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Assessing the prevalence, risk factors, and socio-demographic predictors of malaria among pregnant women in the Bono East Region of Ghana: a multicentre hospital-based mixed-method cross-sectional study

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Abstract

Background Malaria is one of the world's most lethal vector-borne diseases, causing significant health burdens in endemic countries. Several studies on the prevalence of malaria among pregnant women in Ghana have been conducted in various parts of the country, yielding evidence pointing to intra- and inter-regional variations. The current study assessed the prevalence, risk factors, and sociodemographic predictors of malaria among pregnant women in the Bono East Region of Ghana.

Methods This multicentre hospital-based study employed a mixed-method cross-sectional design. A multistage sampling technique was used to select seven health facilities and recruited 1452 pregnant women who attended ANC at seven selected health facilities. Haematological examination, a structured closed-ended questionnaire, in-depth interviews (IDIs), and focus group discussions (FGDs) were used to obtain relevant data. Quantitative data were analysed with STATA 14 (StataCorp, College Station, USA). Likewise, the four-step thematic analysis was used to analyse qualitative data. A significant level was set at ($p < 0.05$) at a 95% confidence interval (CI).

Results The ages of the pregnant women at enrolment ranged between 17 and 40 years, with a mean (SD) of 28.8 ± 3.73 (95% C.I: 28.63–29.02). The overall prevalence of malaria infection among pregnant women was 10.8% (95% CI: 9.32–12.56). Presence of farm or domestic animals, living close to drainage tunnels, living near overgrown vegetation, not married, not having formal education, living in extended-type households, living in compound-type households, mud and thatch households, mud and iron sheet households, primigravidae, multiparity, first-time pregnant women, second-time, third-time, fourth-time, and fifth-time ANC visits, blood groups A, B, and AB were independent factors or predictors significantly associated with increased risk of malaria.

Conclusion The current study revealed an approximately 10.8% prevalence of malaria among pregnant women. The prevalence revealed, was, however, higher than the national prevalence of 8.6%. The high prevalence of malaria, associated risk factors, and sociodemographic and maternal predictors highlight the need to strengthen screening for malaria, administer treatments, monitor maternal and foetal health, and provide education and counselling.

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Keywords Antenatal clinic, Interventions, Malaria, Pregnancy, Prevalence, Risk factors, Socio-demographic predictors

Background

Malaria is one of the most lethal vector-borne diseases. It is endemic to 104 tropical and subtropical countries in Africa, Central and South America, Asia, and Oceania [1]. The transmission of human malaria is through the bite of an infected female *Anopheles* mosquito, which injects *Plasmodium* parasites, in the form of sporozoites, into the bloodstream. Since the parasite species' life cycle involves developing, maturing, reproducing, and being discharged from erythrocytes into the bloodstream to infect more erythrocytes and hepatocytes, malaria symptoms can be cyclic or periodic [2]. Fever, headache, nausea, and flu-like symptoms are among the symptoms, but their manifestations vary depending on the *Plasmodium* species and the person infected. Globally, 249 million cases of malaria were reported in the year 2022 across 85 endemic countries [3]. This marks a noticeable increase from the 2021 figures, which estimated the number of cases to be 247 million [3]. Notably, most of this increase was observed in countries within the African Region (Ethiopia, Nigeria, Uganda), Asia (Pakistan), and Oceania (Papua New Guinea) [3].

Malaria cases in African regions disproportionately account for a large proportion of the global malaria burden [4]. With an estimated 234 million cases in 2021 in the African region, four African countries accounted for slightly more than half of all malaria deaths worldwide: Nigeria (31%), the Democratic Republic of the Congo (13%), Niger (4%), and the United Republic of Tanzania (4%) [5]. Ghana is among 15 countries noted to have a high malaria endemic burden. It is responsible for 4.3% of malaria cases in West Africa [4]. However, between 2020 and 2021, Ghana made significant progress in malaria control, with a steady output of 165 cases per 1000 of the population at risk, while mortality declined slightly by 1.7% (from 0.39 to 0.38 per 1000 of the population at risk) [6]. To reduce the country's malaria burden, Ghana implemented a high-burden, high-impact approach in November 2019 [7]. This targeted approach, which included the use of vaccines, the distribution of long-lasting insecticide-treated mosquito nets, intermittent preventive treatment with sulfadoxine-pyrimethamine for the prevention of malaria during pregnancy, seasonal malaria chemoprevention targeting treatment of children under five years of age with sulfadoxine-pyrimethamine and amodiaquine and other interventions, has been highly effective in malaria control and elimination efforts [7]. This strategy has significantly reduced the prevalence of malaria among children under five years of age, from approximately 20.6% in 2016 to 8.6% in 2023. It has also decreased in-patient hospital deaths due to malaria, from 428 in 2018 to 155 in 2022 [7]. Currently, this effective approach is the mainstay of the National Malaria Strategic Elimination Plan 2024–2028, a comprehensive blueprint designed to accelerate progress [7].

Susceptibility to malaria is higher in pregnant women than in non-pregnant women [8]. The increased risk can be explained from two biological perspectives. The first involves the alteration of immunity during pregnancy [9]. During pregnancy, there is a substantial increase in the cortisol level, while at the same time, the levels of prolactin decrease appreciably, causing non-specific immunosuppression [10]. This immunosuppression leads to transient damage of cell-mediated immunity, which aids in the development of the placenta and growing foetus. Notably, cell-mediated immune mechanisms play a vital role in pregnancy, especially during malaria protection, and their suppression partially explains why pregnant women may be vulnerable to malaria infection [11]. The second biological mechanism involves the selective accumulation of infected erythrocytes in the placenta [12].

Consequently, malaria during pregnancy is among the diseases noted to cause adverse conditions. To foetuses, pre-birth complications such as abortion, stillbirth, and congenital infections may result from malaria [13]. For newborns, malaria may have post-birth consequences, such as low birth weight due to prematurity and intrauterine growth retardation. Even if an infant survives the adverse outcomes associated with malaria during pregnancy, he or she is prone to live through the long-lasting effects of intrauterine malaria infection, which may in turn affect his or her physical and cognitive development, leading to learning disabilities [14].

In Ghana, several studies have been conducted in various parts of the country, yielding evidence pointing to intra- and inter-regional variations. Despite the growing body of malaria research, it continues to affect the livelihoods of people in the Bono East Region [4]. The Region has unique environmental, climatic, and socioeconomic factors that can influence the prevalence and severity of malaria. A previous study conducted in the region has provided evidence of a high prevalence of 20.4% of malaria among pregnant women [15]. To the best of our knowledge, this was the only peer-reviewed published study that provided empirical data on malaria among pregnant women in the region. Hence, further research aimed at probing into the prevalence, related risk factors, and sociodemographic predictors of malaria among pregnant women will offer crucial insights into their vulnerability and associated risks. This study, therefore, determined the prevalence of malaria among pregnant women in the Bono East Region of Ghana. The study

also assessed various risk factors and sociodemographic predictors associated with high malaria risk. The study's findings will aid in developing targeted policies and effective interventions aimed at malaria elimination among pregnant women. Furthermore, it will also contribute to the data needed for monitoring and evaluation of the ongoing prevention efforts, ultimately enhancing healthcare outcomes among pregnant women.

Methods

Study area

The study was conducted in seven health facilities in seven municipalities/districts (namely: Atebubu-Amantin Municipal, Kintampo South District, Kintampo North Municipal, Nkoranza South Municipal, Techiman Municipal, Pru East District, and Pru West District). These seven municipalities/districts were all within the Bono East Region. Projections from the 2020 population and housing census indicated a total of 1,203,400 people, occupying 22,952 km^2 piece of land in the middle of Ghana, with a population density of 48.75 per sq km [16]. The Bono East Region borders the Savannah Region to the north, the Bono Region to the west, the Ashanti Region to the south, and Volta Lake to the east. It is made up of eleven municipalities/districts, with Techiman as its capital [16]. The region is located within the forest-savannah transitional ecological zone in the middle belt of Ghana. It experiences a double rainfall pattern, averaging 1399.5 mm per year, with average monthly temperatures ranging between 22 °C and 33 °C [17]. The major rainfall season typically occurs from March to June, while the minor season spans from September to November. These periods correspond to two peaks in malaria transmission [18]. Likewise, the region has abundant land and vegetation cover (savannah, tropical forest, and mangrove and swampy areas) with several rivers and streams [17]. The abundant land and vegetation, combined with the rainfall pattern and warm temperatures, create convenient conditions for the breeding of female *Anopheles* mosquitoes, thereby increasing malaria transmission in the region [19]. The predominant mosquito vectors distributed throughout the region are *Anopheles gambiae*, *Anopheles arabiensis,* and *Anopheles funestus* [20].

Study design

This was a multicentre hospital-based mixed-method cross-sectional study designed to explore the prevalence, risk factors, and sociodemographic and maternal predictors of malaria among 1452 pregnant women over a specific time frame (from September 2023 to June 2024). This time frame included the minor rainfall season from September 2023 to November 2023 and the major season from March 2024 to June 2024. This design was selected to efficiently gather data from diverse populations of pregnant women across multiple health facilities and the two main rainy seasons.

Study population

The study population comprised consented pregnant women who attended antenatal clinics (ANC) in selected healthcare facilities.

Inclusion criteria

Pregnant women who lived in the selected municipalities/districts, who also attended ANC at the seven selected health facilities at the time of the study, and who agreed to participate were included.

Exclusion criteria

The study was limited to all other pregnant women. Pregnant women who did not attend ANC at the selected health facilities during the study were excluded. This could lead to selection bias, which may potentially influence the generalizability of the results. In addition, pregnant women who resided in the selected municipalities/districts and attended ANC at selected health facilities but were not willing to participate were excluded. Furthermore, pregnant women who agreed to participate in the study during the recruitment phase, but chose not to participate during the survey itself were excluded. Moreover, if there were no reliable interpreters to bridge language barriers to facilitate easy understanding, pregnant women who consented were excluded. Similarly, pregnant women who felt any form of discomfort were excluded. Finally, pregnant women who failed to provide consent for inclusion for personal reasons were also excluded.

Sample size estimation

The sample size for the study was estimated using Slovin's formula, expressed as;

$$\frac{N}{1+\mathrm{N}(e)^2}$$

where (N = 33,395) is the population of pregnant women registered in the selected municipals'/districts' ANC record book for 2022, as shown in Table 1, and (e) is the standard error (Chosen to be 3% [21, 22]).

$$= \frac{33395}{1+33395(0.03)^2}$$

$$1075.33$$

$$\approx 1075$$

Table 1 Sample size proportional to each selected municipality/district

Municipal/District	The population of pregnant women in 2022	Sample proportion %	Estimated sample size	Approximated sample size
Atebubu-Amantin	5192	15.6	226.5	226
Kintampo North	6186	18.5	268.6	269
Kintampo South	2205	6.6	95.8	96
Nkoranza South	3932	11.8	171.3	171
Techiman Municipal	9334	27.9	405.1	405
Pru East	4140	12.4	180.1	180
Pru West	2406	7.2	104.5	105
Total	33,395	100	1451.9	1452

A 35% of 1075, which is 377 rounded to the nearest decimal, was added to give a total sample size of 1452. The rationale was to obtain more reliable and precise estimates to make desirable inferences about the population from which the sample was drawn [22, 23] and also to satisfy one of the assumptions of the logistic regression analysis, which emphasizes the presence of a larger sample size [24]. Each study site was allotted a quota based on the sample size proportional to the respective municipality/districts to maintain representativeness as presented in Table 1. Pregnant women were randomly selected using balloting until their numbers were proportional to the sample size of the representative municipalities/districts.

Enrolment of participants

Pregnant women were enrolled at various ANCs of the seven selected municipal/district health facilities. The general introduction of the study was made known to pregnant women during their routine health education session by the senior midwives of the selected health facilities. An initial examination was performed to determine the eligibility of pregnant women. After screening for eligibility, pregnant women who met the inclusion criteria were approached to discuss the study's objectives, benefits, and risks, and obtain their consent for participation. Pregnant women were informed that the decision to participate in the study was entirely voluntary and that declining to participate was not a problem. Moreover, participants signed or thumb-printed a written consent form after receiving a thorough explanation before engaging in the study. Consent was also sought from the parents or guardians of participants aged below 18 years.

Variables of interest

Outcome variable: The outcome variable explores the malaria status of pregnant women at the time of data collection. This variable was categorical, and measured on a dichotomous scale. It was coded as (0—Negative and 1—Positive).

Predictor variable: Risk factors associated with malaria mono-infection, sociodemographic and maternal characteristics (including age, marital status, education, religious affiliation, employment status, type of occupation, monthly income, household structure, household type, household category, number of people in the household, haemoglobin (Hb) levels, syphilis, sickling status, gravidity, parity, antenatal care (ANC) visit, gestation, glucose-6-phosphate dehydrogenase (G6PD), and blood group).

Data collection methods

Several instruments were used to collect relevant data for this study. These included a self-designed obstetric template, a haematological examination, a structured closed-ended questionnaire, in-depth interviews (IDIs), and focus group discussions (FGDs). Maternal (Obstetrics) parameters were collected from the antenatal care (ANC) records book using an obstetric record template. The template consisted of nine (9) items: gravidity, parity, antenatal care (ANC) visit, gestation, Glucose-6-phosphate Dehydrogenase (G6PD), blood group, haemoglobin (Hb) levels, sickling, and syphilis status. The previous Hb levels of pregnant women during the study were averaged to determine the proportion of pregnant women who were anaemic during pregnancy. Information not documented in the ANC record book was verbally retrieved.

In addition, a structured closed-ended questionnaire was used to collect data, particularly on the sociodemographic characteristics of pregnant women and risk factors associated with malaria. The questionnaire was adapted from the Ghana Demographic and Health Survey and the Ghana Living Standards Survey Round 6, which were modified to suit the purpose of this study. The questionnaire was administered via face-to-face interviews. Reliable interpreters were assigned to interview participants who did not understand English in their language of choice. In instances where there were

no reliable interpreters for the language of their choice, a pregnant woman was excluded from the study.

Blood sample collection and laboratory examination

At the laboratory, the left arms of the pregnant women were cleaned with 70% denatured alcohol, and approximately 5 ml of venous blood was collected into purple-top EDTA tubes following the standard operating procedure (SOP) performed by a trained medical laboratory technician. For the diagnosis of malaria, thick blood films were prepared on a glass slide using 10 µl of blood and evenly spread to cover an area of 15 × 15 mm. The smear was stained with 10% Giemsa for 15 min and then examined under oil immersion (X100) using a binocular light microscope. The slides were double-read by trained Microscopists. Asexual parasite densities were estimated by counting the number of parasites per 200 white blood cells (WBCs) in the thick film. Parasite counts were converted to parasites per microlitre (µl) using a relative WBC count of 8000 leukocytes per µl of blood [25]. A sample was considered negative if no parasite was counted after 200 high-power fields were read [25]. If there were inconsistencies in the reading of the slide (positive or negative or a 50% or more difference in parasite density), the senior microscopist's reading was accepted as the true report.

Data management and statistical analysis

All data were examined for completeness, consistency, and clarity as part of data management. The examined data were coded, entered, and cleaned using Microsoft Excel version 2016 (Microsoft, USA) before it was analysed using STATA 14 (StataCorp, College Station, USA). Descriptive statistical analyses were performed to provide summary output tables of the frequency, percentage distribution, and mean with standard deviations (S.D.) for continuous variables. Pearson's chi-square tests were performed to determine differences in proportion at a significance level of 5%. In addition, bivariate and multivariate logistic regression analyses were performed to compute odd ratios and identify the factors or predictors that were significantly associated with malaria among the pregnant women studied, with a 5% significance level and 95% confidence interval (CI).

Likewise, thematic analysis was used to analyse qualitative data, with a focus on four steps: transcription, profiling, coding and thematic framework. Focus group discussions (FGDs) and in-depth interviews (IDIs) with consented pregnant women and health workers were recorded and transcribed verbatim from the preferred language of the participants into English. Transcripts were reviewed with audio recordings to check for possible omissions of participants' relevant responses. Coding was performed manually by identifying keywords pertinent to the study in the interviews. Microsoft Word was used to sort the information, edit it, and categorize it according to themes to match the objectives of the study.

Logistic regression model

This study primarily focused on risk assessment; hence logistic regression was employed to predict the degree of influence that selected predictor variables have on the occurrence of the outcome variable's categories. In this study, all measurements were observed, and there were no missing values. The general model of the logistic regression equation is expressed as;

$$\log(p) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \tag{1}$$

where p is the probability of the dependent event (Malaria mono-infection) occurring, β_0 is the intercept, and $\beta_1, \beta_2, \ldots \beta_k$ are the coefficients for the independent variables $X_1, X_2, \ldots X_k$.

From the model, given the risk factors and sociodemographic parameters, the study's logistic regression model was written as:

For risk factors of malaria mono-infection

$$\begin{aligned}\log\left(\mathrm{p}_{\mathrm{Malaria}}\right) = {} & \beta_0 + \beta_1 \times \text{ceramic/tiles/terrazo} \\ & + \beta_2 \times \text{cement as building material} \\ & + \beta_3 \times \text{woolen, synthetic carpet} \\ & + \beta_4 \times \text{linoleum, rubber carpet} \\ & + \beta_5 \times \text{netted windows} \\ & + \beta_6 \times \text{windows fitting perfectly} \\ & + \beta_7 \times \text{domestic or farm animals} \\ & + \beta_8 \times \text{proximity to refuse dump} \\ & + \beta_9 \times \text{proximity to water body} \\ & + \beta_{10} \times \text{proximity to drainage tunnel} \\ & + \beta_{11} \times \text{proximity to overgrown vegetation} \\ & + \beta_{12} \times \text{household toilet facilities} \\ & + \beta_{13} \times \text{clothes hanging in sleeping rooms} \\ & + \beta_{14} \times \text{sleeping under ITNs} \\ & + \beta_{15} \times \text{using mosquito coils} \\ & + \beta_{16} \times \text{using mosquito repellents} \\ & + \beta_{17} \times \text{using mosquito sprays} \\ & + \beta_{18} \times \text{uptake of IPTp} - \text{SP} \\ & + \beta_{19} \times \text{history of IRS}\end{aligned} \tag{2}$$

For sociodemographic and maternal predictors of malaria mono-infection

Table 2 Sociodemographic and obstetric characteristics of pregnant women

Variable	[n]	[%]
Age ($\bar{x}$ ± SD)	28.8 ± 3.73 (95% C.I: 28.63–29.02)	
< 18 years	7	0.5
18–25	167	11.7
26–30	1088	76.1
31–40	168	11.7
Marital status		
Not married	118	8.3
Married	1308	91.5
Cohabitation	4	0.3
Educational attainment		
No formal education	414	29
Primary education	612	42.8
Junior High School	251	17.6
Senior High School	127	8.9
Tertiary	26	1.8
Religious affiliation		
Islam	233	16.3
Christianity	1194	83.5
African tradition	3	0.2
Employment status		
Employed	1396	97.6
Unemployed	34	2.4
The type of occupation		
Hairdressing	275	19.2
Seamstress	234	16.4
Farming	204	14.3
Civil service	26	1.8
Trading/Marketing	613	42.9
Domestic activities	44	3.1
Housewife (unemployed)	14	1
Student (unemployed)	6	0.4
None (unemployed)	14	1
Monthly income		
Gh¢ 100–500	692	48.4
Gh¢ 600–1000	538	37.6
Gh¢ 1100–2000	141	9.9
Gh¢ 2100–3000	19	1.3
Gh¢ 3100–4000	6	0.4
None	34	2.4
Household structure		
Extended	1086	75.9
Nuclear	344	24.1
Household type		
Compound House	1009	70.6
Self-Contain House	421	29.4
Household category		
Mud with thatch	27	1.9
Mud with iron sheets	129	9
Blocks with iron sheets	1274	89.1
Number of people in a household		
1–5	895	62.6
6–10	532	37.2
11–15	3	0.2
Gravidity		
Primigravida	335	23.4
Secundigravida	624	43.6
Multigravida	471	32.9
Parity		
Nulliparous	296	20.7
Multiparous	1134	79.3
ANC Visits ($\bar{x}$ ± SD)	2.85 ± 1.9 (95% CI: 2.76–2.95)	
1–3	990	69.3
4–6	340	23.8
7–9	100	7
Gestation		
First trimester	1051	73.5
Second trimester	256	17.9
Third trimester	123	8.6
G6PD		
No defect	1371	95.9
Partial defect	49	3.4
Full defect	10	0.7
Blood group		
A	422	29.5
B	420	29.4
AB	251	17.6
O	337	23.6
Anaemia		
Non-anaemic	122	8.5
Mild anaemia	449	31.4
Moderate anaemia	843	59
Severe anaemia	16	1.1
Sickling		
Positive	45	3.1
Negative	1385	96.9
Syphilis		
Positive	37	2.6
Negative	1393	97.4

$\bar{x}$, Mean; SD, Standard deviation; n, Frequency; %, Percentage

Field survey, 2024

$$\begin{aligned}\log\left(p_{Malaria}\right) &= \beta_0 + \beta_1 \times \text{age} + \beta_2 \times \text{marital status} \\ &+ \beta_3 \times \text{educational attainment} \\ &+ \beta_4 \times \text{type of occupation} \\ &+ \beta_5 \times \text{monthly income} + \beta_6 \\ &\times \text{household structure} + \beta_7 \times \text{household type} \\ &+ \beta_8 \times \text{household category} + \beta_9 \\ &\times \text{numver of people in a household} \\ &+ \beta_{10} \times \text{gravidity} + \beta_{11} \times \text{parity} + \beta_{12} \\ &\times \text{ANC visits} + \beta_{13} \times \text{gestation} + \beta_{14} \times \text{G6PD} \\ &+ \beta_{15} \times \text{blood group} + \beta_{16} \times \text{anaemia} + \beta_{17} \\ &\times \text{sickling} + \beta_{18} \times \text{syphilis}\end{aligned} \quad (3)$$

Results

Sociodemographic and obstetric characteristics of pregnant women

The estimated sample size for this study included 1452 pregnant women. Out of 1452 participants, 1430 participated in the study. Twenty-two pregnant women declined to participate, indicating a non-response rate of 1.52%. Hence, the analyses were based on the 1430 pregnant women who participated. The sociodemographic and obstetric characteristics of pregnant women are presented in Table 2. The ages of pregnant women ranged from 17 to 40 years, with a mean of 28.8 ± 3.73 (95% C.I: 28.63–29.02). A large percentage of pregnant women (76.1%, n = 1088) were between the ages of 26 and 40 years. Most pregnant women (76.1%, n = 1088) were married. Likewise, most of the women (42.8%, n = 612) had attended primary school. Furthermore, a significant majority of the pregnant women were Christians (83.5%, n = 1194). In terms of employment status, a large majority of pregnant women (97.6%, n = 1396) were employed. They were engaged in various occupations, including hairdressing (19.2%, n = 275), seamstress (16.4%, n = 234), farming (14.3%, n = 204), trading (42.9%, n = 613), civil service (1.8%, n = 26), and domestic activities (3.1%, n = 44).

Regarding monthly income, most pregnant women (48.4%, n = 692) earned between Gh¢100 and 500. Consistent with household structure, a large majority of pregnant women (75.9%, n = 1086) lived in extended households (households which comprise husband/ male partner and wife/ female partner and children and relatives). In addition, 70.6% (n = 1009) of the participants lived in compound houses. The majority (89.1%, n = 1274) lived in houses made of blocks with iron sheets. In terms of household size, pregnant women (62.6%, n = 895) lived in households whose capacity were 1–5 (see Table 2).

Table 3 Prevalence of malaria mono-infection among pregnant women

Data collection site	Participant's malaria status				% Total
	Positive		Negative		
	[n]	[%]	[n]	[%]	
Atebubu-Amantin Municipal	19	1.3	204	14.3	15.6
Kintampo North Municipality	27	1.9	238	16.6	18.5
Kintampo South District	9	0.6	85	5.9	6.6
Nkoranza South Municipality	18	1.3	151	10.6	11.8
Techiman Municipal	43	3	356	24.9	27.9
Pru East District	28	2	149	10.4	12.4
Pru West District	11	0.8	92	6.4	7.2
Total	155	10.8	1275	89.2	100

n, Frequency; %, Percentage

Field survey, 2024

For obstetric characteristics, a substantial majority (43.6%, n = 624) of the participants were secundigravida. Among those with two previous pregnancies, 43.8% (n = 627) had one child. Likewise, 16.6% (n = 238) of those with three or more previous pregnancies had three children. The number of times pregnant women had attended ANC ranged from 1 to 9, with a mean attendance of 2.85 ± 1.9 (95% CI: 2.76–2.95). The proportion of pregnant women (31.2%, n = 446) who were first-time ANC visitors. Regarding gestation, most pregnant women (73.5%, n = 1051) were in their first trimester. Regarding G6PD status, most pregnant women (95.9%, n = 1371) had no defect. Likewise, a significant proportion of the pregnant women (29.5%, n = 422) had blood type A. The haemoglobin (Hb) levels of the pregnant women ranged from 6.2 to 13.3 g/dl, with a mean Hb level of approximately 9.76 ± 1.09 g/dl (95% CI: 9.71–9.82). A considerable majority of the pregnant women (59%, n = 843) had moderate anaemia. On the other hand, 8.5% (n = 122) were not anaemic. A substantial majority of pregnant women (96.9%, n = 1385) had no sickle cell trait. In addition, 97.4% (n = 1393) of pregnant women tested negative for syphilis (see Table 2).

Prevalence of malaria mono-infection among pregnant women

This study assessed the prevalence of malaria among pregnant women who consented to participate across the selected study sites. The study was further grounded on the null hypothesis that "*there is no statistically significant difference between the proportion of pregnant women who are infected with malaria and*

those who are not infected" as against the alternative hypothesis that "*there is a statistically significant difference between the proportion of pregnant women who are infected with malaria and those who are not mono-infected*". The estimated prevalence rate was 10.8% (95% CI: 9.32–12.56), as presented in Table 3. A statistically significant intergroup difference was observed between the proportion of pregnant women who were infected with malaria and those who were not infected ($\chi^2 = 877.203$, DF = 1, $p < 0.05$). In stratifying the prevalence according to study areas, Techiman Municipal had the highest prevalence (3.0%, n = 43), followed by Pru East District (2.0%, n = 28). In contrast, Pru West District had the lowest prevalence (0.8%, n = 11). A spatial statistically significant difference was observed between the proportion of pregnant women with evidence of malaria across all the selected study sites ($\chi^2 = 36.895$, DF = 6, $p < 0.05$).

The observed prevalence of malaria was reinforced by feedback obtained during a series of in-depth interviews (IDIs) with senior midwives (in-charges) at the selected health facilities. These key informants noted the following:

> *"...There are records of every form of disease, provided it concerns pregnant women. However, for this year, we did not conduct detailed research to determine the most prevalent diseases; however, based on our observations and records, malaria stands out as particularly common. In addition, we have noted cases of HBV, HIV, hypertension, diabetes, and UTIs. Among these, UTIs were the most frequent, likely because of increased vaginal discharges and challenges with personal hygiene during pregnancy. However, based on our records, malaria, UTIs, and HBV appear to be the most prevalent..."—(In-charge, IDI-PWD)*
>
> *"...During my ten years of service in this unit, I have observed that, aside from HBV and malaria, pregnant women often experience health-related complications, such as low haemoglobin levels and UTIs. One notable trend is the increase in HBV cases three years ago, but more recently, there has been a decline, though not eliminated entirely..."—(In-charge, IDI-PED)*

Risk factors for malaria mono-infection

Risk factors associated with malaria among pregnant women are presented in Table 4. After adjusting the factors to eliminate confounders during multivariate analysis, pregnant women with netted windows had a lower risk of malaria infection than those without netted windows (AOR = 0.06; 95% CI: 0.03–0.12). Similarly, pregnant women whose household windows fit perfectly into the walls had lower odds of acquiring malaria than those whose windows did not fit perfectly (AOR = 0.05; 95% CI: 0.02–0.10). Consistently, pregnant women using insecticide mosquito coils had a lower likelihood of being infected with malaria than non-users (AOR = 0.26; 95% CI: 0.14–0.47). Pregnant women using mosquito sprays had a lower risk of malaria infection than non-users (AOR = 0.35; 95% CI: 0.19–0.66). In addition, pregnant women who regularly adhered to IPTp-SP during antenatal care visits had lower odds of being infected than those who did not adhere (AOR = 0.14; 95% CI: 0.11–0.45). Finally, the study revealed that the likelihood of malaria is extremely reduced among pregnant women whose households underwent indoor residual spraying (IRS) compared with those whose households did not undergo such spraying (IRS) (AOR = 0.25; 95% CI: 0.16–0.66).

In contrast, pregnant women who had farm or domestic animals in their households had higher odds of being malaria-positive compared with those without such animals (AOR = 18.59; 95% CI: 9.28–27.21). Additionally, pregnant women living close to drainage tunnels had a higher likelihood of contracting malaria than those living farther away (AOR = 2.53; 95% CI: 1.34–4.78). Furthermore, pregnant women living near overgrown vegetation had 2.47 times the odds of being infected with malaria compared with those living farther away (AOR = 2.47; 95% CI: 1.04–5.83) (see Table 4).

The FDGs revealed that household factors and lifestyle choices of certain pregnant women were aligned with the identified risk factors associated with malaria. Some participants made the following remarks:

> *"... In my current situation, I reside with my family in Brekente (a sub-village within the Pru East District). As you may know, many of our homes were constructed from mud and iron sheets. During the night, the rooms become excessively hot, and as a pregnant woman, I struggle to endure the heat. Consequently, I sleep on my apetewoezor (a mat crafted from palm tree branches) outside the room, without the protection of a mosquito net..."—(5^{th} Pregnant Woman, FGD-PED)*
>
> *"... For me, the mosquito net mesh was too tight, restricting airflow. Whenever I try to sleep inside it, I sweat excessively, and I have been advised that heat is not healthy for me or my baby. Consequently, I opt not to sleep on the net. In addition, mosquito coils intensify my respiratory issues and cause me to develop catarrh..."—(1^{st} Pregnant Woman, FGD-TM)*
>
> *"... Mosquito repellent works well for me, but I only use it during the rainy season. Our house is situated*

Table 4 Association between risk factors and malaria mono-infection among pregnant women

Variable	Frequency	Malaria status		COR [95%CI]	p-value	AOR [95%CI]	p-value
		Positive	Negative				
	n [%]	n [%]	n [%]				
Ceramic/Tiles/Terrazzo as the main material for household floors							
Yes	523 (36.6)	75 (5.2)	448 (31.3)	1.73 (1.23–2.42)	0.001*	NA	NA
No	907 (63.4)	80 (5.6)	827 (57.8)	1		1	
Cement as the main material for household floors							
Yes	856 (59.9)	80 (5.6)	776 (54.3)	0.68 (0.49–0.95)	0.027*	NA	NA
No	574 (40.1)	75 (5.2)	499 (34.9)	1		1	
Woollen/Synthetic carpet as the main material for household floors							
Yes	49 (3.4)	0 (0.0)	49 (3.4)	NA	NA	NA	NA
No	1381 (93.6)	155 (10.8)	1226 (85.7)	1		1	
Linoleum/Rubber Carpet as the main material for household floors							
Yes	2 (0.1)	0 (0.0)	2 (0.1)	NA	NA	NA	NA
No	1428 (99.9)	155 (10.8)	1273 (89.0)	1		1	
Netted windows in household							
Yes	1212 (84.8)	54 (3.8)	1158 (81.0)	0.05 (0.03–0.07)	0.000*	0.06 (0.03–0.12)	0.000*
No	218 (15.2)	101 (7.1)	117 (8.2)	1		1	
Household windows fitting perfectly into the wall							
Yes	1262 (88.3)	65 (4.5)	1197 (83.7)	0.04 (0.03–0.06)	0.000*	0.05 (0.02–0.10)	0.000*
No	168 (11.7)	90 (6.3)	78 (5.5)	1		1	
Presence of farm or domestic animals in the household							
Yes	415 (29.0)	110 (7.7)	305 (21.3)	7.77 (5.37–11.25)	0.000*	18.59 (9.28–27.21)	0.000*
No	1015 (71.0)	45 (3.1)	970 (67.8)	1		1	
Closeness of household to refuse dumping site							
Yes	79 (5.5)	22 (1.5)	57 (4.0)	3.53 (2.09–5.96)	0.000*	1.44 (0.51–4.09)	0.483
No	1351 (94.5)	133 (9.3)	1218 (85.2)	1		1	
Closeness of household to water body							
Yes	89 (6.2)	29 (2.0)	60 (4.2)	4.66 (2.88–7.53)	0.000*	1.17 (0.48–2.84)	0.722
No	1341 (93.8)	126 (8.8)	1215 (85.0)	1		1	
Closeness of household to drainage tunnel							
Yes	301 (21.0)	64 (4.5)	237 (16.6)	3.16 (2.23–4.48)	0.000*	2.53 (1.34–4.78)	0.004*
No	1129 (79.0)	91 (6.4)	1038 (72.6)	1		1	
Closeness of household to overgrown vegetation							
Yes	112 (7.8)	31 (2.2)	81 (5.7)	3.68 (2.34–5.79)	0.000*	2.47 (1.04–5.83)	0.039*
No	1318 (92.2)	124 (8.70	1194 (83.5)	1		1	
Availability of household toilet facility							
Yes	836 (58.5)	84 (5.9)	752 (52.6)	0.82 (0.58–1.15)	0.254	2.10 (0.95–4.06)	0.062
No	594 (41.5)	81 (5.0)	523 (36.6)	1		1	
Clothes hanging in a sleeping room							
Yes	493 (34.5)	68 (4.8)	425 (29.7)	1.56 (1.11–2.19)	0.010*	1.19 (0.62–2.28)	0.587
No	937 (65.5)	87 (6.1)	850 (59.4)	1		1	
Sleeping in an insecticide-treated mosquito net							
Yes	792 (55.4)	57 (4.0)	735 (51.4)	0.42 (0.30–0.60)	0.000*	3.76 (0.41–4.25)	0.240
No	638 (44.6)	98 (6.9)	540 (37.8)	1		1	
Using an insecticide mosquito coil							
Yes	835 (58.4)	38 (2.7)	797 (55.7)	0.19 (0.13–0.28)	0.000*	0.26 (0.14–0.47)	0.000*
No	595 (41.6)	117 (8.2)	478 (33.4)	1		1	
Use of mosquito repellent							
Yes	695 (48.6)	47 (3.3)	648 (45.3)	0.42 (0.29–0.60)	0.000*	1.08 (0.58–2.02)	0.800

Table 4 (continued)

Variable	Frequency	Malaria status		COR [95%CI]	p-value	AOR [95%CI]	p-value
		Positive	Negative				
	n [%]	n [%]	n [%]				
No	735 (51.4)	108 (7.6)	627 (43.8)	1		1	
Using insecticide mosquito spray							
Yes	1008 (70.5)	66 (4.6)	942 (65.9)	0.26 (0.18–0.36)	0.000*	0.35 (0.19–0.66)	0.001*
No	422 (29.5)	89 (6.2)	333 (23.3)	1		1	
Uptake of IPTp-SP during ANC visits							
Always	842 (58.9)	58 (4.1)	784 (54.8)	0.37 (0.26–0.52)	0.000*	0.14 (0.11–0.45)	0.025*
Not always	588 (41.1)	97 (6.8)	491 (34.3)	1		1	
History of indoor residual spraying in household							
Yes	131 (9.2)	5 (0.3)	126 (8.8)	0.30 (0.12–0.75)	0.010*	0.25 (0.16–0.66)	0.005*
No	1299 (90.8)	150 (10.5)	1149 (8.8)	1		1	

ANC antenatal care, *AOR* adjusted odds ratio, *COR* crude odds ratio, *IPTp-SP* intermittent preventive treatment with sulfadoxine-pyrimethamine; *p < 0.05; n, Frequency; %, Percentage

Field survey, 2024

near a large gutter on Cherehin Road (a village in the Kintampo South District). This gutter tends to fill up and becomes clogged during the rainy season, creating an ideal breeding ground for mosquitoes. To prevent malaria, I rely on a repellent. However, since there's currently no consistent rainfall, I haven't been using the repellent, mosquito coils, or mosquito nets…" (10th Pregnant Woman. FDG-KSD)

"…To be honest, the SP medication they provide us with during ANC visits is quite big, making it very challenging to swallow. Even if I manage to swallow it, I often feel like vomiting afterwards. Sometimes, I only take it when I come for an ANC check-up. However, there are months when just the thought of having to take this medication prevents me from attending ANC appointments. At times, it is my husband who insists that I go for ANC visits. If something could be done about the size of the medication, it would be much easier for us to take it…" (7th Pregnant Woman, FGD-KNM), seconded by (4th Pregnant Woman, FGD-KNM).

Sociodemographic and maternal predictors of malaria mono-infection

The sociodemographic and maternal predictors of malaria infection among pregnant women are presented in Table 5. In the multivariable analyses, the likelihood of malaria was 63.97 times higher among unmarried pregnant women (AOR = 63.97; 95% CI: 31.21–73.10) compared with those who were married and cohabitated. In terms of educational attainment, the odds of malaria were 2.16 times higher among pregnant women without formal education (AOR = 2.16; 95% CI: 1.35–3.46) compared with those with primary, junior high school, secondary high school, and tertiary education. Regarding household structure as a sociodemographic predictor, pregnant women living in extended-type households had an increased likelihood of contracting malaria (AOR = 6.64; 95% CI: 2.83–9.56) compared with those in nuclear-type households. For household type, pregnant women living in compound-type households had an increased risk of malaria (AOR = 3.29; 95% CI: 1.64–6.60) compared with those living in self-contained households. Concerning household category, the risk of malaria was higher among pregnant women residing in households constructed with mud and thatch (AOR = 10.62; 95% CI: 2.08–14.07), followed by those whose primary building materials were mud and iron sheets (AOR = 2.51; 95% CI: 1.06–5.94) (see Table 5).

Regarding gravidity, primigravidae had 8.10 times the odds of malaria (AOR = 8.10; 95% CI: 3.16–10.78) compared with secundigravida and multigravida. On parity, pregnant women with one child had significantly higher risks of malaria (AOR = 2.73; 95% CI: 1.04–4.12) compared with those who had no child, two, three, or four or more children. Likewise, the risk of malaria was extremely high among first-time pregnant women (AOR = 52.54; 95% CI: 8.63–69.66), second-time (AOR = 35.80; 95% CI: 5.72–44.07), third-time (AOR = 19.50; 95% CI: 2.94–26.07), fourth-time (AOR = 35.02; 95% CI: 5.42–46.27), and fifth-time (AOR = 20.60; 95% CI: 2.61–32.56) ANC attendees. Concerning gestation, the likelihood of malaria was lower among pregnant women in their first and second trimesters (AOR = 0.02; 95% CI: 0.01–0.78) and (AOR = 0.04; 95% CI: 0.01–0.12), respectively. In terms of blood group, pregnant women in the A (AOR = 4.16; 95%

Table 5 Association between socio-demographic and maternal predictors and malaria mono-infection among pregnant women

Variable	Frequency	Malaria status		COR [95%CI]	p-value	AOR [95%CI]	p-value
		Positive	Negative				
	n [%]	n [%]	n [%]				
Age							
18–25	167 (11.7)	13 (0.9)	154 (10.8)	0.50 (0.05–4.53)	0.543	0.60 (0.19–1.87)	0.379
26–30	1088 (76.1)	127 (8.9)	961 (67.2)	0.79 (0.09–6.63)	0.831	1.52 (0.68–3.37)	0.301
31–40	168 (11.7)	14 (1.0)	154 (10.8)	0.54 (0.06–4.85)	0.587	1	
< 18 years	7 (0.5)	1 (0.1)	6 (0.4)	1		1	
Marital status							
Not married	118 (8.3)	81 (5.7)	37 (2.6)	36.50 (23.18–57.49)	0.000*	63.97 (31.21–73.10)	0.000*
Married	1308 (91.5)	74 (5.2)	1234 (86.3)	1		1	
Cohabitation	4 (0.3)	0 (0.0)	4 (0.3)	1		1	
Educational attainment							
No formal education	414 (29.0)	95 (6.6)	319 (22.3)	2.73 (1.92–3.89)	0.000*	2.16 (1.35–3.46)	0.001*
Primary education	612 (42.8)	60 (4.2)	552 (38.6)	1		1	
Junior High School	251 (17.6)	0 (0.0)	251 (17.6)	1		1	
Senior High School	127 (8.9)	0 (0.0)	127 (8.9)	1		1	
Tertiary	26 (1.8)	0 (0.0)	26 (1.8)	1		1	
Type of occupation							
Hairdressing	275 (19.2)	29 (2.0)	246 (17.2)	0.70 (0.15–3.31)	0.661	0.06 (0.01–0.68)	0.053
Seamstress	234 (16.4)	18 (1.3)	216 (15.1)	0.50 (0.10–2.40)	0.388	0.06 (0.01–0.70)	0.074
Farming	204 (14.3)	42 (2.9)	162 (11.3)	1.55 (0.33–7.21)	0.573	0.19 (0.01–2.05)	0.174
Civil service	26 (1.8)	0 (0.0)	26 (1.8)	1		1	
Trading/Marketing	613 (42.9)	61 (4.3)	552 (38.6)	0.66 (0.14–3.03)	0.596	0.11 (0.01–1.13)	0.064
Domestic activities	44 (3.1)	0 (0.0)	44 (3.1)	1		1	
Housewife (unemployed)	14 (1.0)	2 (0.1)	12 (0.8)	1		1	
Student (unemployed)	6 (0.4)	1 (0.1)	5 (0.3)	1.20 (0.08–16.43)	0.891	0.92 (0.05–14.40)	0.955
None (unemployed)	14 (1.0)	2 (0.1)	12 (0.8)	1		1	
Monthly income							
Gh₵ 100–500	692 (48.4)	93 (6.5)	599 (41.9)	0.90 (0.34–2.38)	0.833	3.31 (1.34–8.16)	0.109
Gh₵ 600–1000	538 (37.6)	49 (3.4)	489 (34.2)	0.58 (0.21–1.56)	0.284	1.30 (0.50–3.34)	0.584
Gh₵ 1100–2000	141 (9.9)	8 (0.6)	133 (9.3)	0.34 (0.10–1.14)	0.082	1	
Gh₵ 2100–3000	19 (1.3)	0 (0.0)	19 (1.3)	1		1	
Gh₵ 3100–4000	6 (0.4)	0 (0.0)	6 (0.4)	1		1	
None	34 (2.4)	5 (0.3)	29 (2.0)	1		1	
Household structure							
Extended	1086 (75.9)	140 (9.8)	946 (66.2)	3.24 (1.87–5.60)	0.000*	6.64 (2.83–9.56)	0.000*
Nuclear	344 (24.1)	15 (1.0)	329 (23.0)	1		1	
Household type							
Compound house	1009 (70.6)	134 (9.4)	875 (61.2)	2.91 (1.81–4.69)	0.000*	3.29 (1.64–6.60)	0.001*
Self-contain house	421 (29.4)	21 (1.5)	400 (28.0)	1		1	
Household type							
Compound house	1009 (70.6)	134 (9.4)	875 (61.2)	2.91 (1.81–4.69)	0.000*	3.29 (1.64–6.60)	0.001*
Self-contain house	421 (29.4)	21 (1.5)	400 (28.0)	1		1	
Household category							
Mud with thatch	27 (1.9)	10 (0.7)	17 (1.2)	5.13 (2.30–11.44)	0.000*	10.62 (2.08–14.07)	0.004*
Mud with iron sheets	129 (9.0)	14 (1.0)	115 (8.0)	2.85 (1.30–6.19)	0.039*	2.51 (1.06–5.94)	0.035*
Blocks with iron sheets	1274 (89.1)	131 (9.2)	1143 (79.9)	1		1	
Number of people in household							
1–5	895 (62.6)	80 (5.6)	815 (57.0)	0.19 (0.01–2.18)	0.186	0.12 (0.01–1.56)	0.106
6–10	532 (37.2)	74 (5.2)	458 (32.0)	0.32 (0.02–3.60)	0.359	0.21 (0.01–2.83)	0.245

Table 5 (continued)

Variable	Frequency	Malaria status		COR [95%CI]	p-value	AOR [95%CI]	p-value
		Positive	Negative				
	n [%]	n [%]	n [%]				
11–15	3 (0.2)	1 (0.1)	2 (0.1)	1		1	
Gravidity							
Primigravida	335 (23.4)	85 (5.9)	250 (17.5)	5.59 (3.53–8.85)	0.000*	8.10 (3.16–10.78)	0.000*
Secundigravida	624 (43.6)	43 (3.0)	581 (40.6)	1.21 (0.74–2.00)	0.438	0.48 (0.17–1.35)	0.167
Multigravida	471 (32.9)	27 (1.9)	444 (31.0)	1		1	
Parity							
0	296 (20.7)	34 (2.4)	262 (18.3)	1.60 (0.88–2.92)	0.120	0.28 (0.10–0.76)	0.202
1	627 (43.8)	86 (6.0)	541 (37.8)	1.96 (1.15–3.35)	0.012*	2.73 (1.04–4.12)	0.040*
2	28 (2.0)	2 (0.1)	26 (1.8)	0.96 (0.20–4.34)	0.950	1.46 (0.27–7.91)	0.656
3	238 (16.6)	15 (1.0)	223 (15.6)	0.83 (0.40–1.69)	0.615	0.94 (0.40–2.16)	0.889
4+	241 (16.9)	18 (1.3)	223 (15.6)	1		1	
ANC visits							
1	446 (31.2)	71 (5.0)	375 (26.2)	2.65 (1.61–4.37)	0.010*	52.54 (8.63–69.66)	0.000*
2	320 (22.4)	38 (2.7)	282 (19.7)	1.88 (1.43–2.23)	0.003*	35.80 (5.72–44.07)	0.000*
3	224 (15.7)	13 (0.9)	211 (14.8)	0.86 (0.18–1.02)	0.041*	19.50 (2.94–26.07)	0.002*
4	181 (12.7)	19 (1.3)	162 (11.3)	1.64 (1.36–2.44)	0.020*	35.02 (5.42–46.27)	0.000*
5	97 (6.8)	6 (0.4)	91 (6.4)	0.92 (0.17–1.83)	0.024*	20.60 (2.61–32.56)	0.004*
6	62 (4.3)	0 (0.0)	62 (4.3)	1		1	
7	64 (4.5)	6 (0.4)	58 (4.1)	1.44 (0.27–7.63)	0.662	1.23 (0.20–7.61)	0.819
8	30 (2.1)	2 (0.1)	28 (2.0)	1		1	
9	6 (0.4)	0 (0.0)	6 (0.4)	1		1	
Gestation							
First trimester	1051 (73.5)	104 (7.3)	947 (66.2)	0.34 (0.21–0.53)	0.000*	0.02 (0.01–0.78)	0.000*
Second trimester	256 (17.9)	21 (1.5)	235 (16.4)	0.27 (0.15–0.50)	0.000*	0.04 (0.01–0.12)	0.000*
Third trimester	123 (8.6)	30 (2.1)	93 (6.5)	1		1	
G6PD							
No defect	1371 (95.9)	130 (9.1)	1241 (86.8)	0.10 (0.02–0.36)	0.000*	0.06 (0.08–0.24)	0.124
Partial defect	49 (3.4)	20 (1.4)	29 (2.0)	0.69 (0.17–2.69)	0.593	0.29 (0.06–1.43)	0.129
Full defect	10 (0.7)	5 (0.3)	5 (0.3)	1		1	
Blood group							
A	422 (29.5)	51 (3.6)	371 (25.9)	4.07 (2.08–7.94)	0.000*	4.16 (2.12–8.13)	0.000*
B	420 (29.4)	61 (4.3)	359 (25.1)	5.03 (2.60–9.73)	0.000*	5.07 (2.61–9.82)	0.000*
AB	251 (17.6)	32 (2.2)	219 (15.3)	4.33 (2.13–8.77)	0.000*	4.37 (2.15–8.89)	0.000*
O	337 (23.6)	11 (0.8)	326 (22.8)	1		1	
Anaemia							
Non-anaemic	122 (8.5)	18 (1.3)	104 (7.3)	1.55 (0.86–2.79)	0.142	1.45 (0.80–2.63)	0.220
Mild anaemia	449 (31.4)	45 (3.1)	404 (28.3)	1		1	
Moderate anaemia	843 (59.0)	89 (6.2)	754 (52.7)	1.05 (0.72–1.54)	0.764	1.04 (0.70–1.52)	0.839
Severe anaemia	16 (1.1)	3 (0.2)	13 (0.9)	2.07 (0.56–7.54)	0.269	1.87 (0.50–6.91)	0.346
Sickling							
Positive	45 (3.1)	5 (0.3)	40 (2.8)	1.02 (0.40–2.64)	0.952	0.75 (0.27–2.11)	
Negative	1385 (96.9)	150 (10.5)	1235 (86.4)	1		1	
Syphilis							
Positive	37 (2.6)	7 (0.5)	30 (2.1)	1.96 (0.84–4.54)	0.116	2.46 (0.97–6.18)	0.056
Negative	1393 (97.4)	148 (10.3)	1245 (87.1)	1		1	

ANC antenatal care, *AOR* adjusted odds ratio, *COR* crude odds ratio, *G6PD* Glucose-6-phosphate dehydrogenase, *p < 0.05; n, Frequency; %, Percentage

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CI: 2.12–8.13), B (AOR = 5.07; 95% CI: 2.61–9.82) and AB (AOR = 4.37; 95% CI: 2.15–8.89) blood groups had higher risks than those in the O group (see Table 5).

Discussion

Prevalence of malaria mono-infection among pregnant women

The overall prevalence of malaria mono-infection among pregnant women was approximately 10.8% (95% CI: 9.32–12.56). A statistical significance was observed between the proportion of pregnant women with evidence of malaria mono-infection and those without malaria ($\chi^2 = 1327.891$, DF = 1, $p < 0.05$). This underscores sufficient evidence to reject the null hypothesis that "*there is no statistically significant difference between the proportion of pregnant women with malaria-mono-infection and those who are not infected*". Therefore, this study failed to reject the alternative hypothesis that "*there is a statistically significant difference between the proportion of pregnant women with malaria mono-infection and those who are not infected*".

A series of previous studies conducted in Ghana have also reported a high prevalence of malaria among pregnant women [15, 26, 27]. Although the rate of occurrence reported in these studies differs from the result of the current study, all the prevalence observed was higher than the national prevalence of 8.6% [28]. A previous study conducted outside Ghana has also reported the prevalence of malaria among pregnant women [29]. The differences in reported prevalence may be due to geographical variations, intensity of malaria transmission, enforcement of preventive guidelines, and adherence to these guidelines.

The high prevalence rate above the national standard observed in this study could be attributed to susceptibility to risk factors and non-adherence to malaria preventive guidelines on pregnant women. At the institutional level, this surge in prevalence could be due to challenges in the implementation of recommended preventive guidelines and limitations in the availability of interventions. Some feedback during the IDIs with senior midwives and FDGs with consented pregnant women confirmed that some pregnant women did not adhere to certain interventions. For instance, one of them recounted:

> *"...To a significant extent, there is negligence on the part of many pregnant women. Despite providing ITNs for malaria prevention, a considerable number of pregnant women fail to consistently use them." (Incharges, IDI-KSD & IDI-PED)*

> *"...To be honest, the SP medication they provide us with during ANC visits is quite big, making it very challenging to swallow. Even if I manage to swallow it, I often feel like vomiting afterwards ..."—(4th Pregnant woman, FGD-KNM).*

Risk factors for malaria mono-infection

A series of risk factors significantly associated with malaria mono-infection among pregnant women were identified. Pregnant women whose households had netted windows that fit perfectly into the walls had a lower risk of malaria. This observation is consistent with a previous study [30]. This can be attributed to the mesh size when used as a screen for household windows. The relatively smaller mesh size creates a physical barrier that may reduce the influx of mosquitoes into various household rooms in households.

Additionally, the risk of malaria infection was higher among pregnant women whose households had farm or domestic animals, which is consistent with earlier reports [31]. This could be attributed to the skin, fur, and feathers of some domestic or farm animals generating and contributing to some of the cues which attract mosquitoes to homes, as well as the presence of puddles of water, troughs, or other containers where animals drink providing breeding sites for mosquitoes [32]. On the contrary, some studies emphasized that some farm animals, particularly cattle, could serve as barriers to malaria transmission by drawing mosquito bites away from humans [33], thus yielding an increased nonprophylactic effect [31]. Be that as it may, there are several other studies which have shown that some of the main malaria vectors are mostly anthropophilic and anthropophagic; they prefer to feed on humans when both humans and animals are present in a given location [34]. The complex interaction between domestic or farm animals and malaria risk underscores the need for constructing isolated and well-maintained shelters for animals.

Furthermore, the study revealed that pregnant women living close to drainage tunnels had a higher likelihood of malaria infection, which is consistent with a previous study [35]. Drainage tunnels accumulate stagnant water, thereby providing suitable sites for larval growth, resulting in an increase in mosquito density. This observation necessitates the regular cleaning and maintenance of drainage systems to prevent water from becoming stagnant. Likewise, pregnant women residing in households closer to drainage tunnels could be encouraged to use window screens and doors to prevent mosquitoes from entering their rooms.

Consequently, the study reported a higher likelihood of malaria infection among pregnant women whose

households were closer to overgrown vegetation, which is also consistent with a previous study in Uganda [36]. The mechanisms underlying this observation may be multifaceted, but overgrown vegetation may reduce airflow and sunlight penetration. This could result in creating a cooler and more humid environment, including temporary resting places, which may tend to favour the development and survival of mosquitoes. To mitigate this, there is a need for regular clearing and trimming of overgrown vegetation around households to reduce mosquito densities.

In addition, the study revealed lower odds of malaria among pregnant women who used insecticide mosquito coils and sprays than among non-users. This is consistent with a previous study [37]. Mosquito coils and sprays are not recommended as preventive measures for malaria vector control due to the health hazards and possible risks associated with their usage [38]. However, they contain insecticides that are expected to vaporize slowly to protect against mosquito bites. The effectiveness of these insecticides depends on a series of factors, including their concentration and duration of use. These insecticides may only prevent mosquitoes from biting, but they might not have a total knock-off effect on mosquitoes [39]. Although insecticide mosquito coils may provide some protection against mosquito bites, exclusively relying on them may not provide complete protection against malaria. Hence, it should be considered part of an all-inclusive malaria prevention and control approach.

Moreover, the study found that the risk of malaria was reduced among pregnant women who regularly adhered to the IPTp-SP during antenatal care visits. IPTp-SP helps to clear existing parasites and provides a prophylactic effect against further parasitic loads during pregnancy, thereby decreasing the risk of severe malaria and pregnancy-related complications. This observation is consistent with a series of previous studies [13, 40].

Finally, the study reported that pregnant women whose households underwent indoor residual spraying (IRS) had decreased odds of being infected with malaria. IRS involves spraying insecticides on the indoor walls and surfaces of houses in areas of high malaria endemicity. The insecticides used in IRS are typically long-lasting and can remain effective on treated surfaces for several months, providing longstanding defence against mosquitoes. Upon contact with treated surfaces, mosquitoes are either repelled or killed. This significantly reduces the parasitic density and feeding behaviour of mosquitoes within households and communities. The findings of this study confirm a study conducted in Northern Ghana [41].

Sociodemographic and maternal predictors of malaria mono-infection

In this study, the risk of malaria infection was approximately 64 times higher among unmarried pregnant women, which is consistent with a previous study [42]. This could be attributed to several factors, including income, support system, behavioural practises and frequent access to healthcare services. Unlike unmarried women, married women often have higher household incomes and better access to resources because of their planned saving culture and the improved socioeconomic status of their male partners [43]. In effect, these situations could enhance the financial capacity of these women to acquire malaria interventions, such as ITNs, mosquito coils, repellents, and sprays. In addition, reminders of the need to adhere to these interventions by spouses could influence consistent use, thereby reducing the risk of malaria infection.

The study further revealed an increased risk of malaria infection among pregnant women without formal education, which is also affirmed by previous reports [29, 44]. Unlike pregnant women without formal education, those with formal education have better access to information about malaria prevention and seeking early medical care. These factors, coupled with adequate knowledge regarding various risk factors, may decrease susceptibility and thus transmission.

In terms of household structure, the risk of malaria infection was higher among pregnant women living in extended-type households. For household type, pregnant women living in compound-type households had an increased risk of malaria. A characteristic feature shared by both extended and compound-type households was the household density, the number of rooms, and shared amenities such as toilet facilities, bathrooms, kitchens, and a common playground for children. A study of pregnant women resident in urban slums in southern Ghana revealed that more persons in the household were associated with an increased risk of malaria infection [45]. Because both extended and compound-house-type households have relatively a greater number of individuals, they may experience more crowded living conditions, which could potentially increase the risk of malaria transmission because mosquitoes have more potential hosts to bite. Moreover, in both extended and compound-type households, improper waste disposal could create a conducive environment for mosquito breeding, increasing the risk of malaria transmission.

Consequently, pregnant women residing in households constructed with mud and thatch, or iron sheets had increased odds of malaria infection. This finding

was consistent with a previous study [46]. This can be ascribed to the poor or weak structural make-up of households constructed with mud. These households have a series of gaps in both walls and roofs which provide entry portals for mosquitoes.

Gravidity and parity were also significantly associated with an increased risk of malaria, which is consistent with previous reports [15, 47, 48]. This could be due to a lack of acquired immunity against malaria. Multiple pregnancies enhance the ability of women to develop specific immunity against malaria [49]. Thus, the primigravidae have a comparatively lower number of antibodies for protection against *Plasmodium* parasites, which in turn increases the risk of infection.

Furthermore, lower ANC visit was identified as a significant predictor of malaria among pregnant women, which is in agreement with a series of previous studies [50, 51]. The World Health Organization (WHO) recommends at least eight ANC visits during pregnancy, with the first visit occurring during the first trimester of pregnancy [50]. As part of the routine associated with antenatal care, diagnoses are performed on pregnant women to determine pregnancy-related complications [50]. This approach allows for early detection and treatment, which could only be forfeited if the recommended number of ANC visits is not adhered to. Consequently, another significant predictor of malaria was gestation, which is consistent with earlier reports [15, 48]. This study, in particular, revealed a lower risk of malaria among pregnant women in their first and second trimesters.

Finally, the study revealed a higher risk of malaria among pregnant women with blood groups A, B, and AB, respectively. This observation was affirmed in a previous study [52] and could be attributed to the presence of A and B antigens on the surfaces of red blood cells of blood groups A, B, and AB, which facilitate the rosetting of parasitized erythrocytes and cytoadherence [53]. This further contributes to the pathogenesis of severe malaria by obstructing microvascular blood flow [54]. Existing reports point to the fact that because A and B antigens are not present on the surfaces of the red blood cells of blood group O, rosetting is reduced in the red blood cells of individuals who are of blood group O compared with non-O blood groups (A, B, and AB) [55].

Conclusion

This study provided significant insights into the prevalence of malaria among pregnant women in the Bono East Region of Ghana. The overall malaria prevalence of approximately 10.8% was higher than the national prevalence of 8.6%. The high prevalence of malaria, associated risk factors, and sociodemographic and maternal predictors highlight significant areas for targeted interventions. These include developing standard operations for home healthcare by assigning healthcare personnel to groups of pregnant women to provide healthcare services, including screening for malaria, administering treatments, monitoring maternal and foetal health and providing education and counselling. This could be achieved by determining the optimal number of pregnant women per group that a healthcare team (consisting of midwives, obstetricians, health educators, and community health nurses) can manage effectively. Likewise, community-based educational outreach programmes could be implemented, especially in rural areas to provide pregnant women with insights into regular consultations and early adherence to interventions.

Abbreviations

ANC	Antenatal care
AOR	Adjusted odds ratio
CI	Confidence interval
COR	Crude odds ratio
EDTA	Dipotassium ethylenediaminetetraacetic acid
FGDs	Focus group discussions
G6PD	Glucose-6-phosphate dehydrogenase
GDHS	Ghana Demographic and Health Survey
GLSS6	Ghana Living Standards Survey Round 6
HB	Haemoglobin
IDIs	In-depth interviews
IPTp-SP	Intermittent preventive treatment with sulfadoxine-pyrimethamine
ITNs	Insecticide-treated mosquito nets
SOP	Standard operating procedure
UTIs	Urinary tract infections
WHO	World Health Organization

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Author contributions

D.B. conceived and designed the study in consultation with D.H., R.B.B., and D.D.Y. D.B. and R.B.B. collected, analysed and interpreted the data. D.B. contributed materials and wrote the first draft of the manuscript. R.B.B., D.H., and D.D.Y. reviewed, made the necessary inputs and corrected the original dissertation and the first draft of the manuscript. This study was part of the dissertation of D.B. towards his master of philosophy degree in public health under the direct supervision of D.H., R.B.B., and D.D.Y. All authors reviewed and approved the final manuscript.

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Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to anonymity and confidentiality but are available from corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The protocol of the study was reviewed and approved by the Committee on Human Research, Publication, and Ethics (CHRPE), Kwame Nkrumah University of Science and Technology, School of Medical Sciences (CHRPE/AP/1081/23).

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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