref=reference)

Table 4 shows that covariates living in poorly built houses were statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.0001) (OR 2.441, 95% CI: 1.562-3.816). The results indicated that living in an open house was statistically significantly associated with the prevalence of malaria in the bivariate model (p=0.0001) (OR 0.417, 95% CI: 0.256-0.678). The result showed that having broken walls was not statistically significantly associated with the prevalence of malaria in the bivariate model at (p=0.249) Also, presence of open windows/windows without nets had a statistically significant association with the prevalence of malaria in the bivariate model at (p=0.0001) (OR 2.470, 95% CI: 1.572-3.882).

Discussion of Findings

Risk factors for malaria infection among residents in communities in Bono region of Ghana

The findings of this study revealed that the sex of the participants was significantly associated with the prevalence of malaria in the bivariate model. The result indicated that females were less susceptible to malaria than males), and age and educational level of the participants did not show statistically significant associations with the prevalence of malaria. This suggests that across all age groups and education levels, the likelihood of contracting malaria was relatively similar. This implies that the risk of malaria is not necessarily influenced by a person's age or level of formal education in this population. This could be due to uniformly high exposure rates to malaria vectors or limited variation in preventive practices across these groups. Occupational status was significantly associated with malaria prevalence. This indicates that the type of work a person engages in may affect their malaria risk. For example, individuals involved in outdoor occupations (such as farming or fishing) may be more exposed to mosquito bites, especially in evening or nighttime work. This finding emphasizes the importance of targeted interventions for high-risk occupational groups. Alcohol consumption had a statistically significant association with malaria prevalence, whereas ever being drunk did not. This may suggest that regular alcohol use, rather than occasional or extreme use (i.e., drunkenness) contributes more to malaria risk. Alcohol consumption can affect sleep patterns (e.g., sleeping outdoors or without protective measures) or reduce immune responses, thereby increasing susceptibility. Tobacco consumption also showed a statistically significant association with malaria, but being under the influence of tobacco did not. This implies that habitual tobacco use is linked to higher malaria risk, potentially through its effects on health and immunity, rather than through behavioral disorientation or temporary impairment. Heavy rainfall did not show a significant association with malaria prevalence, but a long humid period did. While rainfall contributes to mosquito breeding, it may not always correlate directly with malaria cases, especially if water stagnation and breeding are not prolonged. On the other hand, extended humidity can create favorable conditions for mosquito survival and transmission, leading to increased malaria risk. Living in poorly built houses and living in open houses were significantly associated with malaria prevalence. Poor housing conditions, such as inadequate walls and roofs, or a lack of secure doors and windows, can increase mosquito entry and exposure during peak biting hours. Open houses, in particular, provide little to no protection against vectors. The presence of broken walls did not show a significant association, which might be due to other overlapping housing conditions having a stronger impact (e.g., whether the house is open or has net-covered windows). The presence of open windows or windows without nets was also significantly associated with malaria prevalence. This highlights the role of structural barriers in preventing mosquito entry. The use of window nets is a well-known and effective strategy for malaria prevention; however, their lack increases vulnerability. There is a similarity between this study and the findings by Thomas et al. (2018) in India, who found that breeding habitats were recorded as risk factors for malaria. The climate, vegetation, and mosquito species in this study area may be similar to those in southern Karnataka and Chennai, India, which influence the local dynamics of malaria transmission. The findings in this study are not the same as those by Gopika et al. (2024) in the southern province of Karnataka, India, who found that advancing age, illiteracy, and rural, tribal, and migrant were risk factors for malaria. Gopika et al. identified advancing age, illiteracy, and tribal/migrant status as key risk factors. These variables may not be relevant or pronounced in your study population. Differences in health literacy, beliefs about malaria, and access to health care can affect malaria risk and reporting. The difference in study area has better distribution and usage of insecticide-treated nets (ITNs), indoor residual spraying (IRS), or more active community health campaigns, which could reduce malaria prevalence even among higher-risk groups. Differences in sanitation, drainage, and housing quality can affect mosquito breeding and human exposure. These differences in the findings may be linked to better environmental management, reducing the importance of breeding habitats as a risk factor, unlike in Chennai, where Thomas et al. noted poor drainage as a key driver. The consistency between our findings and previous findings may be linked to similarity in external factors, such as sociodemographic characteristics, socioeconomic features, environmental degradation, deforestation, and climate change.

Risk factors for malaria infection in the Bono Region of Ghana

The study revealed that poorly built houses, open portions in roofs, and broken walls significantly contributed to malaria risk. These structural deficiencies make it easier for mosquitoes to enter homes and bite occupants, especially at night when Anopheles mosquitoes (malaria vectors) are most active. This finding supports prior evidence that housing quality plays a critical role in protecting individuals from vector exposure. Homes lacking physical barriers (e.g., sealed windows, intact walls, roofing) are more likely to serve as entry points or resting places for mosquitoes. Interestingly, the study found that access to healthcare facilities for malaria treatment had no strong influence on the occurrence of malaria. This suggests that although treatment is important for disease management, it does not prevent infection. It may also indicate issues like delayed health-seeking behavior, low utilization of health care services, or infection occurring before treatment can be accessed, emphasizing the importance of prevention over cure. The control of mosquito breeding sites substantially reduced malaria prevalence. Bushes around houses, stagnant water, and slow-flowing water bodies near homes were strongly associated with higher malaria prevalence. These environments serve as ideal breeding grounds for mosquitoes. This finding highlights that environmental and structural conditions around the home significantly influence malaria transmission risk, more so than access to treatment facilities. There is an agreement between finding in this study finding by Rana, Shrestha and Chimoriya, (2020), who reported that living in a modern house, defined as the use of non-earth floors, non-thatched roofs, and non-mud walls, was associated with an increased malaria incidence compared with living in a traditional home. Other factors found to be associated with the incidence of malaria included living in a town versus a rural setting, and sleeping in a room with openings to the outside (windows, eaves, and airbricks). Similarly, Nieto-Sanchez et al. (2022) in Ethiopia found that thatched-roofed houses, eves, and crack reductions were associated with the occurrence of malaria. This agrees with the findings of Isiko et al. (2024), who reported that houses with walls built using rudimentary materials were associated with the prevalence of malaria. The uniformity of the findings is attributed to the similarity in environmental degradation, policy changes, population growth conditions deforestation, climate change are implicated in the prevalence of malaria.

Individual-level factors associated with malaria infection among residents of the Bono Region of Ghana.

The findings revealed that several individual-level factors are associated with malaria infection. While the under-five age did not show a strong association with malaria prevalence in this study, pregnancy was significantly associated with a higher malaria prevalence. The under-five children are traditionally considered highly vulnerable due to their immature immune systems; however, the lack of a strong association may reflect the effective use of preventive measures (e.g., insecticide-treated nets) among this group or reporting biases in infection or testing patterns. On the other hand, the strong link with pregnancy is consistent with previous research. Pregnant women are at greater risk of malaria because of changes in immunity and physiological factors. Malaria during pregnancy can lead to maternal anemia, low birth weight, and poor pregnancy outcomes, making it a key target group for intervention. A statistically significant association was found between rare use of ITNs and malaria prevalence. Participants who rarely used ITNs were more likely to contract malaria. This supports the well-established role of ITNs as a highly effective malaria prevention tool, particularly in high-transmission settings. The implication is that consistent and correct use of ITNs can substantially reduce exposure to infective mosquito bites, especially during sleeping hours when Anopheles mosquitoes are most active. The study observed that the use of alternative mosquito control measures (such as coils, sprays, and repellents) may also influence malaria prevalence. These methods offer some level of protection, especially in environments where ITN use may not be feasible (e.g., outdoors or in workplaces). However, they are often less effective than ITNs and may vary in terms of quality, coverage, and duration of protection. Ideally, their use should complement and not replace core interventions such as ITNs or indoor residual spraying. A significant association was found between spending time outdoors in the evening or night hours (6pm–6am) and malaria prevalence. This is expected because Anopheles mosquitoes are most active during twilight and nighttime. Individuals outdoors during these times are at increased risk of mosquito bites, especially in areas without effective vector control. This finding reinforces the need for behavioral education to discourage evening outdoor exposure in the absence of protective measures, such as repellents and protective clothing. Participants who traveled to malaria-endemic regions in the past 3–6 months had significantly higher malaria prevalence. This suggests that mobility and travel history are important risk factors, as individuals may be exposed to different or more intense transmission settings, especially if they do not carry or use protective measures while traveling. This has implications for malaria surveillance and control, indicating the need for targeted health education and travel advisories, and possibly prophylactic interventions for high-risk travelers. The present study aligns with previous research that highlighted the multifaceted determinants of malaria prevalence, particularly insecticide-treated net (ITN) ownership and usage, demographic variables, and access to health care. First, the consistency between this study and the findings of Mensah and Anto (2020) is noteworthy. They reported that factors such as the ownership and usage of ITNs, acquisition of ITNs through antenatal care (ANC) visits, purchase of nets from stores, and user-reported irritation caused by ITNs were significantly associated with malaria incidence. This emphasizes that while access to ITNs is vital, actual usage and user experience (e.g., irritation or discomfort) also play critical roles in determining their effectiveness. This suggests the need for public health strategies not only to increase the distribution of ITNs but also to improve their design and user acceptability to ensure regular use. Similarly, the findings of Aheto (2022) in Ghana also corroborate the present study's results. His research showed that malaria prevalence among children was significantly influenced by ITN coverage and geographical disparities. This reinforces the idea that although national strategies may increase overall ITN coverage, the distribution and utilization rates can vary widely across regions, which in turn affects malaria risk. This calls for context-specific interventions, such as more focused distribution and behavior change communication in underserved or high-risk areas. Additionally, Gul et al. (2021) in Papua New Guinea found that variables such as age, residence (rural vs urban), and access to medical treatment were positively correlated with malaria. This complements the current study's findings by underlining how demographic and socioeconomic factors influence malaria vulnerability. Rural areas often have limited access to healthcare, poor housing conditions, and higher mosquito breeding environments, all of which contribute to elevated malaria risk. Overall, this discussion underscores the need for comprehensive malaria control strategies that go beyond ITN distribution. Effective malaria prevention requires enhanced community engagement to promote consistent ITN use, design improvements in ITNs to reduce user discomfort, targeted health education that considers regional and demographic differences, and improved access to timely medical care, especially in rural and marginalized populations. These findings collectively suggest that both structural factors (e.g., residence, health care access) and behavioral aspects (e.g., ITN use and perception) must be addressed concurrently for malaria interventions to be truly effective.

Environmental factors associated with malaria infection in the Bono Region of Ghana

In this study, most respondents experienced a heavy rainy period and a long, warm humidity. These environmental factors were associated with an increased prevalence of malaria infection in the communities. Findings in this study show similarity with previous studies. Longo-Pendy et al. (2024) in Woleu-Ntem, northern Gabon, and increased urbanization, hot spots in ambient temperature, moderate rainfall, and land use patterns were associated with the prevalence of malaria. Similarly, Musoke et al. (2018) in Wakiso District, Uganda, found that environmental risk factors associated with the prevalence of malaria were vessels that could potentially hold water for mosquito breeding and stagnant water in compounds. Another study by Yakudima et al. (2023) in Jigawa State, Nigeria, reported a positive association between the incidence of malaria and factors such as water storage containers, distance to mosquito breeding grounds, rainfall, and relative humidity. They reported that the incidence of malaria was caused by both climatic and non-climatic environmental factors. In this vein, Segun et al. (2020) reported that an increase in temperature and humidity was implicated in the increase in the prevalence of malaria in Abuja, Nigeria. The support in the findings by previous studies can be attributed to the similarity in environmental factors and climate change.

Conclusion

In conclusion, this study highlights that the persistence of malaria in Bono Island is largely driven by preventable environmental and behavioral risk factors. The findings underscore the urgent need for targeted environmental management, improved housing standards, increased community sensitization on preventive measures and enhanced malaria control programmes to reduce transmission and improve public health outcomes.

Recommendations

Based on the findings and conclusions of this study, the following recommendations were made;

1. Health care workers should collaborate with community leaders to organize a health education programme that will focus on improving preventive measures against malaria in communities. Given the peak number of malaria cases during the rainy season (notably June), pre-emptive spraying and larviciding should be performed seasonally in high-prevalence areas.
2. Since poor housing conditions (open roofs, broken walls, open windows without nets) significantly contribute to malaria risk, health care workers should collaborate with community leaders to organize health education programmes that support the improvement of housing infrastructure (e.g., subsidized mosquito-proofing materials). In addition, regular inspections and community outreach can educate households about structural risks and encourage modifications that reduce exposure to mosquitoes.
3. The study found that only a few participants used ITNs regularly, despite their significant association with malaria prevention. Healthcare workers should collaborate with community leaders to organize awareness campaigns that emphasize consistent use, targeting households with pregnant women, children, and travelers. Since the use of repellents, coils, and sprays was minimal, awareness campaigns should promote their proper and safe use, especially in homes where ITNs are unavailable.
4. Health care workers should be made to encourage at-risk individuals (e.g., travelers to endemic areas, pregnant women) to take chemoprophylaxis, which was underutilized according to the findings. Despite most respondents having access to healthcare, the delay or lack of treatment for symptoms such as fever, chills and vomiting needs to be addressed through improved service delivery and education on early care-seeking.
5. Women and pregnant individuals who are found to be more vulnerable should be prioritized in intervention programmes. This includes free ITNs, prenatal preventive treatments, and awareness campaigns tailored to their needs. As occupational status is significantly associated with malaria risk, especially for outdoor or agricultural workers, employers and local authorities should implement workplace-based interventions such as the provision of repellents and education.
6. Continued tracking of seasonal and community-specific malaria prevalence will support the early detection of outbreaks and guide resource allocation. The association between environmental conditions and malaria trends underscores the need to incorporate EIA enforcement and urban planning into malaria control strategies.
7. Governments should ensure that construction and land-use activities undergo EIAs to prevent environmental degradation that favors mosquito breeding. The Government, health care workers, and the community should collaborate to control and reduce the prevalence of malaria in Bono communities. This can be achieved by involving health, housing, water, sanitation, and environmental agencies to ensure a holistic approach.

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