BMJ Open

Maternal anaemia and polycythaemia during pregnancy and risk of inappropriate birth weight for gestational age babies: a retrospective cohort study in the northern belt of Ghana

Silas Adjei-Gyamfi ,[1] Mary Sakina Zakaria,[1] Abigail Asirifi,[2] Sulley Issahaku,[3] Mohammed Awal Ibrahim,[1] Paul Armah Aryee[4]

To cite: Adjei-Gyamfi S, Zakaria MS, Asirifi A, *et al*. Maternal anaemia and polycythaemia during pregnancy and risk of inappropriate birth weight for gestational age babies: a retrospective cohort study in the northern belt of Ghana. *BMJ Open* 2024;**14**:e082298. doi:10.1136/bmjopen-2023-082298

► Prepublication history for this paper is available online. To view these files, please visit the journal online (https://doi.org/10.1136/bmjopen-2023-082298).

Received 19 November 2023
Accepted 30 July 2024

For numbered affiliations see end of article.

Correspondence to
Silas Adjei-Gyamfi;
adjeigyamfis@yahoo.com

ABSTRACT

Background Small for gestational age (SGA) and large for gestational age (LGA) births are topical issues due to their devastating effects on the life course and are also accountable for neonatal mortalities and long-term morbidities.

Objective We tested the hypothesis that abnormal haemoglobin levels in each trimester of pregnancy will increase the risk of SGA and LGA deliveries in Northern Ghana.

Design A retrospective cohort study was conducted from April to July 2020.

Settings and participants 422 postpartum mothers who had delivered in the last 6–8 weeks before their interview dates were recruited through a systematic random sampling technique from five primary and public health facilities in Northern Ghana.

Primary measures Using the INTERGROWTH-21st standard, SGA and LGA births were obtained. Haemoglobin levels from antenatal records were analysed to determine their effect on SGA and LGA births by employing multinomial logistic regression after adjusting for sociodemographic and obstetric factors at a significance level of α=0.05.

Results Prevalence of anaemia in the first, second and third trimesters of pregnancy was 63.5%, 71.3% and 45.3%, respectively, and that of polycythaemia in the corresponding trimesters of pregnancy was 5.9%, 3.6% and 1.7%. About 8.8% and 9.2% of the women delivered SGA and LGA babies, respectively. After adjusting for confounders, anaemic mothers in the third trimester of pregnancy had an increased risk of having SGA births (adjusted OR, aOR 5.56; 95% CI 1.65 to 48.1; p<0.001). Mothers with polycythaemia in the first, second and third trimesters of pregnancy were 93% (aOR 0.07; 95% CI 0.01 to 0.46; p=0.040), 85% (aOR 0.15; 95% CI 0.08 to 0.64; p<0.001) and 88% (aOR 0.12; 95% CI 0.07 to 0.15; p=0.001) protected from having SGA births, respectively. Interestingly, anaemia and polycythaemia across all trimesters of pregnancy were not statistically significant with LGA births.

Conclusion Anaemia during pregnancy increased from the first to the second trimester and subsequently decreased in the third trimester while polycythaemia consistently decreased from the first to the third trimester. LGA babies were more predominant compared with SGA babies. While anaemia in the third trimester of pregnancy increased the risk of SGA births, polycythaemia across the trimesters offered significant protection. Healthcare providers and stakeholders should target pressing interventions for anaemia reduction throughout pregnancy, especially during the third trimester to achieve healthy birth outcomes.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The assessment of abnormal haemoglobin levels and inappropriate birth weight for gestational age babies was based on WHO and INTERGROWTH standards, respectively, which gives an objective assessment of the main study variables.

⇒ The study was focused on lesser-researched adverse birth outcomes (thus, small for gestational age and large for gestational age births) rather than well-recognised birth outcomes like low birth weight, stillbirths and preterm births.

⇒ Additionally, this study is generalisable and replicable to settings that have similar geographical characteristics to those of Northern Ghana.

⇒ However, the retrospective design is a study limitation due to possible measurement and documentation errors that could occur from some of the secondary data obtained.

⇒ Primary data collection was done during the early period of the COVID-19 pandemic and, therefore, the fear associated with it could deter mothers from seeking postnatal services, which might have affected our study results.

INTRODUCTION

In both developed and developing countries, low and high haemoglobin (Hb) levels during pregnancy have been a great public health concern[1] due to their devastating effects on adverse birth outcomes and life course, which may subsequently lead to long-term health problems such as diabetes, cancer, hypertension and stroke.[2 3] Hb is an iron-containing oxygen transport protein in the erythrocytes of humans that carries oxygen from the lungs to the body tissues.[1] Hb concentration during pregnancy is categorised into low, normal and high (elevated) levels. The low and high Hb levels are regarded as abnormal and are termed as anaemia and polycythaemia, respectively.[1 4] A measure of Hb concentration not only serves as the best reliable and trustworthy indicator of anaemia and polycythaemia at the population level but also remains the standard test for pregnant women during antenatal visits which is used to assess anaemia or polycythaemia status[4] but is not indicative of the cause.[1] The global mean Hb concentration in pregnancy is 114 g/L with anaemia predominance at 38.2%.[1] Recent studies have illustrated that more than half of all pregnant women in Egypt, Ghana and Kenya are anaemic.[5–7] Although there are relatively limited studies on the prevalence of maternal anaemia or polycythaemia across trimesters of pregnancy in most developing countries, retrospective studies in China and Ethiopia have revealed that the incidence of anaemia increases as pregnancy progresses from the first to third trimester.[8 9] Unlike anaemia, polycythaemia has been misperceived as a sign of good nutritional status and has not received much attention. Hence, most studies do not consider polycythaemia as a public health issue.

The risk for women to deliver babies with inappropriate birth weights for their gestational age is key in obstetric care due to its serious consequences on maternal and child health. Nonetheless, not much importance has been given to this category of adverse birth outcomes as compared with others such as low birth weight, macrosomia, preterm and post-term newborns.[10 11] Inappropriate birth weight for gestational age births can be classified into small for gestational age or small for date (SGA) and large for gestational age or large for date (LGA). In 2012, an approximated 23 million infants were born with SGA.[11] Geographically, while the rates of SGA births in Asia, Europe and Southern America are relatively low,[10 12 13] high incidences have been recorded in sub-Saharan Africa.[14 15] Alternatively, more than 10% of American and Asian women deliver LGA infants every year.[10 12 16 17]

There has been a long-standing connection between abnormal Hb levels during pregnancy and adverse birth outcomes.[1 2] Globally, low Hb during pregnancy is one of the main risk factors for adverse birth outcomes and neonatal mortalities.[2] Although numerous studies have extensively documented that maternal anaemia or polycythaemia could cause a series of adverse birth outcomes like preterm births, low birth weight and perinatal deaths,[18 19] enough attention has not been placed on SGA and LGA births.[13 14] The few studies that explored the relationship between anaemia or polycythaemia and LGA or SGA births have also been quite controversial. While some earlier studies found maternal low or elevated Hb levels to be associated with SGA or LGA infants,[20 21] a few other studies reported no association between abnormal Hb levels and SGA or LA infants.[12 15] Notwithstanding, these studies could not tell the particular trimester at which the associations were made.

Furthermore, current reports have indicated that the correlation between abnormal Hb levels and LGA or SGA births is mostly influenced by the specific time point of Hb assessment.[22 23] Some studies have unveiled that anaemia or polycythaemia in the first trimester is significantly related to SGA or LGA infants[24 25] while other studies have disclosed that this relationship is more significant in the second or third trimester.[22 23 26 27] Similar studies also revealed no association between SGA or LGA births and abnormal Hb levels across the three trimesters of pregnancy.[28 29] Yet, data from low-income and middle-income countries are relatively scarce.

Remarkably, most earlier studies have only assessed Hb levels at one time point and only considered a few observed changes over time during pregnancy. By reviewing Hb levels across multiple or different time points, it is significant to assess the longitudinal changes and consequently perform a more rigorous exploration of the associations between abnormal Hb levels and the risk of delivering SGA or LGA infants. Additionally, as reported by Adjei-Gyamfi *et al*, the incidence of maternal anaemia in the three trimesters of pregnancy in Northern Ghana remains high and that of polycythaemia is very significant.[18] However, the longitudinal changes of Hb levels across the trimesters of pregnancy on SGA or LGA births in the region are not established. In this retrospective cohort study, we aimed to test the hypothesis that anaemia and/or polycythaemia in each consecutive trimester of pregnancy will increase the risk of SGA and LGA births among Ghanaian women in the northern belt of the country.

MATERIALS AND METHODS

Study design

We conducted a retrospective cohort study on postpartum mothers who had delivered in the last 6–8 weeks prior to their interview dates in the northern belt of Ghana. This approach was employed to determine the association between abnormal Hb levels during pregnancy and the risk of SGA and LGA births.

Study setting

The study was conducted in Savelugu municipality of the Northern Region of Ghana. This periurban municipality has 5 major public health facilities including the municipal hospital and 21 community-based health planning services zones that provide maternal, neonatal and child healthcare services to all inhabitants of the municipality and beyond. The total antenatal registrants and deliveries in 2020 were 2160 and 3974, respectively, while the proportion of postnatal registrants was estimated at 99%.[30]

Study population

A population comprising all postpartum mothers who had delivered in the last 6–8 weeks prior to their interview dates and attending postnatal care was recruited. Postpartum mothers with no live births, without antenatal and/or delivery records and who absented themselves from first-trimester antenatal services were excluded from the study.

Sample size and sampling procedure

Applying the Cochran (1977) formula,[31] $n = \frac{Z^2 \ X \ p(1-p)}{e^2}$ for sample size determination, the minimum sample size of 384 was initially approximated at 95% CI corresponding to standard normal variate (z=1.96), margin of error (e=0.05) and a population proportion of 50% (p=0.5) due to the paucity of available data on SGA and LGA births in Ghana. To cater for incomplete and damaged questionnaires, 10% of the sample was added to adjust the final sample size to 423.

The study included all five public health facilities in the municipality. In each health facility, the study sample was extracted using a systematic random sampling procedure. The names of the postpartum mother–child dyads in the postnatal care registers were used as the sampling frame.

Data collection

Based on existing literature and previous studies,[18 19 23 26] a well-structured and pretested questionnaire was designed to collect the data from April to July 2020 with the support of trained research assistants. Most of the data were collected from antenatal, and delivery records in the maternal and child health books. Data on obstetrics (parity, gravidity, antenatal visits, iron folic acid intake, sulfadoxine-pyrimethamine (SP) intake) and health status during pregnancy (malaria infection, tetanus-diphtheria immunisation, past family planning use, Hb levels at each trimester of pregnancy) were extracted from antenatal records while information on the mode and type of delivery was confirmed from delivery records. Other maternal information including sociodemographic (occupation, religion, age, education, ethnicity) and socioeconomic characteristics, insecticide-treated bed nets' use, and knowledge level on the association of abnormal Hb concentration with LGA or SGA births were obtained through structured interviews.

Measurement of study variables

The dependent variables were inappropriate birth weight for gestational age (SGA and LGA) births while the principal independent variable was abnormal Hb levels (anaemia and polycythaemia) in all trimesters of pregnancy. LGA and SGA were assessed by using the INTERGROWTH-21st standard.[11] LGA was defined and measured as birth weight above the 90th percentile of the gestational age in a given reference population while SGA was measured as birth weight below the 10th percentile of the gestational age in a given reference population.[11 32] Hb level less than 110 g/L at any of the trimesters of pregnancy was regarded as anaemia while Hb level equal to or greater than 132 g/L was classified as polycythaemia.[1 19]

The other independent variables of interest were collected and categorised based on previous studies and biological plausibility.[18 24 27] Mother's knowledge level on the relationship of abnormal Hb levels with SGA or LGA babies was summed up for each participant. Appropriate and inappropriate responses were scored 1 point and 0 point, respectively. Using the median cut-point, an absolute composite knowledge score was estimated using 48 items and categorised into adequate and inadequate knowledge levels, with a probable lowest score of zero and the highest score of 48.[18] Socioeconomic status (SES) or wealth index was assessed based on possession of household assets, housing quality and availability of household utilities among others which were used as proxy indicators for the SES of mothers. By using principal component analysis, the SES of the mothers was divided into tertiles; high, middle and low SES.[33] The frequency of antenatal visits was categorised as less than eight visits and at least eight visits per the WHO's revised recommendations for positive pregnancy outcomes.[34] Parity was grouped as one birth (delivery) and two or more births while gravidity was classified into one pregnancy and two or more pregnancies.[18]

Statistical analysis

The data set was cleaned and coded for statistical analysis using STATA V.17.0 (Stata Corporation, Texas, USA). The dependent variable was coded as SGA=1, appropriate for gestational age (AGA)=2 and LGA=3. The 'AGA' was used as the base outcome (reference point) during analyses. χ^2/Fisher's exact tests were used to determine the association between dependent variables (SGA and LGA) and each independent variable. We further carried out univariate logistic regressions to show their strength of associations at a p value of less than 0.05. Multinomial logistic regression was used to assess the association between SGA and LGA, and independent predictor variables while controlling for potential confounders. Some confounding variables adjusted for included maternal age, maternal knowledge level, antenatal visits, delivery mode and SP intake. Adjusted OR (aOR) with a 95% CI was run to identify the statistically significant effect of abnormal Hb levels (anaemia and polycythaemia) on SGA and LGA births.

Patient and public involvement

Patients and/or the public were not involved in the design, conduct, reporting or dissemination plans of this research.

Table 1 Sociodemographic characteristics of respondents (n=422)

Characteristics	Frequency distribution	Small for gestational age (SGA)	Appropriate for gestational age (AGA)	Large for gestational age (LGA)	P value*
	Total (%)	SGA (%)	AGA (%)	LGA (%)	
Maternal age group					
Less than 20 years	38 (9.0)	9 (24.3)	27 (7.8)	2 (5.1)	0.010+
20–35 years	340 (80.6)	26 (70.3)	283 (81.8)	31 (79.5)	
More than 35 years	44 (10.4)	2 (5.4)	36 (10.4)	6 (15.4)	
Mean (SD)=27.63 (6.02)					
Marital status					
Single	30 (7.1)	6 (16.2)	22 (6.4)	2 (5.1)	0.092
Married	389 (92.2)	30 (81.1)	322 (93.0)	37 (94.9)	
Divorced/widowed	3 (0.7)	1 (2.7)	2 (0.6)	0 (0.0)	
Maternal education status					
No formal	182 (43.1)	22 (59.5)	197 (56.9)	21 (53.8)	0.884
Formal	240 (56.9)	15 (40.5)	149 (43.1)	18 (46.2)	
Maternal ethnic group					
Gonja/Frafra	56 (13.3)	5 (13.5)	42 (12.1)	9 (23.1)	0.356
Dagomba/Mamprusi	340 (80.6)	28 (75.7)	283 (81.8)	29 (74.3)	
Others†	26 (6.1)	4 (10.8)	21 (6.1)	1 (2.6)	
Religious affiliation					
Christianity	49 (11.6)	5 (13.5)	38 (11.0)	7 (18.0)	0.710
Islam	373 (88.4)	32 (86.5)	308 (89.0)	32 (82.0)	
Employment status					
Unemployed	153 (36.3)	11 (29.7)	124 (35.8)	18 (46.1)	0.602
Informal	228 (54.0)	22 (59.5)	189 (54.6)	17 (43.6)	
Formal	41 (9.7)	4 (10.8)	33 (9.6)	4 (10.3)	
Maternal socioeconomic status					
Low	170 (40.3)	15 (40.5)	138 (39.9)	17 (43.6)	0.996
Middle	84 (19.9)	7 (19.0)	70 (20.2)	7 (19.9)	
High	168 (39.8)	15 (40.5)	138 (39.9)	15 (38.5)	
Sex of neonate					
Male	210 (49.8)	20 (54.0)	172 (49.7)	18 (46.2)	0.788
Female	212 (50.2)	17 (46.0)	174 (50.3)	21 (53.8)	
Maternal knowledge					
Inadequate	124 (29.4)	19 (51.4)	97 (28.0)	8 (20.5)	0.006+
Adequate	298 (70.6)	18 (48.6)	249 (72.0)	31 (79.5)	

+p<0.05.
*χ2/Fisher's exact test
†Asante, Ewe, Kusasi.

RESULTS

Background characteristics

Tables 1 and 2 describe the sociodemographic and obstetric characteristics of 422 mother–baby dyads who were included in the study. However, the dataset for one participant (mother–baby dyad) was excluded from the analysis due to insufficient or incomplete information. The mean (±SD) age of the studied women was 27.63 (±6.02) years and that of the babies was 2.86 (±1.97) weeks. Female (50.2%) and male (49.8%) babies were almost equally represented. The majority of the women were from the Islam religious group (88.2%), Dagomba/Mamprusi ethnic group (80.6%) and had marriage partners (92.2%). While a significant proportion of the

Table 2 Obstetric characteristics of respondents (n=422)

Characteristics	Frequency distribution	Small for gestational age (SGA)	Appropriate for gestational age (AGA)	Large for gestational age (LGA)	P value*
	Total (%)	**SGA (%)**	**AGA (%)**	**LGA (%)**	
Number of pregnancies					
0–1	111 (26.3)	13 (35.1)	92 (26.6)	6 (15.4)	0.142
2 or more	311 (73.7)	24 (64.9)	254 (73.4)	33 (84.6)	
Number of deliveries					
0–1	120 (26.3)	13 (35.1)	100 (28.9)	7 (18.0)	0.228
2 or more	302 (71.6)	24 (64.9)	246 (71.1)	32 (82.0)	
Frequency of antenatal visits					
Less than 8	304 (72.0)	33 (89.2)	249 (72.0)	22 (56.4)	0.006+
8 or more	118 (28.0)	4 (10.8)	97 (28.0)	17 (43.6)	
Prepregnancy body mass index					
Overweight	130 (30.8)	8 (21.6)	106 (30.6)	16 (41.0)	0.438
Normal	279 (66.1)	28 (75.7)	229 (66.2)	22 (56.4)	
Underweight	13 (3.1)	1 (2.7)	11 (3.2)	1 (2.6)	
Sulfadoxine-pyrimethamine intake					
None	25 (5.9)	2 (5.4)	21 (6.1)	2 (5.1)	0.031+
1–3 doses	249 (59.0)	28 (75.7)	205 (59.2)	16 (41.0)	
>3 doses	148 (35.1)	7 (18.9)	120 (34.7)	21 (53.9)	
Tetanus-diphtheria immunisation					
Not immunised	31 (7.4)	2 (5.4)	25 (7.2)	4 (10.3)	0.706
Immunised	391 (92.6)	35 (94.6)	321 (92.8)	35 (89.7)	
Insecticide-treated bed nets (ITNs) use					
No ITNs use	152 (36.0)	20 (54.0)	119 (34.5)	13 (33.3)	0.057
ITNs use	270 (64.0)	17 (46.0)	227 (65.6)	26 (66.7)	
Family planning (FP) use					
No FP use	347 (82.2)	31 (83.8)	286 (82.7)	30 (76.9)	0.652
FP use	75 (17.8)	6 (16.2)	60 (17.3)	9 (23.1)	
Iron folic acid intake					
No	7 (1.7)	0 (0.0)	7 (2.0)	0 (0.0)	1.000
Yes	415 (98.3)	37 (100.0)	339 (98.0)	39 (100.0)	
Gestational malaria infection					
Episode	59 (14.0)	32 (86.5)	46 (13.3)	8 (20.5)	0.466
No episode	363 (86.0)	5 (13.5)	300 (86.7)	31 (79.5)	
Type (place) of delivery					
Skilled (facility)	392 (92.9)	33 (89.2)	325 (93.9)	34 (87.2)	0.196
Unskilled (home)	30 (7.1)	4 (10.8)	21 (6.1)	5 (12.8)	
Mode of delivery					
Vaginal	379 (89.8)	31 (83.8)	321 (92.8)	27 (69.2)	<0.001+
Caesarian section	43 (10.2)	6 (16.2)	25 (7.2)	12 (30.8)	

+p<0.05.
*χ2/Fisher's exact test.

Table 3 Association of anaemia and polycythaemia with small and large for gestational age births (n=422)

Haemoglobin (Hb) levels across trimesters of pregnancy	Prevalence	Small for gestational age	Appropriate for gestational age	Large for gestational age	P value*
	Total (%)	n (%)	n (%)	n (%)	
First-trimester Hb levels					
Anaemia (<110 g/L)	268 (63.5)	25 (67.6)	221 (63.9)	22 (56.4)	0.568
Normal (110–131 g/L)	129 (30.6)	6 (16.2)	111 (32.1)	12 (30.8)	Reference
Polycythaemia (≥132 g/L)	25 (5.9)	6 (16.2)	14 (4.0)	5 (12.8)	0.002+
Mean (SD)=104.2 (15.9)					
Second-trimester Hb levels					
Anaemia	301 (71.3)	28 (75.7)	253 (73.1)	20 (51.3)	0.014+
Normal	106 (25.1)	1 (2.7)	88 (25.4)	17 (43.6)	Reference
Polycythaemia	15 (3.6)	8 (21.6)	5 (1.5)	2 (5.1)	<0.001+
Mean (SD)=102.1 (14.7)					
Third-trimester Hb levels					
Anaemia	191 (45.3)	33 (89.2)	147 (42.5)	11 (28.2)	<0.001+
Normal	224 (53.0)	1 (2.7)	196 (56.6)	27 (69.2)	Reference
Polycythaemia	7 (1.7)	3 (8.1)	3 (0.9)	1 (2.6)	0.004+
Mean (SD)=106.8 (15.6)					

+p<0.05.
*χ2/Fisher's exact test.

women were self-employed (54.0%), about 43.1% of them had no formal education. More than two-thirds (70.6%) of the women had adequate knowledge about abnormal Hb levels and their effects on SGA or LGA births.

Of the studied participants, 73.7% had two or more pregnancies and 71.6% had delivered two or more times. Surprisingly, less than one-third of the women (28.0%) made at least eight antenatal visits before childbirth while prepregnancy underweight and overweight women were 3.1% and 30.8%, respectively. Most of the women received iron-folic acid tablets (98.3%) and were immunised with tetanus-diphtheria (92.6%) while more than half took one to three doses of SP (59.0%) during pregnancy. A greater number of the women delivered at health facilities (92.9%) and 89.8% had spontaneous vaginal delivery.

Prevalence of anaemia and polycythaemia across trimesters of pregnancy and, SGA and LGA births

The mean (±SD) Hb concentration from the first to third trimesters of pregnancy was 104.2 (±15.9) g/L, 102.1 (±14.7) g/L and 106.8 (±15.6) g/L, respectively. The prevalence of anaemia in the first, second and third trimesters of pregnancy was 63.5% (95% CI 58.7% to 68.1%), 71.3% (95% CI 66.8% to 75.6%) and 45.3% (95% CI 40.4% to 50.1%), respectively. Additionally, the corresponding rate of polycythaemia in the first, second, and third trimesters of pregnancy was 5.9% (95% CI 3.9% to 8.6%), 3.6% (95% CI 2.0% to 5.8%) and 1.7% (95% CI 1.1% to 3.4%) (table 3). As shown in figure 1, about 8.8% (95% CI 6.2% to 11.9%) and 9.2% (95% CI 6.7% to 12.4%) of the women delivered SGA and LGA babies, respectively.

Bivariate association of SGA and LGA births with background characteristics

At the bivariate level, maternal age (p=0.010), maternal knowledge (p=0.006), frequency of antenatal visits (p=0.006), SP intake (p=0.031) and delivery mode (p<0.001) were associated with inappropriate birth weight for gestational age (SGA and LGA) births (tables 1 and 2). Additionally, anaemia in the second (p=0.014) and third (p<0.001) trimesters of pregnancy was significantly associated with SGA and LGA births. There was also a significant association between polycythaemia in the first (p=0.002), second (p<0.001) and third (p=0.004) trimesters of pregnancy and, SGA and LGA births (table 3).

Multivariate analysis for the effect of anaemia and polycythaemia on SGA and LGA births

The multivariate association between dependent and independent variables is exhibited in table 4. After adjusting for background characteristics (maternal age, maternal knowledge, antenatal visits, SP intake and delivery mode), anaemic mothers in the third trimester of pregnancy were 5.56 times more likely to deliver SGA babies (aOR 5.56; 95% CI 1.65 to 48.1; p<0.001). Mothers with polycythaemia in the first, second and third trimesters of pregnancy had lower risks of SGA births by 93% (aOR 0.07; 95% CI 0.01 to 0.46; p=0.040), 85% (aOR

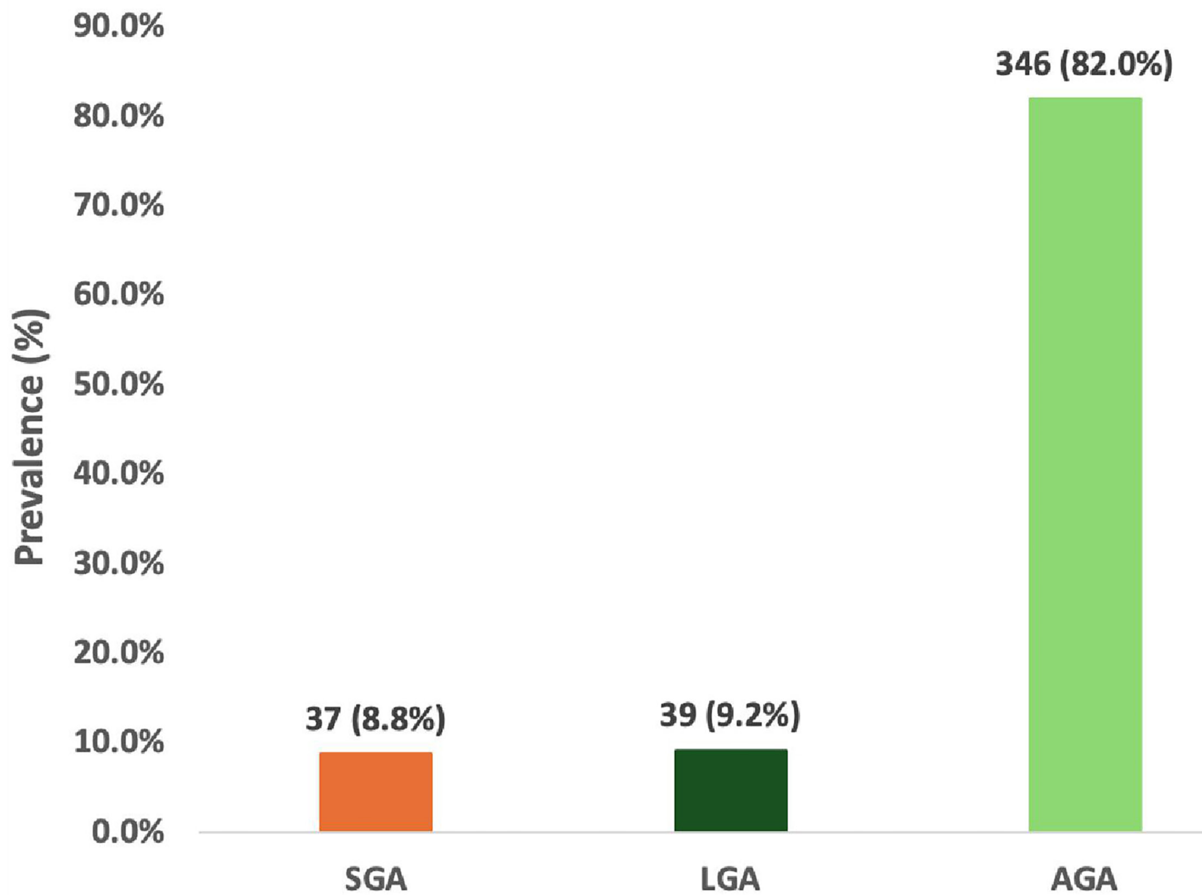

Figure 1 Prevalence of small and large for gestational age (SGA and LGA) births. AGA, appropriate for gestational age.

0.15; 95% CI 0.08 to 0.64; p<0.001) and 88% (aOR 0.12; 95% CI 0.07 to 0.15; p=0.001), respectively. Additionally, teenage mothers (thus, mothers aged less than 20 years old) were more likely to give birth to SGA babies (aOR 4.47; 95%CI 1.51 to 13.3; p=0.007). Mothers who had inadequate knowledge about abnormal Hb levels and their effects on SGA or LGA births were about four times more likely to give birth to SGA babies (aOR 3.63; 95% CI 1.48 to 8.92; p=0.005).

Although there was no significant association between anaemia and polycythaemia in each trimester of pregnancy and LGA births after adjusting for maternal age, maternal knowledge level, antenatal visits and SP intake, LGA babies were significantly associated with the likelihood of a mother delivering through CS mode (aOR 4.90; 95% CI 2.06 to 11.7; p<0.001).

DISCUSSION

The study assessed the prevalence of anaemia and polycythaemia as well as SGA and LGA births and explored the effects of these abnormal Hb levels at different trimesters of pregnancy on SGA and LGA births in Savelugu municipality of the Northern region of Ghana.

The study reported mean Hb levels of 104.2 g/L, 102.1 g/L and 106.8 g/L from the first to the third trimester of pregnancy, respectively. The mean Hb level at each trimester in this study was lower than the global mean Hb[1] and that of a reported study from Ethiopia.[8] Thus, while our study's mean Hb level in each trimester is classified as low (anaemia), that of the reported studies is categorised as normal. The prevalence of anaemia in the first, second and third trimesters of gestation in our study was estimated at 63.5%, 71.3% and 45.2%, respectively. Thus, anaemia prevalence across the trimesters of pregnancy in our study is a burden since it is more than 40.0% of the population.[1] Though Ghana lacks national estimates to compare this study's rate to,[7 35 36] a retrospective study from China,[9] respectively, reported lower rates of anaemia in the first (2.7%), second (14.7%) and third (16.6%) trimesters of pregnancy as compared with the present study. Contextual and societal diversities in study areas of Ghana and China are more likely to account for the variations in the anaemia prevalence. Moreover, the greater prevalence of anaemia in our study could be a result of unhealthy dietary practices such as pica (ie, an appetite deviation for non-food substances like ice, clay, soap and chalk) commonly practised among pregnant mothers in Northern Ghana[37] which might symbolise micronutrient deficiencies like iron, folic acids and other vitamins.[38] Every pregnancy undergoes a natural haemodilution process during the second trimester of pregnancy which causes a physiological decline of Hb by nearly

Table 4 Multivariate analysis for effect of anaemia and polycythaemia on small and large for gestational age (SGA and LGA) births (n=422)

Characteristics	Multinomial logistic regression (appropriate for gestational age=base outcome)							
	SGA				LGA			
	cOR (95%CI)	P value	aOR (95%CI)	P value	cOR (95%CI)	P value	aOR (95%CI)	P value
First-trimester Hb levels								
Anaemia	2.09 (0.83 to 5.25)	0.116	1.91 (0.52 to 7.06)	0.329	0.92 (0.44 to 1.92)	0.827	1.27 (0.57 to 2.82)	0.554
Normal	Reference				Reference			
Polycythaemia	0.08 (0.02 to 0.28)	0.001+	**0.07 (0.01 to 0.46)**	**0.040+**	3.30 (1.91 to 10.8)	0.048+	2.90 (0.73 to 11.6)	0.132
Second-trimester Hb levels								
Anaemia	9.74 (1.30 to 72.6)	0.026+	5.20 (0.63 to 42.8)	0.125	0.41 (0.21 to 0.82)	0.011+	0.54 (0.25 to 1.15)	0.109
Normal	Reference				Reference			
Polycythaemia	0.14 (0.01 to 0.36)	<0.001+	**0.15 (0.08 to 0.64)**	**<0.001+**	2.07 (0.37 to 11.6)	0.407	1.33 (0.18 to 9.79)	0.777
Third-trimester Hb levels								
Anaemia	4.40 (3.95 to 32.5)	<0.001+	**5.56 (1.65 to 48.1)**	**<0.001+**	0.54 (0.26 to 1.13)	0.103	0.75 (0.34 to 1.67)	0.480
Normal	Reference				Reference			
Polycythaemia	0.12 (0.02 to 0.47)	<0.001+	**0.12 (0.07 to 0.15)**	**0.001+**	2.42 (0.24 to 24.1)	0.451	1.84 (0.15 to 22.8)	0.634
Maternal age group								
Less than 20 years	3.63 (1.54 to 8.53)	0.003+	**4.47 (1.51 to 13.3)**	**0.007+**	0.68 (0.15 to 2.98)	0.605	0.87 (0.18 to 4.21)	0.866
20–35 years	Reference				Reference			
More than 35 years	0.60 (0.14 to 2.65)	0.505	0.29 (0.03 to 2.52)	0.264	1.52 (0.59 to 3.90)	0.382	1.74 (0.61 to 4.97)	0.300
Maternal knowledge level								
Inadequate	2.71 (1.36 to 5.38)	0.004+	**3.63 (1.48 to 8.92)**	**0.005+**	0.66 (0.29 to 1.49)	0.320	0.78 (0.33 to 1.88)	0.582
Adequate	Reference						Reference	
Frequency of antenatal visits								
Less than 8	3.21 (1.11 to 9.31)	0.031+	1.94 (0.50 to 7.49)	0.336	0.50 (0.26 to 0.91)	0.047+	0.69 (0.32 to 1.48)	0.345
8 or more	Reference				Reference			
Sulfadoxine-pyrimethamine intake								
None	0.70 (0.16 to 3.13)	0.638	1.20 (0.23 to 6.37)	0.830	1.22 (0.26 to 5.68)	0.800	1.74 (0.34 to 8.82)	0.502
1–3 doses	Reference				Reference			
>3 doses	0.43 (0.18 to 1.01)	0.052	0.73 (0.24 to 2.16)	0.564	2.24 (1.13 to 4.46)	0.021+	1.94 (0.91 to 4.15)	0.088
Mode of delivery								
Caesarian section	2.49 (0.95 to 6.52)	0.064	4.24 (0.93 to 7.41)	0.065	5.71 (2.58 to 12.6)	<0.001+	**4.90 (2.06 to 11.7)**	**<0.001+**
Vaginal	Reference				Reference			
Regression model								
R^2	*0.469*							

Continued

Table 4 Continued

Characteristics	Multinomial logistic regression (appropriate for gestational age=base outcome)
P value	*<0.001*+

+p<0.05.
Bold aOR, 95%CI, P value=significant values for associated factors
aOR, adjusted OR; cOR, crude OR; Hb, haemoglobin.

0.5–1.4g/L.[39 40] This haemodilution theory could explain the higher anaemia prevalence in the second trimester compared with the first and third trimesters in this study. It, therefore, creates an argument for Hb adjustment of about 0.5g/L for anaemia detection in the second trimester of pregnancy, especially in Ghana.[18 41] On one hand, there are several interventions offered during antenatal services including the supply of iron and folic acid (IFA) supplements[34] which are anticipated to correct anaemia identified during antenatal registration (mostly in the first trimester of pregnancy) and also safeguard non-anaemic mothers from becoming anaemic. So, in women who are not given IFA supplements, their Hb levels fall sharply at 20 weeks gestation, then remain fairly constant up to 30 weeks gestation and finally rise slightly afterward[39 40] which makes these women more anaemic throughout pregnancy. Nonetheless, our study illustrated a reduction of anaemia prevalence in the third trimester of gestation which may reflect the impact of IFA intake from the first trimester of gestation.

On the other hand, from the first to the third trimester of pregnancy, the present study disclosed the predominance of polycythaemia to be 5.9%, 3.6% and 1.7%, respectively. Thus, maternal elevated Hb concentration reduces as the pregnancy progresses to term. Our study's higher prevalence of polycythaemia in the first trimester of pregnancy could happen due to acute dehydration resulting from vomiting and inadequate intake of fluids which reduces blood plasma volume and causes Hb levels to go up via compensational mechanisms.[38 42] Although there is a misconception of polycythaemia as a sign of good nutritional status during pregnancy, appropriate education and counselling procedures must be rendered to mothers with polycythaemia due to its unwanted effects on pregnancy outcomes.[19 43]

SGA prevalence in this study was 8.8% which is lesser than the rate reported in India (12.0%)[44] and Uganda (14.0%).[14] Also, compared with other studies conducted in Thailand[10] and Brazil[12] with respective SGA incidence rates of 2.6% and 4.5%, this study's finding is higher. A higher SGA prevalence in our study might be due to low antenatal attendance for routine check-ups and improved quality of care, as most mothers (72.0%) found in our study made less than eight antenatal visits.

The present study estimated the prevalence of LGA to be 9.2%, which was comparable with results from North America (USA)[17] and South America (Brazil)[12] with a prevalence of 11.0% and 16.0%, respectively. Pregnancy-related obesity and diabetes are very rampant among Americans[45] as compared with Ghanaians.[7 35] Hence, prepregnancy obesity and gestational diabetes which are known predisposing factors for LGA births[12 45] might be the reason behind the greater LGA rates among these American mothers.

Our study results showed that women with anaemia in the third trimester of pregnancy were more likely to give birth to SGA infants. In line with this study, many other findings revealed a significant relationship between anaemia in the third trimester of pregnancy and SGA births[26 27] while a retrospective inquiry from Pakistan was not consistent.[28] Throughout pregnancy, there is a physiological fall in Hb levels from the early trimester to the third.[39] This is attributable to the increase in blood plasma volume exceeding the rise in red cell mass[46] which results in the delivery of SGA babies. The final trimester of pregnancy is a critical window for the fetus as most biological insults like anaemia and maternal diseases during this trimester could result in SGA births.[21 27] Furthermore, of the 191 anaemic mothers found in the third trimester of pregnancy, the proportion of those who didn't take more than 3 doses of SP tablets (n=143; 74.9%) was greater than those who ingested more than 3 doses ($p<0.001$ in χ^2/Fisher's exact test). A greater proportion (n=147; 77.0%) of these mothers with third-trimester anaemia attended less than eight antenatal visits while very few made at least eight antenatal visits ($p=0.040$ in χ^2/Fisher's exact test). Thus, mothers who took few SP doses and had fewer antenatal visits during pregnancy increased the risk of developing anaemia in the third trimester of gestation[5 47 48] which could upsurge SGA births in the study area.

Maternal polycythaemia across all trimesters of pregnancy reduced the risk of SGA infants. This implies that mothers who had elevated Hb levels in each trimester of pregnancy served as a significant protection against the delivery of SGA infants. In Finland and Wales, maternal polycythaemia in the second or third trimester of gestation was shown to be statistically significant with an increased risk of SGA babies[22 23] which is incongruent with the present study. Indeed, there is an argument that polycythaemia causes high blood viscosity which results in compromised oxygen supply to placental tissues leading to an increased risk of adverse birth outcomes.[43] Other scholars also assert that elevated Hb could be associated with increased or adequate Hb levels during pregnancy that supplies sufficient oxygen or nutrients to the maternal and fetal tissues leading to appropriate fetal growth and development which tends to be protective against SGA births.[38 49]

Teenage mothers (thus, mothers aged less than 20 years) were more likely to give birth to SGA infants in the present study. Our study is parallel to a cross-sectional survey in Southern Ghana.[50] Since teenage mothers are not physiologically, psychologically and physically developed to cope with the changing demands of pregnancy including fetal–maternal nutrition and healthcare activities among others, it might lead to adverse birth outcomes including SGA births. Interestingly, the prevalence of teenage pregnancy in our study was 9.0% (95% CI 6.5% to 12.2%). Though teenage pregnancy prevalence in our study is slightly lower than that of Ethiopia (12.0%),[51] it still calls for greater education and awareness on sexual and reproductive health with more emphasis on family planning because it creates a higher risk of pregnancy-related complications among adolescents in the region.

In this study, less than half of mothers (n=124; 29.4%) had inadequate knowledge about abnormal Hb levels and risk of SGA or LGA births which mirrored some findings from India and Kenya.[52 53] The present study disclosed that having inadequate knowledge about abnormal Hb levels and SGA or LGA births increased the risk of SGA deliveries. The capacity of pregnant women to ascertain adequate knowledge on Hb levels is very assistive and predictive in preventing or reducing adverse birth outcomes like SGA births through the daily consumption of anaemia-preventive diets.[52 54] Hence, efforts must be put in place to bridge the knowledge gap on Hb significance and adverse obstetric outcomes during pregnancy.

Anaemia and polycythaemia in each trimester of pregnancy offered no statistical relationship with LGA births in our study. However, caesarian section (CS) mode of delivery was statistically associated with LGA births. Some African and Asian studies disclosed that mothers who delivered through CS are more likely to give birth to LGA infants[13 55 56] which reflect the findings of our study. The prevalence of CS delivery mode in this study was 10.2% (95% CI 7.5% to 13.5%) which falls within the WHO recommended rate of 5%–15%.[57] CS delivery mode is a major consequence and competitive risk factor of large-weight births like LGA,[58] although LGA births are not regularly diagnosed or assessed in most Ghanaian health facilities. CS delivery poses a serious threat to maternal and child health due to increased complications resulting in high incidences of maternal and perinatal deaths in most developing countries.[59] Therefore, obstetric tools like Friedman's curve and non-clinical involvements such as childbirth preparation classes should be reinforced in all health facilities to lessen the CS delivery rate and its associated complications,[57 60] especially in low-resource settings like Ghana.

Limitations of the study

The prevalence of anaemia, polycythaemia, SGA and LGA could be underestimated or overestimated by the time and/or season of data collection. This is because the data were collected from April to July 2020, which is the rainy and farming season for the Savelugu citizenry, so health visits are negatively affected. Hence, some respondents may not be available during data collection. Moreover, there might be possible sampling bias as a result of the non-selection of mothers who were absent from antenatal services in the first trimester of pregnancy or lost their antenatal records. Finally, information bias could occur since we collected some secondary data from the antenatal and/or delivery records. Some of the data might be incorrect due to inaccurate measurement and documentation.

CONCLUSION

Anaemia during pregnancy was generally high but increased from the first to the second trimester and subsequently decreased in the third trimester while polycythaemia consistently decreased from the first to the third trimester. LGA babies were more predominant compared with SGA babies. While anaemia in the third trimester of pregnancy increased the risk of SGA births, polycythaemia across the trimesters offered significant protection. Interestingly, anaemia and polycythaemia in all the trimesters of pregnancy were not statistically associated with LGA births.

Attaining Sustainable Development Goal 3 by 2030 is a positive step to reduce adverse birth outcomes such as SGA and LGA births.[3] Ghana Health Service and other stakeholders should have a critical look at appropriate anaemia prevention and treatment measures across all trimesters of pregnancy, especially during the third trimester. Collaboration between local governments and health facilities should be enhanced to create extensive awareness of third-trimester anaemia via community health education. Health facilities should be empowered to build the capacities of all their health professionals especially midwives, community health nurses and medical officers on third-trimester anaemia and its effects on SGA births and/or other adverse pregnancy outcomes. Furthermore, national, regional or global studies should consider polycythaemia as a public health concern and give it the necessary attention. We recommend that a larger study should be conducted to investigate the effects of low or elevated Hb levels across each trimester of pregnancy on SGA or LGA births as well as other adverse birth outcomes in Ghana.

Author affiliations
[1]Savelugu Municipal Hospital, Ghana Health Service, Savelugu, Northern Region, Ghana
[2]Department of Midwifery, Garden City University College, Kenyasi - Kumasi, Ashanti Region, Ghana
[3]Nanton District Health Directorate, Ghana Health Service, Nanton, Northern Region, Ghana
[4]School of Allied Health Sciences, University for Development Studies, Tamale, Northern Region, Ghana

Acknowledgements The authors wish to show their gratitude to the data collectors, study participants and management of the study sites (health facilities) for their cooperation and unwavering support. We also thank the Nutritional Science Department of the University for Development Studies for offering supportive supervision during this study.

Contributors SAG, MSZ, AA and PAA formulated the research questions, designed and conceptualised the study. SAG, MSZ, AA, SI and MAI carried out the data collection while SAG, SI, MAI and PAA performed the data analysis and interpretations. SAG is the guarantor. All authors contributed to reviewing and approving the final manuscript.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study involves human participants and the Institutional Review Board of the Navrongo Health Research Centre offered ethical approval for this study (reference number: NHRCIRB373). The Savelugu Municipal Health Directorate granted permission to use the municipal health facilities as the study sites for data collection. Written informed consent/assent was obtained from all study participants and/or legal representatives before data collection. Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available on reasonable request. The datasets will be made available by the corresponding author, without undue reservation.

ORCID iD
Silas Adjei-Gyamfi http://orcid.org/0009-0008-8496-4099

REFERENCES

1 WHO. *The global prevalence of anaemia in 2011*. Geneva, 2015. Available: www.who.int
2 Stephen G, Mgongo M, Hussein Hashim T, *et al*. Anaemia in pregnancy: prevalence, risk factors, and adverse perinatal outcomes in Northern Tanzania. *Anemia* 2018;2018.
3 WHO. SDG 3: ensure healthy lives and promote wellbeing for all at all ages. WHO; 2017.
4 Stevens GA, Finucane MM, De-Regil LM, *et al*. Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. *Lancet Glob Health* 2013;1:e16–25.
5 Rezk M, Marawan H, Dawood R, *et al*. Prevalence and risk factors of iron-deficiency anaemia among pregnant women in rural districts of Menoufia governorate, Egypt. *J Obstet Gynaecol* 2015;35:663–6.
6 Okube OT, Mirie W, Odhiambo E, *et al*. Prevalence and factors associated with anaemia among pregnant women attending antenatal clinic in the second and third trimesters at Pumwani maternity hospital, Kenya. *Kenya Open J Obstet Gynecol* 2015;16–27. Available: http://www.scirp.org/journal/ojoghttp://dx.doi.org/10.4236/ojog.2016.61003http://creativecommons.org/licenses/by/4.0/
7 Ghana Statistical Service (GSS),Ghana health service (GHS) & II. *Ghana demographic and health survey 2014*. Rockville, Maryland, USA, 2015.
8 TekluA, WorkuM, Ambachew H, *et al*. Prevalence of anemia among women receiving antenatal care at Boditii health center, Southern Ethiopia. *CMR* 2015;4:79.
9 Lin L, Wei Y, Zhu W, *et al*. Prevalence, risk factors and associated adverse pregnancy outcomes of anaemia in Chinese pregnant women: a multicentre retrospective study. *BMC Pregnancy Childbirth* 2018;18:1–8.
10 Boriboonhirunsarn D. Prevalence and risk factors for inappropriate birth weight for gestational age. *Asian Biomed (Res Rev News)* 2017;9:637–42.
11 Lee ACC, Kozuki N, Cousens S, *et al*. Estimates of burden and consequences of infants born small for gestational age in low and middle income countries with INTERGROWTH-21 st standard: analysis of CHERG datasets. *BMJ* 2017;358.
12 Silveira LRPD, Schmidt MI, Reichelt AAJ, *et al*. Obesity, gestational weight gain, and birth weight in women with gestational diabetes: the LINDA-Brasil (2014-2017) and the EBDG (1991-1995) studies. *J Pediatr (Rio J)* 2021;97:167–76.
13 Kuciene R, Dulskiene V, Medzioniene J. Associations between high birth weight, being large for gestational age, and high blood pressure among adolescents: a cross-sectional study. *Eur J Nutr* 2018;57:373–81.
14 Zakama A, Kajubi R, Kakuru A, *et al*. 633: Generation of a malaria-negative African birthweight standard for diagnosis of small for gestational age. *Am J Obstet Gynecol* 2020;222.
15 Sania A, Smith ER, Manji K, *et al*. Neonatal and infant mortality risk associated with preterm and small for gestational age births

in Tanzania: individual level pooled analysis using the intergrowth standard. *J Pediatr* 2018;192:66–72.
16 Zheng W, Zhang L, Tian ZH, *et al*. Analysis of population attributable risk of large for gestational age. *Zhonghua Fu Chan Ke Za Zhi* 2019;54:833–9.
17 Jones-Smith JC, Dow WH, Oddo VM. Association between Native American-owned casinos and the prevalence of large-for-gestational-age births. *Int J Epidemiol* 2017;46:1202–10.
18 Adjei-Gyamfi S, Musah B, Asirifi A, *et al*. Maternal risk factors for low birthweight and macrosomia: a cross-sectional study in Northern Region, Ghana. *J Health Popul Nutr* 2023;42:1:16.
19 Adjei-Gyamfi S, Asirifi A, Aiga H. Prevalence and associated risk factors of preterm and post-term births in northern Ghana: a retrospective study in Savelugu municipality. *J Pediatr Perinatol Child Health* 2023;07:235–48.
20 Sukrat B, Wilasrusmee C, Siribumrungwong B, *et al*. Hemoglobin concentration and pregnancy outcomes: a systematic review and meta-analysis. *Biomed Res Int* 2013;2013:769057.
21 Young MF, Oaks BM, Tandon S, *et al*. Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. *Ann N Y Acad Sci* 2019;1450:47–68.
22 Randall DA, Patterson JA, Gallimore F, *et al*. The association between haemoglobin levels in the first 20 weeks of pregnancy and pregnancy outcomes. *PLoS One* 2019;14:e0225123.
23 Ronkainen J, Lowry E, Heiskala A, *et al*. Maternal hemoglobin associates with preterm delivery and small for gestational age in two Finnish birth cohorts. *Eur J Obstet Gynecol Reprod Biol* 2019;238:44–8.
24 Badfar G, Shohani M, Soleymani A, *et al*. *Maternal anemia during pregnancy and small for gestational age: a systematic review and meta-analysis*. . Taylor and Francis Ltd, 2019:32. 1728–34.
25 Yi S-W, Han Y-J, Ohrr H. Anemia before pregnancy and risk of preterm birth, low birth weight and small-for-gestational-age birth in Korean women. *Eur J Clin Nutr* 2013;67:337–42.
26 Yuan X, Hu H, Zhang M, *et al*. Iron deficiency in late pregnancy and its associations with birth outcomes in Chinese pregnant women: a retrospective cohort study. *Nutr Metab (Lond)* 2019;16:30.
27 Nair M, Choudhury MK, Choudhury SS, *et al*. Association between maternal anaemia and pregnancy outcomes: a cohort study in Assam, India. *BMJ Glob Health* 2016;1:e000026.
28 Mahmood T, Rehman AU, Tserenpil G, *et al*. The association between iron-deficiency anemia and adverse pregnancy outcomes: a retrospective report from Pakistan. *Cureus* 2019;11:e5854.
29 Ruwanpathirana T, Fernando DN. Risk factors for 'small for gestational age babies' *Indian J Pediatr* 2014;81:1000–4.
30 Savelugu Municipal Health Directorate (Ghana Health Service). Annual performance report 2020: Savelugu municipal health directorate. Savelugu, Northern Region, 2021.
31 Cochran WG. *Samling techniques*. John Wiley & Sons, Inc, 1977:448.
32 Black RE. Global prevalence of small for gestational age births. *Nestle Nutr Inst Workshop Ser* 2015;81:1–7.
33 Saaka M, Oladele J, Larbi A, *et al*. Dietary diversity is not associated with haematological status of pregnant women resident in rural areas of Northern Ghana. *J Nutr Metab* 2017;2017:8497892.
34 World Health Organization. *WHO recommendations on antenatal care for a positive pregnancy experience*. Geneva, 2016.
35 Mocking M, Savitri AI, Uiterwaal CSPM, *et al*. Does body mass index early in pregnancy influence the risk of maternal anaemia? An observational study in Indonesian and Ghanaian women. *BMC Public Health* 2018;18:873.
36 University of Ghana, GroundWork, University of Wisconsin-Madison, KEMRI-WellcomeTrust U. Ghana micronutrient survey 2017. Accra, Ghana, 2017. Available: http://groundworkhealth.org/wp-content/uploads/2018/06/UoG-GroundWork_2017-GHANA-MICRONUTRIENT-SURVEY_Final_180607.pdf
37 Abubakari A, Jahn A. Maternal dietary patterns and practices and birth weight in Northern Ghana. *PLoS One* 2016;11:e0162285.
38 Alwan NA, Cade JE, McArdle HJ, *et al*. Maternal iron status in early pregnancy and birth outcomes: insights from the baby's vascular health and iron in pregnancy study. *Br J Nutr* 2015;113:1985–92.
39 Churchill D, Nair M, Stanworth SJ, *et al*. The change in haemoglobin concentration between the first and third trimesters of pregnancy: a population study. *BMC Pregnancy Childbirth* 2019;19:359.
40 Paintin DB, Thomson AM, Hytten FE. Iron and the haemoglobin level in pregnancy. *BJOG* 1966;73:181–90.
41 Abaane DN, Adokiya MN, Abiiro GA. Factors associated with anaemia in pregnancy: a retrospective cross-sectional study in the Bolgatanga municipality, Northern Ghana. *PLoS One* 2023;18:e0286186.
42 Mulyani EY, Briawan D, Santoso BI, *et al*. Effect of dehydration during pregnancy on birth weight and length in West Jakarta. *J Nutr Sci* 2021;10:e70.
43 Yip R. Significance of an abnormally low or high hemoglobin concentration during pregnancy: special consideration of iron nutrition. *Am J Clin Nutr* 2000;72:272–9.
44 Gautam Paudel P, Sunny AK, Gurung R, *et al*. Prevalence, risk factors and consequences of newborns born small for gestational age: a multisite study in Nepal. *BMJ Paediatr Open* 2020;4:e000607.
45 Chen L, Mayo R, Chatry A, *et al*. Gestational diabetes mellitus: its epidemiology and implication beyond pregnancy. *Curr Epidemiol Rep* 2016;3:1–11.
46 Perry D, Lowndes K. Blood disorders specific to pregnancy. In: *Oxford textbook of medicine*. 2010: 2173–85. Available: http://repository-tnmgrmu.ac.in/9486/
47 Nurnaningsih N, Ahmad M, Sunarno I, *et al*. Risk factors for the anemia in pregnant women: a literature review. Nurse Heal J Keperawatan 2022;11:137–50.
48 Iyanam VE, Idung AU, Jombo HE, *et al*. Anaemia in pregnancy at booking: prevalence and risk factors among antenatal attendees in a Southern Nigeria general hospital. *AJMAH* 2019;15:1–11.
49 Gaillard R, Eilers PHC, Yassine S, *et al*. Risk factors and consequences of maternal anaemia and elevated haemoglobin levels during pregnancy: a population-based prospective cohort study. *Paediatr Perinat Epidemiol* 2014;28:213–26.
50 Agbozo F, Abubakari A, Der J, *et al*. Prevalence of low birth weight, macrosomia and stillbirth and their relationship to associated maternal risk factors in Hohoe municipality, Ghana. *Midwifery* 2016;40:200–6.
51 Kassa GM, Arowojolu AO, Odukogbe A-TA, *et al*. Trends and determinants of teenage childbearing in Ethiopia: evidence from the 2000 to 2016 demographic and health surveys. *Ital J Pediatr* 2019;45:153.
52 Kamau M, Kimani S, Mirie W. Counselling and knowledge on iron and folic acid supplementation (IFAS) among pregnant women in Kiambu County, Kenya: a cross-sectional study. *AAS Open Res* 2018;1:21.
53 Kumary TV, Baby A, Venugopal J, *et al*. Knowledge on management of anemia during pregnancy: a descriptive study. *Arch Med Health Sci* 2014;2:140.
54 Thabit MF. Maternal knowledge related to anemia during pregnancy among a sample of mothers attending primary health care centers. Baghdad. *Al Kindy Col Med J* 2017;13:72–7.
55 Hua X-G, Jiang W, Hu R, *et al*. Large for gestational age and macrosomia in pregnancies without gestational diabetes mellitus. *J Matern Neonatal Med* 2019;1–10.
56 Tarimo CS, Mahande MJ, Obure J. Prevalence and risk factors for caesarean delivery following labor induction at a tertiary hospital in North Tanzania: a retrospective cohort study (2000-2015). *BMC Pregnancy Childbirth* 2020;20:173.
57 WHO. WHO recommendations: non-clinical interventions to reduce unnecessary caesarean sections. 2018.
58 Koyanagi A, Zhang J, Dagvadorj A, *et al*. Macrosomia in 23 developing countries: an analysis of a multicountry, facility-based, cross-sectional survey. *Lancet* 2013;381:476–83.
59 Said AS, Manji KP. Risk factors and outcomes of fetal macrosomia in a tertiary centre in Tanzania: a case-control study. *BMC Pregnancy Childbirth* 2016;16:243.
60 Mohammadbeigi A, Farhadifar F, Soufi Zadeh N, *et al*. Fetal macrosomia: risk factors, maternal, and perinatal outcome. *Ann Med Health Sci Res* 2013;3:546–50.