Prenatal malaria exposure and risk of adverse birth outcomes: a prospective cohort study of pregnant women in the Northern Region of Ghana

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ABSTRACT

Objective Malaria remains endemic in most of sub-Saharan Africa and has a negative impact among pregnant women, resulting in morbidity and poor birth outcomes. The purpose of this study was to assess the relationship between malaria and adverse birth outcomes among prenatal women in the Northern Region of Ghana.

Design This is a prospective cohort study of singleton pregnancies at 28 weeks of gestational age and above recruited between July 2018 and May 2019 from four public hospitals in the Northern Region of Ghana.

Outcome measures Low birth weight (LBW), preterm birth and perinatal death.

Results A total of 1323 pregnant women completed the study out of the 1626 recruited, with an average age of 27.3±5.2 years. The incidence of malaria in this population was 9.5% (95% CI 7.9 to 11.1). After adjusting for newborn admissions to the neonatal intensive care unit, parity, maternal age and glucose-6-phosphate dehydrogenase, women who were exposed to malaria during the third trimester of pregnancy had 2.02 times (95% CI 1.36 to 2.99) higher odds of premature delivery. Furthermore, they had 2.06 times (95% CI 1.09 to 3.93) higher chance of giving birth to babies with LBW, irrespective of their socioeconomic status. With an OR of 1.02 (95% CI 0.26 to 4.01), there was no difference in perinatal mortality between pregnant women with malaria and those without malaria after adjusting for caesarean section.

Conclusion This study confirms that prenatal malaria increases the odds of both preterm and LBW deliveries. A decisive policy to eradicate or minimise perinatal malaria is needed to contribute to the prevention of LBW and adverse pregnancy outcomes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This was a prospective cohort study done to investigate the relationship between maternal malaria in the third trimester and birth outcomes in Tamale, Ghana.
⇒ The study provides detailed information on malaria and adverse birth outcomes that is not otherwise readily available due to the challenges of under-reporting and poor record linkage of surveillance data.
⇒ Rapid diagnostic tests were used to diagnose malaria during pregnancy as a routine procedure among state-licensed laboratory practitioners, which may be a limitation.
⇒ We were unable to account for the effects of malaria on birth outcomes during the early stages of pregnancy.

In malaria-endemic areas in sub-Saharan Africa, women face significant risks throughout their pregnancy. Examples of these risks pregnant women are exposed to include low birth weight (LBW), premature birth and spontaneous abortions. Prenatal malaria is responsible for 5%–12% of LBW and accounts for between 75,000 and 200,000 infant deaths each year. In sub-Saharan Africa, 11 million women were infected with malaria in 2018, resulting in approximately 872,000 newborns born with LBW. In 2018, the Central and Western Africa subregions reported the highest prevalence of malaria in pregnant women, each with 35% prevalence. Furthermore, West Africa had the highest frequency of LBW due to malaria. In particular, the effect of malaria exposure on fetal growth was observed during the third trimester of pregnancy regardless of period of exposure.

Malaria cases increased by half a million in Ghana in 2018 compared with the year...
before. Regarding treatment, a research conducted in
the War Memorial Hospital in the Upper East Region
found that children born to mothers on artemether–
lumefantrine intermittent screening and treatment of
malaria in pregnancy had a lower risk of malaria than
those delivered to mothers on sulfadoxine/pyrimeth-
amine intermittent preventive treatment of malaria in
pregnancy (IPTp-SP). Yet the prevalence of malaria
and poor birth outcomes was 9.0% and 22.2%, respec-
tively, in Kumasi. In Navrongo, uptake of intermittent
preventive treatment of malaria in pregnancy using sulf-
doxine/pyrimethamine at three doses was 76%, while
uptake of five doses was 16%, with women who received
at least three doses having better health outcomes. Given
that Ghana is in an endemic malaria zone, these studies
highlight implementation gaps and provide information
that is useful to improve our malaria prevention policies
and programmes. Unfortunately, there is a dearth in the
Ghanaian literature relating to the role of malaria in poor
birth outcomes in pregnant women in urban settlements
in Northern Ghana.

Furthermore, due to insufficient linkages between
malaria control and prenatal care data, progress in
attaining malaria control among pregnant women has
been slow. In addition, inconsistencies in data manage-
ment practices were discovered during a data quality eval-
uation in several health institutions, posing problems in
data reporting, analysis and application. Therefore, the
precision of aggregate data collected from these facilities
through surveillance is compromised by these discrepan-
cies. We designed this prospective cohort research as an
independent evaluation of birth outcomes among people
with prenatal malaria in light of these difficulties. This
study sought to provide considerably more detailed infor-
mation on the links between prenatal malaria and poor
birth outcomes in pregnant women in Northern Ghana.

METHODS

Setting

Data for this substudy were drawn from a prospective
cohort study that took place in four hospitals in Ghana’s
Northern Region. Three of the hospitals are located in
Tamale, the Northern Region capital, the fourth largest
city in Ghana. The fourth hospital is located in the Save-
lugu Municipality bordered by Tamale to the west. These
areas are located within the Guinea Savannah Belt, with
little seasonal variations in prevalence, and as such
Oheneba-Dorny and colleagues found the prevalence of malaria to be positively correlated with rainfall, with
nearly a borderline significance. The Plasmodium falci-
parum peripheral parasitaemia prevalence in pregnant
women in the Northern Savannah Zone ranged between
26% and 13.4% from 2013 to 2019, respectively.

Design

The study was designed from a parent cohort study that
sought to answer the primary research question of whether
or not different cooking fuel types influenced pregnancy
outcomes and infant respiratory problems. Therefore,
the original sample size calculation was based on the
proportion of pregnant women developing the outcome
(respiratory symptoms) with cooking fuel type as an ex-
posure. The present study answers a secondary research
question about the relationship between prenatal malaria
exposure and the risk of adverse birth outcomes. Thus,
this study design leverages on the advantages of the large
sample size of the original prospective cohort study. As
our main results were statistically significant, we assumed
that the sample size for this study was reasonable.

The study recruited pregnant women in their third
trimester, who primarily cooked their family meals, were
non-smokers and were confirmed to carry singleton preg-
nancies. The process began in July 2018 and ended in
May 2019. The main study was planned with three phases
data collection. At the beginning of the study, women
were screened and recruited. In phase 1, during the third
trimester, we collected demographics, medical history,
exposure data for the primary objective (fuel type) and
exposure for secondary objective (malaria). The
endpoint for this study was birth outcomes and these data
were collected from the labour wards of various hospitals
during phase 2. The final part was the phase 3 follow-up
that involves collection of newborn data.

The original study encountered a methodological short-
coming during its implementation as we initially assumed
recruited pregnant women will return to the hospitals
where they attended antenatal care (ANC) (ie, a recruit-
ment centre) to deliver. However, a few months into the
study, we observed that most of them did not return to
deliver, and given the project’s limited funding we were
unable to follow them up. Therefore, we replaced them
with women who strictly agreed to return to the recruit-
ment centre to give birth. This increased our initial
sample size from 1472 to 1776, as published in Hussein
et al. Consequently, we followed up 1323 pregnant women
in this study; more details can be found in Hussein et al.

Procedures

Baseline data were collected at recruitment using a struc-
tured questionnaire at the ANC centre of each hospital.
Gestational age was routinely ascertained through an
ultrasound during ANC; therefore, our study relied on
a midwife-validated gestational age. Data on pregnancy
outcome were collected at the labour ward of all hospitals
by trained research assistants using a predesigned ques-
tionnaire. Only 88% of our final sample received at least
one sulfadoxine/pyrimethamine (IPTp-SP).

Laboratory procedures

RDT malaria diagnosis

The SD BIOLINE Malaria Ag Pf/Pan rapid diagnostic
test kit (RDT) for malaria was used in all hospitals, with
specificity and sensitivity of 99.5% and 99.7%, respec-
tively. The principal investigator and the research assis-
tants made efforts to observe and monitor adherence
to standard testing protocols at each hospital to ensure that they complied with both the manufacturer’s guide and the fundamental laboratory principles for the test. RDT was performed during the third trimester whenever possible to determine whether or not the study participants had parasitaemia in peripheral blood. Still, we were unable to control for possible measurement bias among the laboratory personnel for malaria.

**Haemoglobin estimation**

All hospitals used a blood analyser to estimate full blood count (FBC), and haemoglobin (Hb) was extracted from the FBC results of all participating pregnant women. Blood sample (5 mL) for Hb estimation was collected into an EDTA tube and mixed with an EDTA anticoagulant. In this study, anaemia was defined as Hb <11.0 g/L.

**Glucose-6-phosphate dehydrogenase test**

The methaemoglobin reduction test was used in all hospitals to screen pregnant women for glucose-6-phosphate dehydrogenase (G6PD). The test result was reported as no defect/normal, partial defect or full defect.

**Data collection**

Computer-assisted personal interviewing was used to gather all data, which was done using the KoboCollect Android app. The data collection procedure is described in detail elsewhere.15

**Outcomes**

The main outcomes of this study were LBW, preterm birth and perinatal death. These were all gathered during delivery in the labour ward of various hospitals. On the seventh day, women were contacted by mobile phone to enquire about the baby’s well-being to ensure that the infant was still alive and to capture neonatal admission at birth, mode of delivery, marital status, parity, G6PD status, genotype, anaemia, socioeconomic status (SES), drinking of alcohol and maternal respiratory condition, and initially added to logistic regression with significance set at \( p \leq 0.05 \). Those with significance were retained in the multiple logistic regression model and the non-significant ones were dropped. Consequently, genotype, anaemia, respiratory condition and drinking of alcohol were all dropped during the initial univariate analysis, which is why some confounders were found in the final model while others were not. Maternal age was, however, non-significant but was retained in the models given its relevance as a confounder and its previously established association with adverse birth outcomes.18 19 For SES, assets from the 2014 Ghana Demographic Health Survey were used to calculate the total assets. We divided the total SES scores into quantiles and considered all scores less than 50 quantiles as poor, from 50 to 75 as moderately rich, and at least 75 more as rich.15 Missing data of more than 10% from any observation were dropped in order to prevent bias, and a single manual imputation was used to address some missing data based on previous patterns of questions.20 Sensitivity analysis was assessed in both univariate and multiple log binomial regression models compared with logistic regression model used in the main analysis.

**Patient and public involvement**

There was no patient and public involvement.

**RESULTS**

Figure 1 shows an elaborate detail of the plan for follow-up during this study, which was published in Hussein et al.15 At baseline, 1626 third trimester pregnant women were recruited, with 1323 women completing the study. The age of pregnant women ranged between 15 and 48 years, and 59.1% were between 25 and 34 years.

In terms of medical history, 14.8% had a parity of four or more children. The incidence of malaria in this cohort was 9.5% (95% CI 7.9 to 11.1). About 6.4% tested positive for sickle cells, and out of these 50.0% who checked for their genotypes were sickled (SS). About 47.9% of women were anaemic, with Hb levels of less than 11 g/dL within their third trimester of pregnancy, while 4.7% had G6PD full defect (table 1).

The incidence of preterm birth among women with malaria was 52.0%. Moreover, the prevalence of LBW was 10.4% among women with malaria and 5.1% among women without malaria. In both mothers with and without malaria, newborn deaths and live births were equally 1.6% (table 2).

Pregnant women with malaria had 2.02 times (95% CI 1.39 to 2.93) increased odds of preterm birth compared with those without malaria after adjusting for parity, maternal age, G6PD deficiency and neonatal admission (table 3).

Furthermore, pregnant women with malaria had 2.06 times (95% CI 1.09 to 3.93) increased odds of LBW
compared with those without malaria after adjusting for parity, maternal age and SES (table 4).

Lastly, with an OR of 1.02 (95% CI 0.26 to 4.01), there was no difference in perinatal mortality between pregnant women with malaria and those without malaria after adjusting for caesarean section. Women who underwent caesarean section had a five times greater risk of perinatal death than those who did not have caesarean section (table 5).

Sensitivity analysis in both the univariate and multiple log binomial regression models did not change the direction or strength of the estimates compared with the logistic regression model for preterm birth, even though the OR marginally exaggerated the relative risk to some magnitude (table 6).

**DISCUSSION**

In this study, malaria was found in nearly 10% of pregnant women. The study also investigated the associations between malaria and preterm birth, LBW and perinatal mortality.

Prenatal malaria was found to be substantially linked with preterm birth and LBW after correcting for parity, mother’s age, G6PD, SES and neonatal hospitalisation at birth, but not with perinatal death after adjusting for caesarean section. Indeed, Nkwabong et al previously reported that third trimester malaria increased the chance of preterm delivery by 5 times and LBW by 2.8 times, which is consistent with our findings. Similarly, Vogel and colleagues similarly conclude from their data that maternal malaria significantly increased the risk of preterm birth by 1.99 times. In Tanzania, similar studies have shown that malaria parasites in mothers’ red blood cells are associated with 3.2 times the risk of premature birth. Compared with people without placental malaria, preterm birth rates increased by 4.7% to 5.6% among pregnant women with placental malaria.

In Brazil, researchers reported that *P. falciparum* species were significantly associated with preterm births, although accounting for less than 40% of the total. In contrast, some authors suggest that such correlations are non-significant. For example, a recent comprehensive study of malaria at birth in Uganda that studied three different parasite detection methods, including peripheral and placental blood microscopy, placental blood loop-mediated isothermal amplification (LAMP), and placental histopathology, found no statistically significant link between malaria and preterm birth for any of the methods. In this study, it was not possible to distinguish between the various species of malaria. However, previous studies have shown that, regardless of the species, malaria can lead to poor birth outcomes. For example, *P. falciparum* in placental blood increased the risk of LBW by around 1.7 times in Malawi and about 3.7-fold increase in Zaire. Furthermore, in Nigeria and Uganda, approximately 33% and 19% of mothers with placental malaria, respectively, delivered LBW babies compared with those without placental malaria.

One interesting aspect that emerged from the analysis is the finding that women who delivered via caesarean section were about five times more likely to suffer perinatal mortality. Notwithstanding, we found that there was
no significant increase in the odds of pregnancy mortality in both adjusted and unadjusted models. In contrast, other studies, such as the one conducted in Zaire in 1993, reported that maternal malaria with chloroquine prophylaxis increased the risk of perinatal death by 12 times after adjusting for parity and prenatal clinic visits.30 In addition, …
Multiple variables such as gender, mother’s age and SES can result in adverse birth outcomes. Therefore, in this study, we adjusted for these significant confounders in the multiple logistic regressions and maintained the

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Logistic regression of preterm and malaria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preterm</td>
<td></td>
</tr>
<tr>
<td>Malaria</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>2.02 (1.36 to 2.99)</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
</tr>
<tr>
<td>First pregnancy</td>
<td>1</td>
</tr>
<tr>
<td>2–3 pregnancies</td>
<td>0.79 (0.61 to 1.03)</td>
</tr>
<tr>
<td>4 or more pregnancies</td>
<td>0.62 (0.42 to 0.93)</td>
</tr>
<tr>
<td>Maternal age (years)</td>
<td></td>
</tr>
<tr>
<td>15–24</td>
<td>1</td>
</tr>
<tr>
<td>25–34</td>
<td>0.75 (0.49 to 1.13)</td>
</tr>
<tr>
<td>35–48</td>
<td>0.59 (0.42 to 0.85)</td>
</tr>
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<td>G6PD</td>
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<tr>
<td>Normal</td>
<td>1</td>
</tr>
<tr>
<td>Partial defect</td>
<td>1.54 (1.01 to 2.37)</td>
</tr>
<tr>
<td>Full defect</td>
<td>0.98 (0.54 to 1.76)</td>
</tr>
<tr>
<td>Neonatal admission at birth</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>1.98 (1.09 to 3.60)</td>
</tr>
</tbody>
</table>

*Significant confounders adjusted in the multiple log binomial model: parity, maternal age, G6PD and neonatal admissions at birth. G6PD, glucose-6-phosphate dehydrogenase.

<table>
<thead>
<tr>
<th>Table 4</th>
<th>Logistic regression of LBW and malaria</th>
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<tbody>
<tr>
<td>LBW</td>
<td></td>
</tr>
<tr>
<td>Malaria</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
</tr>
<tr>
<td>Yes</td>
<td>2.06 (1.09 to 3.93)</td>
</tr>
<tr>
<td>Parity</td>
<td></td>
</tr>
<tr>
<td>First pregnancy</td>
<td>1</td>
</tr>
<tr>
<td>2–3 pregnancies</td>
<td>1.32 (0.76 to 2.28)</td>
</tr>
<tr>
<td>4 or more pregnancies</td>
<td>2.13 (1.03 to 4.39)</td>
</tr>
<tr>
<td>Maternal age (years)</td>
<td></td>
</tr>
<tr>
<td>15–24</td>
<td>1</td>
</tr>
<tr>
<td>25–34</td>
<td>0.70 (0.41 to 1.22)</td>
</tr>
<tr>
<td>35–48</td>
<td>0.45 (0.17 to 1.19)</td>
</tr>
<tr>
<td>Socioeconomic status</td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
<tr>
<td>Moderately rich</td>
<td>0.60 (0.34 to 1.07)</td>
</tr>
<tr>
<td>Rich</td>
<td>0.54 (0.29 to 0.98)</td>
</tr>
</tbody>
</table>

*Significant confounders adjusted in the multiple log binomial model: parity and socioeconomic status. LBW, low birth weight.

P. falciparum malaria during pregnancy increased the risk of neonatal deaths by 2.6 times. Infants delivered to mothers with acute placental infections had a fivefold risk of death.
significant confounders. Women with multiple pregnancies are protected from premature birth. This is apparently due to the extra protection provided by antibodies in subsequent pregnancies against the parasite variant surface antigen VAR2CSA.34 35

Furthermore, regardless of the period of exposure, the effect of malaria exposure on fetal development was detected during the third trimester of pregnancy and has been blamed for poor birth outcomes.6 25 36 This might be because the pathway that connects the mother to the baby throughout pregnancy may impact the fetus’ survival at delivery or even beyond, since the placenta delivers nutrition to the newborn via the umbilical cord. For example, Ouédraogo and his colleagues37 found a connection between umbilical cord parasitaemia and maternal peripheral blood parasitaemia. Also, malaria during pregnancy may have induced excessive stimulation and dysregulated Hb-scavenging system and bioavailability of nitric oxide and L-arginine, which may be associated with poor vascular development and adverse birth outcomes.38 Although we used RDT with peripheral blood, our findings were consistent with the majority of studies on placental malaria.34 35 This is because peripheral blood infections may promote the sequestration of parasites in the placenta and activate immune reactions of antibodies and antigens that may cause complications during delivery.34 35 Furthermore, Kapisi et al.25 found that women who had a high burden of malaria had a 14-fold increased risk of placental malaria by blood microscopy and a fourfold increased risk of LAMP. This could indicate that our group had a higher malaria burden, correlating with previous research using a different technique for diagnosis.25

Table 5  Logistic regression of perinatal mortality and malaria

<table>
<thead>
<tr>
<th>Perinatal mortality</th>
<th>Crude OR (95% CI)</th>
<th>P value</th>
<th>Adjusted OR (95% CI)*</th>
<th>P value (adjusted models)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.01 (0.23 to 4.37)</td>
<td>0.993</td>
<td>1.02 (0.26 to 4.01)</td>
<td>0.983</td>
</tr>
</tbody>
</table>

Mode of delivery

<table>
<thead>
<tr>
<th></th>
<th>Crude OR (95% CI)</th>
<th>P value</th>
<th>Adjusted OR (95% CI)*</th>
<th>P value (adjusted models)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Caesarean section</td>
<td>5.18 (1.88 to 14.26)</td>
<td>0.001</td>
<td>5.17 (1.87 to 14.36)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Significant confounder adjusted in the multiple log binomial model: mode of delivery.

Table 6  Sensitivity analysis using log binomial regression for preterm and malaria

<table>
<thead>
<tr>
<th>Preterm</th>
<th>Crude RR (CI)</th>
<th>P value</th>
<th>Adjusted RR (CI)*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.49 (1.24 to 1.23)</td>
<td>&lt;0.001</td>
<td>1.45 (1.20 to 1.78)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Parity

<table>
<thead>
<tr>
<th></th>
<th>Crude RR (CI)</th>
<th>P value</th>
<th>Adjusted RR (CI)*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First pregnancy</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2–3 pregnancies</td>
<td>0.89 (0.78 to 1.04)</td>
<td>0.150</td>
<td>0.87 (0.74 to 1.02)</td>
<td>0.087</td>
</tr>
<tr>
<td>4 or more pregnancies</td>
<td>0.72 (0.57 to 0.91)</td>
<td>0.006</td>
<td>0.74 (0.57 to 0.96)</td>
<td>0.025</td>
</tr>
</tbody>
</table>

Maternal age (years)

<table>
<thead>
<tr>
<th></th>
<th>Crude RR (CI)</th>
<th>P value</th>
<th>Adjusted RR (CI)*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>15–24</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25–34</td>
<td>1.14 (0.98 to 1.35)</td>
<td>0.106</td>
<td>1.19 (1.01 to 1.42)</td>
<td>0.039</td>
</tr>
<tr>
<td>35–48</td>
<td>0.81 (0.61 to 1.09)</td>
<td>0.181</td>
<td>0.93 (0.67 to 1.29)</td>
<td>0.670</td>
</tr>
</tbody>
</table>

G6PD

<table>
<thead>
<tr>
<th></th>
<th>Crude RR (CI)</th>
<th>P value</th>
<th>Adjusted RR (CI)*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Partial defect</td>
<td>1.29 (1.03 to 1.60)</td>
<td>0.025</td>
<td>1.27 (1.02 to 1.59)</td>
<td>0.036</td>
</tr>
<tr>
<td>Full defect</td>
<td>1.04 (0.74 to 1.48)</td>
<td>0.803</td>
<td>0.98 (0.67 to 1.44)</td>
<td>0.935</td>
</tr>
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</table>

Neonatal admission at birth

<table>
<thead>
<tr>
<th></th>
<th>Crude RR (CI)</th>
<th>P value</th>
<th>Adjusted RR (CI)*</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>1.47 (1.13 to 1.91)</td>
<td>0.004</td>
<td>1.39 (1.07 to 1.83)</td>
<td>0.015</td>
</tr>
</tbody>
</table>

*Significant confounders adjusted in the multiple log binomial model: parity, maternal age, G6PD and neonatal admissions at birth.
†RR, Relative Risk
G6PD, glucose-6-phosphate dehydrogenase.
This study benefited from a large sample size. To date, we have not found any studies that examined the relationship between maternal malaria during delivery and the results of birth in Tamale in the Northern Region of Ghana. In this cohort, RDT was used to diagnose malaria, although the sensitivity to malaria was 19% lower than a microscopic examination of peripheral and placenta blood. However, RDT has been reported to have outperformed microscopy in identifying malaria in other settings. Furthermore, RDT is useful in environments like ours because it produces quick results, requires fewer training and equipment, and has virtually no power interruption. Consequently, especially in hospitals with limited human resources and equipment, rapid malaria detection techniques are imperative for initiating care.

A potential drawback of our study was that we relied on standard laboratories at each hospital to collect data on malaria. While we took every attempt to observe and monitor compliance with established testing techniques, we were unable to account for any measurement bias among laboratory staff for the exposure variable (malaria). However, it should be noted that the RDT method for malaria diagnosis during pregnancy is used routinely in our context and is performed by state-licensed laboratory professionals to diagnose malaria in our population. We also cannot explain the impact of malaria on birth outcomes during the early stages of pregnancy since we only included pregnant women in their third trimester as long as they had done at least one RDT prior to recruitment. This study also failed to account for the number of doses of sulfadoxine/pyrimethamine taken by pregnant women. This denied us the opportunity to measure its confounding effect on malaria and birth outcomes. Nevertheless, our research is comparable with similar studies on the subject matter.

Taken together, these findings indicate that maternal malaria within the third trimester of pregnancy may be a major contributor to LBW and preterm birth in the Northern Region of Ghana.

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