Are there variations in hotspots in clinical malaria in pregnancy and neonatal malaria? Evidence from Ghana

Naa-Korkor Allotey (✉ naa.korkorallotey@ghsmail.org)

Ghana Health Service <https://orcid.org/0000-0003-3955-2745>

Kofi Osae

Ghana Ministry of Health

Wahjib Mohammed

Ghana Health Service

Agnes Millicent Kotoh

UG School of Public Health: University of Ghana School of Public Health

Ernest Kenu

UG School of Public Health: University of Ghana School of Public Health

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Abstract

Background

Malaria in pregnancy (MIP) is a significant public health problem, and affects both mother and foetus. MIP has both direct and indirect effects. These direct effects attributed to malaria in pregnancy are clinical malaria in pregnancy and congenital malaria. Although there has been a steady decline of malaria in pregnancy (MIP); reducing from 9% in 2004 to 1.4% in 2016, the decline, does not seem equitable across the country. There was therefore a need to identify areas where clinical MIP and neonatal was high and target them for interventions (neonatal malaria was used because data for malaria was available only for the first 28 days). As a result, this study sought to use routine data to identify areas of high transmission (hotspots) for clinical malaria in pregnancy and neonatal malaria (extrapolating for congenital malaria hotspots).

Methods

Clinical MIP and neonatal malaria (suspected and confirmed) data were retrieved from the national routine database. Using expected pregnancy and all clinical malaria cases as the denominators of clinical malaria in pregnancy and clinical malaria respectively, the per 1000 cases of malaria in pregnancy and percentage neonatal malaria were calculated for both conditions. These two data sets were fed into ARC GIS software and hotspots spatially determined for both conditions from 2014 to 2016.

Results

Variations in hotspots were identified both chronologically and geospatially for clinical MIP and neonatal malaria respectively. Nevertheless, stable hotspots were found for clinical malaria in pregnancy for the three years and stable hotspots also identified for Neonatal malaria for two years. Congenital malaria was extrapolated from neonatal malaria data only for Bole District in the Northern Region of Ghana for 2015.

Conclusions:

Hotspots for malaria in pregnancy show marked variation year on year both for clinical malaria in pregnancy and neonatal malaria and vary geospatially. The differences in hotspots in clinical malaria in pregnancy and neonatal malaria also show that neonatal malaria cannot be attributed to congenital malaria and therefore is not the effect of malaria in pregnancy. However, stable hotspots for clinical malaria in pregnancy should be targeted for intervention.

Background

Malaria, during pregnancy, is a significant public health problem particularly in sub-Saharan Africa. It affects both the mother and the foetus. (1). Pregnant women constitute the main adult risk group which is serious for the foetus in malaria endemic countries. The condition may be asymptomatic or

symptomatic, and manifests as follows: clinical malaria (symptomatic), maternal anaemia, spontaneous abortion, preterm birth, low birth weight, intrauterine growth retardation, preterm delivery, foetal anaemia, stillbirth and rarely congenital malaria (may manifest as neonatal malaria) (2). These effects of malaria in pregnancy are particularly found in the primigravid and secundigravid women(1) and women living with HIV (3).

Malaria is caused by *plasmodium* sp and transmitted by the infective female *Anopheles* mosquito. The most vulnerable groups are children under five years (accounting for 70% of all 429 000 deaths worldwide in 2015) (4), pregnant women (causing about 10,000 deaths per year) (3) and migrants to endemic countries for less than six months.

Ghana is mesoendemic for malaria and the disease is found in all areas of the country. Prevalence of malaria in Ghana averages 21% among children under five years (indicator used to assess malaria prevalence); ranging from 25% in Northern Region to 5% in Greater Accra(5).

The National Malaria Control Programme (NMCP) has since 2003 revamped interventions to control and reduce the burden of malaria in Ghana. These efforts have contributed to reducing the burden of malaria in pregnancy over the past several years. For example, in 2016, malaria in pregnancy contributed to 1.4% of all malaria outpatient attendances as compared to 9% in 2004(6).

Nevertheless, the NMCP has postulated that the reduction may not be even in all parts of the country. Identifying areas of greatest burden and morbidity, referred to as hotspot, is necessary. It helps in determining populations with greater incidence to enable countries to design targeted control and prevention measures (7). By definition, a hotspot is an area with a higher-than-average level of transmission intensity or burden of disease. Hotspots are not straightforward to determine but are important in ensuring targeted interventions (8). Identification of a hotspot could be a challenge. To address this challenge, some authors have used spatial distribution in the form of hotspots to identify areas of the highest burden [7, [8].

Some authors have used geographic information system (GIS) to identify hotspots of disease prevalence both at the national and international levels. Fobil used GIS to identify hotspots and coldspots relating to malaria and diarrhoea-related mortality in Accra (10). Kenu also used GIS to identify communities with the greatest concentration of buruli ulcer cases along the Densu River in Ghana (11).

Different authors have used various indicators to identify malaria hotspots. These include malaria incidence, asymptomatic parasite carriage, reported fever, drug use, serological responses to malaria-specific antigens, mosquito abundance, and exposure to infected mosquitoes (8,9). Some other authors have identified hotspots at the community level. Bousema et al (12), used age-adjusted prevalence and density of antibodies against malaria to determine hotspots of malaria in a community. In other instances, routine data has been used to identify hotspots. Kamuliwo et al, tracked monthly reported district-level clinical cases of malaria in pregnancy using routine Zambian District Health Information System to detect malaria hotspots in the country (9).

This study therefore sought to ascertain the existence of clinical malaria in pregnancy and neonatal malaria hotspots in the Ghana, and show whether the reduction in malaria in the country is inequitable. It also determined whether districts with hotspots for neonatal malaria could be attributed to hotspots for congenital malaria. This study also determined areas of high malaria morbidity (i.e. malaria in pregnancy and congenital malaria) through geospatial identification of hotspots. This is because clinical malaria in pregnancy and congenital malaria are conditions directly linked to malaria in pregnancy.

Methods

Study Design and Population

The study was a retrospective cross-sectional review of routine data in District Health Information Management Systems 2 (DHIMS2). The population covers pregnant women who have reported with clinical malaria in pregnancy (confirmed and unconfirmed). The second set of study population are neonates (infants less than 28 days) with confirmed and unconfirmed malaria.

Study area

Ghana is endemic for malaria with an estimated population of 28.21 million people in 2016 with population growth rate of 1.9%, projected from the 2010 Population Census. Expected pregnancy is estimated at 4% of the population (13). The rural-urban ratio is 47:53 of the total population (14). Ghana has 10 administrative regions, which are further divided into 216 districts based on the population and land size.

Definition of Variables

In this study, the term 'expected pregnancies' is defined as the number of women in the reproductive age in the population who are expected to become pregnant within each year. Neonatal malaria refers to uncomplicated malaria suspected cases in children 28 days or less reported on the Monthly Morbidity Out-Patient-Department (OPD) returns. Clinical malaria in pregnancy is defined as all pregnant women reporting at health facilities with clinical symptoms of uncomplicated malaria; whether confirmed or not. The information was extracted from the population data form on the DHIMS2 platform and the 2010 Population and Housing Census.

Z-score refers to districts whose clinical malaria in pregnancy and/or neonatal malaria per 1000 respectively are zero, one (+/-1), two (+/- 1.96) or three (+/-2.58) standard deviations away from the mean of each district and its neighbouring districts; number of neighbouring districts ranging from 5 to 10.

In this article, a district was termed "hotspot" or "coldspot" as follows: Hotspot, lighter orange: z-score:1.0; hotspot orange z-score: 1.96; brownish-red hotspot: 2.58

Cold spot: deep blue: z-score: -2.58, dark blue; coldspot; z-score: -1.96, lighter blue: cold spot: z-score: -1.0.

Light yellow; z-score: 0; district has no significant hotspot.

Study participants

The study participants were pregnant women with clinical malaria in pregnancy (confirmed and unconfirmed) and neonates; i.e. infants of 28 days or less with malaria symptoms which were either confirmed or unconfirmed.

Data Collection

All the data used in this study were extracted from the DHIMS2 platform for 2014-2016. The incidence per 1000 was calculated as follows:

Clinical Malaria in Pregnancy: "Uncomplicated Malaria Suspected" data were extracted from Monthly Morbidity OPD Returns for the years 2014-2016. The incidence per 1000 expected pregnancies, calculated using data on the expected pregnancy for districts Population Data extrapolated from the 2010 Population and Housing Census. Both were obtained from the DHIMS2 platform and the z-scores were calculated for each districts). The study population is all cases of uncomplicated clinical malaria in pregnancy (whether tested or not) that was reported on the DHIMS2 platform and all expected pregnancies for all districts.

Data of uncomplicated neonatal malaria (confirmed and unconfirmed) incidence were retrieved for 2014 to 2016 from DHIMS 2 platform. Data on incidence of suspected malaria in children less than 28 days were extracted from the same Monthly Morbidity OPD returns form. All uncomplicated malaria suspected cases for all ages were also extracted from the same form and used as the denominator.

Statistical Analysis

Data on clinical malaria in pregnancy per 1000 and neonatal malaria percentage of all malaria cases were generated and fed separately into Aeronautical Reconnaissance Coverage Geographic Information System (ArcGIS). The mean for all districts was calculated and the z-scores in relation to neighbouring districts obtained. These were plotted spatially using the coordinates of districts.

Hotspot Analysis

The Hot Spot Analysis tool calculates the Getis-Ord Gis statistic for each district. The resultant Z-score gives an indication of which districts have either a high or low value cluster spatially. Each district was assessed in the context of neighbouring districts. A spatial weighted matrix was then created with the following spatial relationship conceptual framework:

Spatial relationship was based on contiguity edges and corners (i.e. which districts share a boundary, a node, or overlap) as means of defining neighbours. Average number of neighbours was six districts, minimum and maximum number of neighbours were 5 and 10 districts respectively.

A hotspot analysis was done using the parameters of the spatial weighted matrix with a Euclidean Distance method to determine clustering of high and low figures of malaria in pregnancy across districts geographically.

A high z-score and small p-value for a district indicated a spatial clustering of high values. A low negative z-score and small p-value indicates a spatial clustering of low values. The higher or lower the z-score, the more intense the clustering. A z-score near zero indicates no apparent spatial clustering.

Results

Demographic Characteristics

Table 1 shows that total the number of cases of clinical malaria in pregnancy identified among girls and women aged 10–49 years for the period 2014–2016 was 933,225. Of this, 383,034 (41%) cases were recorded in 2016 and 24,330 (24.04%), the lowest, in 2014. The mean number of uncomplicated malaria in pregnancy for the three years, 2014–2016, is 311,075. The mean of clinical malaria in pregnancy per 1000 was 347.60.

Table 1
Distribution of Uncomplicated Clinical Malaria in Pregnancy for 2014–2016 for Ghana

Year	Uncomplicated clinical malaria in pregnancy	Percentage	Clinical malaria in pregnancy per 1000 women	Mean of cases per Region	Standard Deviation
2014	224330	24.04	258.95	22433	7436
2015	325861	34.92	359.64	32586.1	1424
2016	383034	41.04	424.21	38303.4	16502
Total	933,225	100	Mean for 2014–2016: 347.6	Mean for 2014–2016: 311,075	

Table 2 shows that a total of 112,951 cases of neonatal malaria were reported for 2014–2016. Neonatal malaria cases represent 0.37% of all malaria cases for 2014, 0.43% for 2015 and 0.37 for 2016 respectively. The ratio of males to females is 1:1.15

Table 2
Distribution of Uncomplicated Neonatal Malaria by Gender for 2014–2016

Year	Males	Females	Neonates with uncomplicated malaria cases	uncomplicated malaria cases	Percentage of neonatal malaria of total malaria cases (%)
2014	14808	16352	31160	8,448,394	0.37
2015	12479	14532	43639	10,186,510	0.43
2016	11141	13497	38152	10,447,524	0.37
Total	38,428	44,381	112,951	29,082,428	0.39

From Fig. 1, the country largely had a zero z-score and no significantly high burden of clinical malaria in pregnancy for the three years (2014–2016). However, variations in the hotspots were identified. Most of the hotspots varied geospatially and chronologically for the three years. For example, in 2014, hotspots were identified in Western, Volta and Upper East Regions. In 2015, hotspots were identified in Western and in Brong Ahafo (Kintampo North, Wenchi and Nkoranza North) Regions and one in Northern Region (which was neighbouring the said districts in Brong Ahafo). Hotspots identified in Brong Ahafo in 2016 and 2015 were the same, Western and in one district in the Eastern Region. Stable hotspots were however, identified for the three consecutive years in Western and Central Region. Districts in Western Region include Prestea Huni Valley, Tarkwa Nsuem, Wassa East and Mporhor and Central Mfantseman. The number of districts identified as hotspots in Western Region was 15 in 2014 as compared to 7 in 2016. It is also worthy of note that coldspots were identified in the Greater Accra Region in 2014 and 2015 but not in 2016. Furthermore, new coldspots were found in some parts of the Northern Regions and in the Volta Region (along the lake).

Figure 2 shows that Ghana generally averaged a zero z-score for neonatal malaria. Nevertheless, some hotspots for neonatal malaria were identified. These hotspots showed variation for the three years under review. However, there was a hotspot in Bole in 2014 and 2015. In addition, hotspots were found for two consecutive years for some districts in the Brong Ahafo, with the number increasing from 7 districts in 2015 to 15 districts in 2016.

Furthermore, it is of interest to note that in 2015, Bole District in the Northern Region was a hotspot for both neonatal malaria and clinical malaria in pregnancy.

Discussion

Malaria morbidity and mortality in Ghana have been largely declining [6, [15]. This decline has also been found in malaria in pregnancy; a condition which has direct effects of clinical malaria in pregnancy and congenital malaria (using neonatal malaria as a proxy in this article). However, authors of this study doubted that the decrease in malaria in pregnancy was not equitable across the country. Consequently, this study sought to establish the existence of hotspots of malaria in pregnancy (if any) in Ghana. These hotspots were measured using incidences of clinical malaria in pregnancy and neonatal malaria.

Clinical Malaria in Pregnancy

The average proportion of clinical malaria in pregnancy was 347.60 per 1000 women. The proportion was highest in 2016 compared to 2014 and 2015. The high incidence for the 2016 year may be attributed to better reporting and not an increase in incidence. Indeed, the introduction of routine data reporting on the platform DHIMS2 has improved to a large extent the quality of data collated from health facilities. Therefore, an increase in proportion of clinical malaria in pregnancy could be linked more to improved reporting. Correspondingly, the assertion of better reporting has also been made by Rouamba, Samadoulougou, Tinto, Alegana and Kirakoya- Samadoulougou (16). Notwithstanding the assertions of improved reporting, Rouamba et al(16) indicated that the World Health Organisation (WHO) has reported increases in global cases of malaria.

Also consistent with the argument of better reporting is the consistent reduction in the prevalence of malaria since the revamping of malaria intervention in 2004. For example, malaria prevalence reduced between 2011 and 2016; from 27.5 % in 2011 (MICS, 2011) to 26.7% in 2014 (GDHS, 2014) to 20.4% in 2016 (Malaria Indicator Survey, 2016) (5) (NB: These figures are from different data sources, but the tools and the respective questions are similar. Therefore inferences can be drawn (5)). From the foregoing possible attributions, further research is needed to ascertain the cause of the increase in burden in 2016.

Figure 1 shows maps of uncomplicated between 2014–2016, and Ghana was found to have an average of zero z-score for clinical malaria in pregnancy. This generally indicates that interventions for fighting malaria (including those targeted for clinical malaria in pregnancy) were largely effective. The average zero z-score for these three years is consistent with findings from Aregawi et al (15). That is, Aregawi et al (15) identified that among all ages, outpatient malaria cases dropped by 57% (95% CI, 47–66%) by first half of 2015.

Nevertheless, hotspots were identified in the country. Some hotspots were stable while others showed variation both geospatially and chronologically year on year. This finding contrasts the results of Bousema et al (12) who identified stable hotspots in his study.

Stable hotspots were identified in the southern part of Western Region for the three years. They include Prestea Huni Valley, Tarkwa Nsuem, Wassa East and Mporhor. Findings of stable hotspot are consistent with those documented by Bousema and others (12) and Kamuliwo et al (9) for clinical malaria in pregnancy. Kamuliwo et al (9) also found stable hotspots (z-score > 2.58) in the north-eastern and south-eastern parts of Zambia.

Another point of interest is that, the districts in which these hotspots were found are largely rural. This finding is consistent with literature, in which greater levels of malaria transmission are found in rural areas compared to urban areas. For example, a desk review, triangulated data from entomological studies and the 2011 Malaria Indicator Cluster Survey (MICS) in the 2012 Ghana Malaria Urban Study (17). The study confirmed higher malaria transmission in rural areas. Stable hotspots in these rural areas may be due to poor health seeking behaviour because of barriers with respect to geographical access. Such an assertion has

also been made by Wiru, Oppong, Gyaase, Agyei, Abubakari, Amenga-Etego, Zandoh & Asante(18). Wiru et al(18) attributed malaria mortality hotspots in their study to districts being mostly rural.

A second reason for these stable hotspots was that they were found mostly in the Forest Ecological Zone. These districts have had their environment largely degraded by illegal mining, resulting in large pools of water suitable for the breeding of the anopheles mosquito (19). The proliferation of such collections of water is likely to lead to an increased number of mosquitoes. Therefore, this increase in mosquitoes, would result in elevated entomological inoculation rates and its related upsurge in malaria transmission rates (20).

In spite of the stability in some hotspots, there were also variability in other hotspots for clinical malaria in pregnancy. In Western Region for example, hotspots reduced from 15 in 2014 to 7 in 2016. This finding is consistent with the reduction of parasite prevalence of malaria (among children less than 5 years) in country-wide surveys of 2014 MICS and 2016 MIS. These two surveys also showed a reduction of parasite prevalence from 39% (2014 MICS) to 22% (2016 MIS)(21). It would imply that malaria transmission has reduced significantly within the two years.

In fact, variability in hotspots in those areas may also be attributed to the level efficiency of the health system; using its six building blocks (i.e. leadership/governance, healthcare financing, health work force, service delivery, health information system and medical products and technologies(22)). Of particular relevance to this study is the improved availability of malaria logistics (in this case, the availability and use of ITNs and sulphadoxine-pyrimethamine (SP) for intermittent preventive treatment (IPTp)). Unfortunately, factors such as supply chain blockages have been found to be a challenge. For example, availability of SP varies year-on-year depending on whether there is accessibility, shortages or mal-distribution at the facility level (23). For instance, in 2016 there were stock outs of SP at the facility level but there were stocks at the regional level (6). Indeed, Bhushan and Bhardwaj (24) identified that some health system effects such as quality of care and critical shortages in commodities had impact on transmission, further impeding reduction in maternal and newborn mortality.

Lastly, variability in hotspots may also be linked to pathogen's natural history (20). For instance, Paull et al (20) identified geospatial heterogeneity as being responsible for transmission of diseases such as SARS and Typhoid. They however concluded that such variability was caused by host factors in 20% of the cases and transmission events in 80% of cases.

Neonatal Malaria

Studies on neonatal malaria are scarce because neonatal malaria is not thought to be common. Therefore, studies to identify hotspots of neonatal malaria are not common either. Albeit, Makhtar (25) in his review of literature reported that neonatal malaria is not as rare as was originally anticipated. Indeed, a meta-analysis by Park, Nixon, Miller, Choi, Kurtis, Friedman & Michelow found a significant pooled adjusted hazard ratio of 1.46 (95% CI, 1.07–2.00; $P < .001$) for neonatal malaria (26). Additionally, by

extrapolation, a congenital malaria was initially misdiagnosed because Kane, Diallo, Dembélé, Fané, et al, (27), did not initially test for neonatal malaria.

Hence, it was not surprising that the review of neonatal malaria incidence for the years 2014–2016 from routine data showed that neonatal malaria in Ghana existed. The review further showed that there were less male neonatal malaria cases reported than females (1:1.15) (Table 2). Lower proportion of males than females with neonatal malaria contradicts findings by Runsewe-Abiodun et al in Nigeria; who found more males than females (1.6:1) had neonatal malaria (28). Runsewe-Abiodun et al's study however reported that the infection was not sex-linked and hence the difference in sex distribution in the two studies cannot be linked to the disease (28).

Our study also revealed that Ghana largely had a zero z-score for neonatal malaria; although hotspots were identified in all the three years under review. Nevertheless, these hotspots for neonatal malaria showed variability year-on-year as with those found for clinical malaria in pregnancy. Hotspots for neonatal malaria were found in the forest ecological zone and rural areas. Hotspots in these identified areas are in tandem with literature because forest zones and rural areas have been documented to have high transmission rates (17).

These hotspots even increased in number in 2016. The increase in hotspots may also be due to better reporting as has been stated above. The increase in hotspots may also be attributed to increased resistance of malaria parasites to the prevailing antimalarial drugs and increased virulence (29).

In spite of hotspot variability, some districts were consistent with hotspots for neonatal malaria for 2015 and 2016 in Ashanti and Brong Ahafo Regions. In addition, it is noted that there was a persistent hotspot in Bole in the western border of Northern Region for two consecutive years (2014–2015). Since Bole is in the western border with la Côte d'Ivoire, it could be that there was consistent transmission across borders.

In 2016, some parts of Northern Ghana (Kumbungu, Tolon and Wa West) had hotspots for neonatal malaria. Some of these districts had the intervention of Indoor Residual Spraying (IRS) discontinued. The emergence of these hotspots may thus be due to suspension of IRS; leading to a rebound effect of malaria cases; particularly for the neonates. This is of particular importance because malaria transmission in Northern Ghana tends to be more seasonal and therefore children in these part are more vulnerable.

Notwithstanding, Kumbungu continues to receive IRS and therefore hotspot can not be completely attributed to a rebound malaria incidence. Additionally, the attribution may not necessarily be associated with cessation of IRS because findings from Kamuliwo et al's work (9), showed the protective effect of IRS.

One must note, albeit, that the neonatal hotspots are few and therefore largely IRS has had protective effect in other districts particularly because there is significant reduction in prevalence of malaria in the

three regions in the north (5). It will be informative to undertake further studies to ascertain the persistent case of hotspots in Northern Ghana.

Interaction of Clinical Malaria in Pregnancy and Neonatal Malaria Hotspots

Generally, districts with hotspots for clinical malaria in pregnancy and neonatal malaria respectively were not the same. This buttresses the findings of Menendez and Mayor (30) that neonatal malaria may have been and identified within the first few days of life.

Yet, of significant interest is that of Bole District, which was found to have elevated levels of both clinical malaria in pregnancy and neonatal malaria for the year 2015. It is therefore supposed that a significant proportion of the clinical malaria may have been vertically transmitted from mothers to the neonates; giving incidences of congenital malaria. This would be recorded as neonatal malaria because the DHIMS 2 data collection platform does not segregate data into first 7 days and above. This assertion is supported by the meta-analysis by Park et al (26). Indeed, Nhama, Varo and Bassat (31) in their commentary have called for further investigation into incidences of suspected congenital and neonatal malaria cases as their burden may be more than may have been originally thought of. Further investigation into effects of stillbirths, congenital anaemia from the neonate in relation to the women with clinical malaria in pregnancy is needed to confirm if reported neonatal malaria in Bole can be attributed to congenital malaria.

Limitations

At the time of data mining, the country had some challenges with data of confirmed cases and therefore it was decided that presumptive diagnosis of malaria be used. This gave a uniform description of clinical malaria in pregnancy and neonatal malaria in pregnancy. Albeit, the findings may not reflect data of confirmed cases.

Conclusion

The country averagely had zero z-score regarding levels of clinical malaria in pregnancy and neonatal malaria. Hotspots were identified for all three years under review but showed year-on-year variations. In the case of clinical malaria in pregnancy, there were stable hotspots in parts of the Western Region and few districts in Central Region. Also, stable hotspots of neonatal malaria were found in parts of the Ashanti and Brong Ahafo Regions and in some parts of the northern regions. It must be noted however that these hotspots were in different parts of the country for clinical malaria in pregnancy and neonatal malaria respectively for the different years.

An exception was found in Bole in 2011, where a hotspot was found for both clinical malaria in pregnancy and neonatal malaria. Therefore, it is suspected that for the year 2015, some neonatal malaria cases reported may have been congenital malaria. It is recommended that Bole be monitored and if a

similar situation ensues, a polymerase chain reaction (PCR) may be carried out to ascertain or contradict the assertion that neonatal malaria was transmitted vertically from the mothers.

Finally, Ghana has to put a system of constant monitoring of hotspots across the country in place, in order to target interventions. This system would be relatively easy to put in place because routine data is constantly being fed into the DHIMS platform.

List Of Abbreviations

MIP: Malaria in Pregnancy

ARC GIS: Aeronautical Reconnaissance Coverage Geographic Information System

WHO: World Health Organisation

NMCP: National Malaria Control Programme

DHIMS2: District Health Information Management Systems

GSS: Ghana Statistical Service

OPD: Outpatient Department

GHS: Ghana Health Service

GIS: Geographic Information System

MICS: Multi Indicator Cluster Survey

GDHS: Ghana Demographic and Health Survey

MIS: Malaria Indicator Survey

CI: Confidence Interval

ITN: Insecticide Treated Nets

IPTp: Intermittent Preventive Treatment for pregnant women

SP: Sulfadoxine-Pyrimethamine

IRS: Indoor Residual Spraying

PCR: Polymerase Chain Reaction

Declarations

Ethical Approval: Data used was secondary data retrieved with the permission of the National Malaria Control Programme of the Ghana Health Service and the Ministry of Health. So, an ethical review was not needed.

Availability of Data: The data that supports the findings of this study will be made available on request from the National Malaria Control Programme of the Ghana Health Service of the Ministry of Health.

Consent for publication: Not applicable

Competing Interest: The authors declare that they have no competing interests.

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Authors' Contributions: NKA, EK, KO and WM designed the study. NKA wrote the initial draft and KO and AMK made critical input in revising the draft. All contributors read and approved the final manuscript.

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Figures

Figure 1

Maps of Districts Showing Hotspots of Clinical Malaria in Pregnancy Incidence for Ghana (2014-2016)

Figure 2

Maps of Districts Showing Hotspots for Neonatal Malaria Incidence for Ghana (2014- 2016)

Supplementary Files

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