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Research article

Maternal hemoglobin and risk of low birth weight: A hospital-based cross-sectional study in Nepal

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ABSTRACT

Background: Maternal hemoglobin during pregnancy is an important predictor of neonatal outcomes such as birth weight. The newborn weight of an infant is considered a crucial factor for morbidity and mortality. This study aimed to assess the association between maternal hemoglobin concentration and newborn weight at term pregnancy.

Methods: A hospital-based cross-sectional study was conducted at Tribhuvan University Teaching Hospital (TUTH), Kathmandu, Nepal from 14th April 2018 to 13th April 2019. Term singleton pregnant women who were admitted for delivery in the labor room of TUTH were included in this study. Maternal characteristics such as age, parity, birth space, ethnicity, education level, dietary habit, body mass index (BMI), and hemoglobin level were recorded. The newborn weight was taken immediately after delivery. The main outcome of this study was the birth weight. The association between hemoglobin level and newborn weight was analyzed using bivariate and multivariable logistic regression analysis.

Results: Of 2,418 term pregnant women, the prevalence of low hemoglobin and high hemoglobin levels were 24% (95% CI: 22–25.4), and 17% (95% CI: 15.7–18.7), respectively. The prevalence of low birth weight (LBW) was 12.9% (95% CI: 11.7–14.4). Multivariable logistic regression analysis showed that those mothers who had low hemoglobin concentration (adjusted Odds Ratio/aOR = 3.77, 95% CI: 2.84–5.01), and high hemoglobin concentration (aOR = 3.07, 95% CI: 2.23–4.24) had higher odds of having LBW compared to mothers having normal hemoglobin level. Mothers with both young age pregnancy (aged 16–20 years) and older pregnancy (aged ≥31 years) (aOR = 1.60, 95% CI: 1.01–2.52) and (aOR = 1.60, 95% CI: 1.06–2.41), respectively had higher odds of LBW compared to mothers aged 21–25 years. Those mothers who attended a primary level of education had higher odds of (aOR = 1.93, 95% CI: 1.05–3.55) LBW compared to those mothers with a higher level of education. Moreover, mothers who belonged to *Janajati* ethnic group (aOR = 0.47, 95% CI: 0.34–0.65) compared to the *Brahmin/Chhetri* ethnic group, and mothers with a birth space of more than three years (aOR = 0.63, 95% CI: 0.41–0.97) compared to those who had less than three years of birth spacing and mothers who were overweight/obese (aOR = 0.74, 95% CI: 0.55–0.99) compared to normal nutritional status had lower odds of having LBW.

Conclusions: Our study concludes that both low and high hemoglobin had an increased risk of having low birth weight. Policies and programs can benefit by adopting the findings of this study. More empirical research is critical to understanding the impact of hemoglobin levels on birth weight.

1. Background

Low birth weight refers to the absolute weight of a newborn whose birth weight is less than 2500 g (5.5 pounds) regardless of gestational age [1, 2]. During pregnancy, a rapid increase in plasma volume allows adequate growth of the fetus [3]. Even in healthy females, this condition induced a slight decrease in hemoglobin (Hb) levels during pregnancy [3, 4]. However, an inadequate increase in plasma volume during pregnancy is a risk factor for low birth weight and placental weight [4]. Low birth weight (LBW) is a major health problem in resource-poor countries [5]. Birth weight is a reliable indicator of the future health and nutritional outcome of infants [6]. Low birth weight baby has a high risk of

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developing long-term neurologic disability, cardiovascular diseases, diabetes, impaired language development, and poor cognitive development [7].

Low concentration of Hb level or maternal anemia is also a common public health problem in low- and middle-income countries (LMICs) where nearly one in every two pregnant women had a low Hb level during pregnancy [8, 9]. South and Southeast Asian countries account for the largest burden of anemia, with an estimated prevalence of 52.5% among women of reproductive age (WRA) [10]. According to World Health Organization (WHO), anemia in pregnancy refers to the condition in which total red blood cells or hemoglobin concentration in blood is less than 110 g/L (less than 11 g/dL) in venous blood during any trimester [11]. Anemia can be categorized as acquired or inherited. The most common acquired anemia includes iron, folate, and vitamin B12 deficiency, chronic disease, acquired hemolytic anemia, and aplastic anemia [11]. Sickle cell anemia, thalassemia, and Fanconi anemia are known as hereditary anemia [11]. Low concentration of Hb in blood during pregnancy is mostly due to iron deficiency [11]. Similarly, nutritional problems such as due to inadequate dietary intake [12], a low diversified diet [13], and inadequate weight gain during pregnancy contribute to a lower intake of nutrients [14].

Despite adequate evidence, the relationship between low hemoglobin levels during pregnancy and adverse birth outcomes is controversial. Though several studies have demonstrated the positive association of low hemoglobin levels with LBW of newborns while some studies have shown no relationship between maternal hemoglobin level and birth weight [15, 16, 17]. Comparatively, there is limited evidence about the association of high maternal hemoglobin concentration during pregnancy with newborn weight. In addition, few studies showed that the maternal hemoglobin level during the different gestational periods has different birth weight outcomes [18, 19]. The previous studies also suggested that maternal hemoglobin concentration differs with maternal age, race/-ethnicity, lifestyle behaviors, socioeconomic status, maternal food habits, nutritional status, altitude, and ecological regions [15]. Moreover, the low Hb concentration during pregnancy and LBW are considered major risk factors for maternal and newborn mortality and morbidity in resource-poor countries like Nepal [20, 21, 22]. On the other hand, several studies have also found that higher maternal hemoglobin levels during pregnancy are linked to a higher chance of having LBW [23, 24].

Several studies from Nepal have explicitly presented the persistently high prevalence of anemia among reproductive-aged women across different ecological regions and among different socioeconomic and ethnic groups [25, 26, 27]. The prevalence of LBW (12%) and low concentration of Hb among pregnant women (46%) has remained stagnant for the last decade (2005–2016) in Nepal [28]. LBW in neonates is the single most common cause of neonatal mortality and morbidity [22]. According to the Multiple Indicator Cluster Survey (MICS), 2019, the neonate mortality rate for Nepal was 16 deaths per 1000 live births [29], a 5% decline from 2016 [28]. The majority of previous research from different countries emphasized the effects of maternal anemia, and only a few studies were found to reveal an association between maternal high hemoglobin levels and newborn outcomes [30]. Although previous studies have examined the association of low hemoglobin concentration with newborn weight, evidence of the association of high Hb with low birth weight is lacking in Nepal. This study aims to assess the association between maternal hemoglobin concentrations and newborn weight at term pregnancy. Since the changes in the Hb concentrations level during pregnancy is most common, it is important to measure its association with LBW, which would fill the gap for the necessity of local evidence in the Nepalese context.

2. Methods

2.1. Study design

A hospital-based cross-sectional study was conducted among pregnant women at term pregnancy (37–42 weeks) who were admitted to the labor room for delivery in Tribhuvan University Teaching Hospital (TUTH), Nepal. The participants were enrolled from 14th April 2018 to 13th April 2019. Tribhuvan University Teaching Hospital is the first Teaching Hospital and a leading institute for medical education in Nepal, which was established in 1983AD [31]. Tribhuvan University Teaching Hospital has been providing multi-speciality healthcare services in Nepal.

2.2. Sampling strategy and setting

Tribhuvan University Teaching Hospital was selected purposively. Since this study was conducted in a hospital's labor room, the principal investigator of this study collected the data during his duty schedule throughout the study period. During the study period, a total of 2,418 term pregnancies were included in this study. A consecutive purposive sampling technique was used to select the participants. The term singleton pregnancy (37–42 weeks period) was included in the study. The pregnant women who were already diagnosed with special medical complications such as diabetes mellitus, hypertension, antepartum hemorrhage, renal disease, cardio-pulmonary disease, and inflammatory bowel diseases were excluded from the study. Similarly, those pregnant women who delivered preterm delivery and those who received a blood transfusion during pregnancy were also excluded from the study.

2.3. Data collection and variables

Data were collected through individual interviews at the labor room/birthing center conducted in the Nepali language by a Gynecology resident (trainee for Master's Degree in Gynaecology) trained for five days on the objective of the study, data collection procedure, sampling method, ethical aspects of the study, data entry techniques, and data management. Term singleton pregnant women who came for delivery in TUTH were admitted to labor room (LR). The history was taken and clinical examinations were conducted during admission. Gestational age was calculated from 1st day of the last menstruation period (LMP) in regularly menstruating women. The LMP was used to measure the gestational age in the previous study [32]. In the case of the irregular menstrual cycle, the pregnancy date was calculated from the 1st trimester Ultrasonogram (USG) scan. If there was a discrepancy in gestational age calculation between the last menstruation period and USG scan of more than two weeks then the gestational age was calculated by USG. A case record form (CRF) was used to record all the information. A face-to-face interview was undertaken to collect data using the semi-structured questionnaire.

2.4. Predictor variables

Predictors of this study were selected based on the literature review mainly on two aspects: 1) socio-demographic characteristics, including maternal age, education level, and ethnicity. The age of the pregnant women was recorded as 16–20, 21–25, 26–30, and ≥31 years. Maternal education is classified into primary (1–5 grade), secondary (6–10 grade), intermediate (11–12 grade), and higher education levels (University level). Ethnicity (categorized as Brahmin/Chhetri, Dalit, Janajati, and others used by the government of Nepal in Nepal Demographic and Health Survey (NDHS) [28]. 2) Maternal health-related characteristics including parity, birth spacing, body mass index (BMI), dietary habit and hemoglobin level were measured. Parity was classified into primipara and multipara. Birth space recoded into ≤3 years and >3 years. The BMI was categorized into underweight (<18.5 kg/m^2), normal (18.5–24.99 kg/m^2), overweight (25–29.99 kg/m^2) and obesity (≥30 kg/m^2) according to the WHO classification. Dietary habits were categorized into vegetarian and non-vegetarian.

Biochemical assessments such as hemoglobin level estimation were taken before delivery. Venous blood was drawn in EDTA vial (~1ml) and sent to the haematology department of TUTH for Hb estimation. The Hb was measured using an automatic analyzer in the lab. (It measures by the non-cyanmethemoglobin method). Hemoglobin level were further classified as low Hb (<11 g/dL), normal Hb (11–13 g/dL) and high Hb (>13 g/dL) [11]. Women with low Hb (<11 g/dL) were further subdivided into 3 groups: mild (10–10.9 g/dL), moderate (7–9.9 g/dL) and severe anemia (<7 g/dL) [11].

2.5. Outcome variable

After delivery and care of the baby, the weight of the baby was taken and recorded. Newborn weight was further dichotomized into low birth weight (<2500 gm), and normal birth weight (≥2500 gm) [1, 2].

2.6. Data management and analysis

Data checking and compiling were done manually to ensure completeness and accuracy before data were entered for analysis. Data were entered in Epi Data version 3.1 and analyzed using Stata/MP version 14.1 (Stata Corp LP, College Station, Texas).

Exploratory data analysis included frequency estimations and cross-tabulations of each predictor and outcome variable. Categorical variables were presented in percentage and frequency. After the normality test, all the continuous data were normally distributed thus we presented continuous variables in mean and standard deviation. In bivariate analysis, binary logistic regression was used to estimate the odds ratio and 95% Confidence Intervals (CIs). Variables that were found statistically significant (95% CI is not overlapping the null) during bivariate analyses were checked for multicollinearity by calculating the Variance Inflation Factor (VIF) [33]. In multivariable logistic regression analysis, all predictor variables were included for adjusting the confounders. Crude odds ratio (cOR) and adjusted odds ratio (aOR) with 95% CIs were calculated to assess the presence and strength of association, with a threshold of $p < 0.05$ used for the determination of statistical significance.

2.7. Ethical considerations

The ethical clearance for this study was obtained from the Institutional Review Committee (IRC) of the Institute of Medicine (IOM), Tribhuvan University Ref: 383 (6-11-E)^2/074/075. Written informed consent was obtained from the participants and all the participants were informed about voluntary participation, their right to refusal at any point, and the confidentiality of their identity.

3. Results

In this study, Figure 1 shows the hemoglobin level of the study participants. The prevalence of low hemoglobin and high hemoglobin was 24% (95% CI: 22–25.4), and 17% (95% CI: 15.7–18.7), respectively. Similarly, the prevalence of mild, moderate, and severe anemia was 15.8% (383/2,418), 7.7% (187/2,418), and 0.1% (3/2,418), respectively (Figure 2).

The mean (SD) of the mother's age was 26.5 (4.3) years and the mean (SD) of the gestation period was 39.2 (1.1) weeks. The mean (SD) hemoglobin level of the mothers was 11.8 (1.3) g/dL. The average BMI of the study population was 23.6 (3.6) kg/m^2. The average birth weight of the newborn was 3.1 (0.4) kg. This study shows more than one-third (37.9%) of the mothers' age groups were between 21-25 years, and 26–30 years, respectively. More than half (57.9%) of the mothers were primipara. Slightly more mothers had attended higher education level (38.1%) followed by intermediate education (37.2%). The majority of the participants belonged to *Brahmin* ethnicity (40.6%) followed by *Janajati* ethnic group (30.9%). More than two-thirds (71.4%) of mothers had a birth spacing of less than three years. Almost all (99.3%) mothers had a non-vegetarian diet habit. Only 3.7% of the mothers were underweight in nutritional status (BMI= <18.5 kg/m^2) and 30% of the mothers were overweight and obesity (BMI = ≥25 kg/m^2). In this study, only 12.9% (95% CI: 11.7–14.4) of the newborn was low birth weight (Table 1).

In bivariate analysis, those mothers who had a low hemoglobin concentrations had 3.85 times (Crude odd ratio, cOR = 3.85, 95% CI: 2.91–5.19) higher odds of LBW compared to mothers having normal hemoglobin levels. Moreover, mothers with high hemoglobin levels were three times (cOR = 3.04, 95% CI: 2.21–4.17) more likely to have LBW compared to mothers with normal hemoglobin levels. Those mothers who practiced vegetarian diet habits had 3.07 times (cOR = 3.07, 95% CI: 1.06–8.92) higher odds of having LBW compared to mothers with non-vegetarian diet habits, and others with young age pregnancy (aged 16–20 years) were 1.71 times (cOR = 1.71, 95% CI: 1.12–2.62) more likely to have higher odds of LBW compared to mothers aged 21–25 years (Table 2).

In this study, several maternal factors predicted a lower likelihood to have LBW: Overweight/obese mothers had lower odds of having LBW (cOR = 0.69, 95% CI: 0.52–0.91) compared to normal BMI status, mothers with birth space of more than three years had lower odds of having LBW (cOR = 0.61, 95% CI: 0.46–0.82) compared to less than three years, multipara mothers had lower odds of having LBW (cOR = 0.70, 95% CI: 0.54–0.89) compared to primipara mothers, and mother who belonged to *Janajati* ethnic group were less likely to have LBW (cOR = 0.51, 95% CI: 0.37–0.68) compared to a *Brahmin/Chhetri* ethnic group (Table 2).

In multivariable analysis, mothers who had low hemoglobin concentration (aOR = 3.77, 95% CI: 2.84–5.01), and high hemoglobin concentrations (aOR = 3.07, 95% CI: 2.23–4.24) had more than three times higher odds of LBW compared to normal hemoglobin concentrations. Likewise, mothers who had both young age pregnancy (aged 16–20 years) and elder pregnancy (aged ≥31 years) (aOR = 1.60, 95% CI: 1.01–2.52) and (aOR = 1.60, 95% CI: 1.06–2.41), respectively were 1.60 times higher odds of LBW compared to mothers aged 21–25 years.

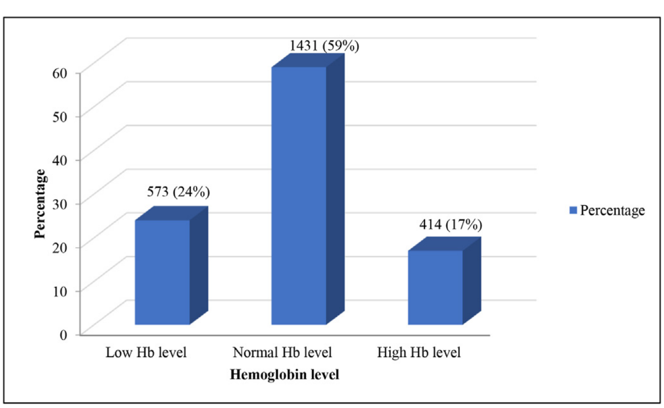

Figure 1. Prevalence of normal, low and high hemoglobin concentration status at term pregnancy.

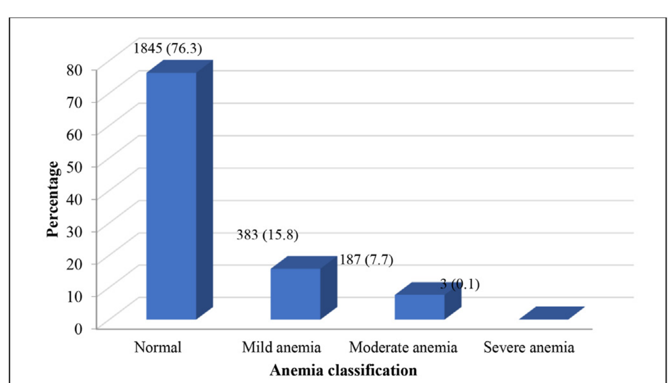

Figure 2. Prevalence of anemia at term pregnancy.

Table 1. Socio-demographic characteristics of the study participants (n = 2,418).

Respondent's characteristics	Total		Low Hb level (<11 gm/dl)		Normal Hb level (11–13 gm/dl)		High Hb level (>13 gm/dl)	
	mean	SD	mean	SD	mean	SD	mean	SD
Mother age	26.5	4.3	26	4	26	4	27	4
Gestational age	39.2	1.1	39.3	1.1	39.3	1	39.1	1
Hemoglobin level	11.8	1.3	10.1	0.8	11.9	0.5	13.7	0.7
Birth weight	3.1	0.4	2.9	0.5	3.1	0.4	2.9	0.5
BMI	23.6	3.6	23.3	3.5	23.6	3.5	23.9	4.1
	n	%	n	%	n	%	n	%
Mothers age groups								
16–20	167	6.9	44	26.3	97	58.1	26	15.6
21–25	918	37.9	221	24.1	542	59.1	155	16.9
26–30	918	37.9	206	22.4	550	59.9	162	17.6
≥31	415	17.3	102	24.6	242	58.3	71	17.1
Parity								
Primipara	1402	57.9	331	23.6	814	58.1	257	18.3
Multipara	1016	42.1	242	24.8	617	60.7	157	15.5
Education level								
Primary	110	4.5	31	28.2	66	60	13	11.8
Secondary	488	20.2	108	22.1	292	59.8	88	18.1
Intermediate	899	37.2	229	25.4	526	58.5	144	16.1
Higher	921	38.1	205	22.3	547	59.4	169	18.3
Ethnicity								
Brahmin	981	40.6	241	24.6	572	58.3	168	17.1
Chhetri	443	18.3	106	23.9	257	58.1	80	18.1
Dalit	103	4.3	24	23.3	65	63.1	14	13.6
Janajati	747	30.9	163	21.8	454	60.8	130	17.4
Others	144	5.9	39	27.1	83	57.6	22	15.3
Birth spacing								
≤3 years	1726	71.4	416	24.1	1007	58.3	303	17.6
>3 years	692	28.6	157	22.7	424	61.3	111	16.1
Dietary habit								
Non vegetarian	2402	99.3	572	23.8	1421	59.2	409	17.1
Vegetarian	16	0.7	1	6.3	10	62.5	5	31.2
BMI								
Underweight	139	5.7	38	27.3	76	54.7	25	17.9
Normal	1543	63.8	380	24.6	911	59.1	252	16.3
Overweight/obesity	736	30.4	155	21.1	444	60.3	137	18.6
Birth weight								
Normal birth weight	2104	87.1	441	20.9	1328	63.1	335	15.9
Low birth weight	314	12.9	132	42.1	103	32.8	79	25.1

Mothers who attended only a primary level of education had almost 2 times (aOR = 1.93, 95% CI: 1.05–3.55) higher odds of LBW compared to those mothers with higher education (Table 2).

In contrast, mothers who belonged to *Janajati* ethnic group were 53% less likely to have LBW (aOR = 0.47, 95% CI: 0.34–0.65) compared to *Brahmin/Chhetri* ethnic group, mothers who had a birth space of more than three years had 37% less likely to have LBW (aOR = 0.63, 95% CI: 0.41–0.97) compared to less than three years birth spacing, and mothers who had overweight/obese nutritional status were 26% lower odds of having LBW (cOR = 0.74, 95% CI: 0.55–0.99) compared to normal BMI status (Table 2).

4. Discussion

This study showed the prevalence of low hemoglobin was 24% in term pregnancy. This prevalence is lower than the previous study conducted at Paropakar Maternity and Women's Hospital, Kathmandu, Nepal among full-term singleton pregnancies in 2013 [34]. Also, this prevalence is lower than the prevalence in nationally representative demographic and health survey data [28]. This may be due to the fact that this study was conducted at a tertiary care hospital in Kathmandu, the capital city of Nepal. In addition, a high number of normal Hb levels could be due to the free distribution of iron folic acids supplementation offered throughout the country. A previous study that utilized spatial analysis also showed the prevalence of anemia was observed lower in urban areas compared to the rural region of Nepal [27]. On the other hand, the prevalence of high hemoglobin was 17% in our study. This prevalence is lower than previous studies conducted in Iran (32%) [35], and neighboring country India (30%) [36] but higher than the prevalence from a study in Northwest China, where hemoglobin levels (≥130 g/L) were 8.2% [24].

In this study, mothers who had low hemoglobin concentration, and high hemoglobin concentrations were found to have higher odds of LBW compared to mothers with normal hemoglobin concentrations. The mothers having low hemoglobin had the chance of giving birth to an LBW which is also supported by the results of the previous studies [14, 30, 34, 37, 38]. The changes in placental angiogenesis are brought by the low level of hemoglobin which limits the availability of oxygen to the fetus and hence can potentially restrict intrauterine growth [39]. Low hemoglobin levels impede the delivery of oxygen and nutrients to the fetus by

Table 2. Bivariate and multivariable logistic regression analysis of maternal factors and newborn birth weight (n = 2,418).

Respondent's characteristics	Normal birth weight (≥2.5 kg)	Low birth weight (<2.5 kg)	Bivariate analysis	P-value[a]	Multivariable analysis	P-value[b]
	n (%)	n (%)	cOR (95% CI)		aOR (95% CI)	
Hemoglobin level (g/dL)						
Low Hb level	441 (20.9)	132 (42.1)	3.85 (2.91–5.10)	<0.001*	3.77 (2.84–5.01)	<0.001*
Normal Hb level	1328 (63.1)	103 (32.8)	Ref		Ref	
High Hb level	335 (15.9)	335 (25.2)	3.04 (2.21–4.17)	<0.001*	3.07 (2.23–4.24)	<0.001*
BMI (kg/m^2)						
Underweight	114 (5.4)	25 (7.9)	1.35 (0.85–2.13)	0.192	1.25 (0.77–2.03)	0.284
Normal	1328 (63.1)	215 (68.5)	Ref		Ref	
Overweight/obesity	662 (31.5)	74 (23.6)	0.69 (0.52–0.91)	0.010*	0.74 (0.55–0.99)	0.047*
Birth space						
≤3 years	1477 (70.2)	249 (79.3)	Ref		Ref	
>3 years	627 (29.8)	65 (20.7)	0.61 (0.46–0.82)	0.001*	0.63 (0.41–0.97)	0.037*
Dietary habit						
Non vegetarian	2093 (99.5)	309 (98.4)	Ref		Ref	
Vegetarian	11 (0.5)	5 (1.6)	3.07 (1.06–8.92)	0.038*	3.04 (0.98–9.43)	0.053
Parity						
Primipara	1197 (56.9)	205 (65.3)	Ref		Ref	
Multipara	907 (43.1)	109 (34.7)	0.70 (0.54–0.89)	0.005*	0.85 (0.58–1.24)	0.420
Age groups						
16–20	133 (6.3)	34 (10.8)	1.71 (1.12–2.62)	0.012*	1.60 (1.01–2.52)	0.042*
21–25	799 (37.9)	119 (37.9)	Ref		Ref	
26–30	812 (38.6)	106 (33.7)	0.87 (0.66–1.15)	0.355	1.12 (0.82–1.53)	0.451
≥31	360 (17.1)	55 (17.5)	1.02 (0.72–1.44)	0.884	1.60 (1.06–2.41)	0.025*
Education level						
Primary	92 (4.4)	18 (5.7)	1.38 (0.80–2.38)	0.239	1.93 (1.05–3.55)	0.033*
Secondary	432 (20.5)	56 (17.8)	0.91 (0.65–1.28)	0.621	1.13 (0.77–1.66)	0.505
Intermediate	773 (36.7)	126 (40.1)	1.15 (0.87–1.51)	0.302	1.26 (0.94–1.70)	0.115
Higher	807 (38.4)	114 (36.3)	Ref		Ref	
Ethnicity						
Brahmin/Chhetri	1213 (57.6)	211 (67.2)	Ref		Ref	
Dalit	87 (4.1)	16 (5.1)	1.05 (0.60–1.83)	0.844	1.06 (0.59–1.91)	0.831
Janajati	686 (32.6)	61 (19.4)	0.51 (0.37–0.68)	<0.001*	0.47 (0.34–0.65)	<0.001*
Others	118 (5.6)	26 (8.3)	1.26 (0.80–1.98)	0.302	1.09 (0.68–1.77)	0.699

*denotes the statistically significant at $P < 0.05$.
[a] Bivariate binary logistic regression analysis.
[b] Multivariable analysis adjusted for all covariates; cOR: crude odds ratio; aOR: adjusted odds ratio; CI: confidence interval.

the mother, as well as the body's oxygen supply and placental growth. These unfavourable repercussions occur in fetal persistent hypoxia and inadequate nutrient intake, leading to poor fetal weight gain and birth outcomes such as LBW [30]. LBW is also common in mothers with high hemoglobin levels. Previous studies have also found that hemoglobin concentration ≥13 g/dL was associated with an increased risk of LBW [24, 30, 35, 36, 37]. The possible reason could be that hyperviscosity due to high hemoglobin levels results in the poor feto-maternal exchange of nutrients jeopardizing the newborn weight [40]. In the third trimester, a high hemoglobin concentration may imply a failure in plasma volume growth [24, 41]. Inadequate plasma volume expansion may be to account for the adverse effects of high maternal hemoglobin concentrations on fetal growth [42]. The possible mechanism could be that inadequate plasma volume expansion during pregnancy triggers a rise in blood viscosity, which affects fetal growth and development by lowering placental blood flow velocity and nutrient delivery capabilities [43, 44]. Reduced oxygen supply to the fetus is caused by increased viscosity associated with poor uterine arterial blood flow [30]. As a result, high Hb levels during pregnancy appear to be linked to a higher risk of negative consequences. Therefore, adequate plasma volume expansion is required for healthy pregnancy outcomes [43].

In the present study, overweight/obese women had a low risk of LBW newborns compared to mothers with normal hemoglobin levels. These finding is supported by other studies [45, 46]. The dietary habit of a mother during pregnancy has a significant role in the maintenance of the proper weight of newborn babies [47]. The present study has found that the plant-based dietary pattern of mothers had more risk of getting a low birth weight baby than that of the non-vegetarian mothers. This finding is in line with the Zulyniak MA et al., study from Canada [6], which found a plant-based diet to be associated with lower birth weight. Animal source food such as an iron-rich diet, and adequate hemopoietic nutrients (iron, vitamin B12, and folic acid) increase the hemoglobin concentrations [12] and reduce the risk of getting low birth weight in the newborn baby.

In this study mothers with multiparity had a low risk of having a low birth weight which was comparable with the finding of the study conducted in Utah, United States [48], where primiparous mothers had LBW. The association between neonatal birth weights with parity was observed in this study. Similarly, the previous study also found that the neonatal birth weight of the multipara was higher (3275.1 ± 461.3 g) than that of the primipara (3262.9 ± 452.3 g) [49] which supports the results of our study.

Maternal age also affects the newborn weight. This study found that the mothers of younger ages (16–20) compared with older age groups had more chance of getting low birth weight. A study from Nepal conducted by Sharma et al., (2015) found younger mothers (less than 20 years) were two times more likely to deliver LBW babies [20]. A study conducted by Wang et al (2020) in the Shaanxi Province of Northwest China also revealed that birth weight increases at a faster rate (16.2 g per year increase of maternal age from 20 to 23 years old) than the age of 24–34 years with the rate of 12.1 gm per year increase of maternal age, which is insignificant after the age of 35 years of mothers [50]. This can be explained in terms of biological factors that teenage mothers do not have a mature reproductive system, adequate weight, and other exogenous factors that affect food and nutrition [51]. In addition, this can be also justified in terms of BMI. The BMI increases with age. Chen et al (2018) from China found that the increasing trend of BMI of Chinese mothers with age (23.0 at the age of 20 to $<$30 years, 24.1 at the age of 30 to $<$40 years, and 24.6 at the age of 40 to $<$50 years) [52] and the more the BMI of the mother, the more the weight of neonate [53]. This can be justified through the maternal anthropometric measurement considered through BMI. The study conducted by Rafia et al., (2020) from Lahore, Pakistan found that the more the BMI of the mother, the higher the chance of having a high birth weight neonate [53].

This study revealed that birth spacing $\leq$3 years had more risk of having low birth weight than the women having birth spacing $>$3 years. This finding is consistent with a previous study conducted in Shaikh Khalifa Bin Zayad Al-Nayan Hospital, Jammu and Kashmir [54]. This might occurs due to increasing competition for maternal nutrition during breastfeeding-pregnancy overlap which leads to suboptimal nutrition for the younger sibling [55].

Ethnicity also affects neonatal birth weight. A previous study indicated that more black mothers (10%) had low birth weight babies than white mothers (4%) which also revealed the association of low birth weight with ethnicity and race [56]. In this study, mothers who belonged to *Janajati* ethnic group (indigenous ethnicities) were less likely to have an LBW baby compared to *Brahmin/Chhetri* ethnic group (non-indigenous ethnicities) which is supported by the results from a previous study [21]. Food practices among the Nepalese population comprise a variety of cuisines based on ethnicity, cultural diversity, and geography. Every ethnic group and community has its own types of food culture, traditions, and way of cooking. The food habit of *Brahmin/Chhetri* compared to *Janjati* is different in terms of tradition, religion, and cultural perspectives. The *Janajati* consumed more animal-source food compared to *Brahmin/Chhetri*. Similarly, the *Janjati* mostly rely on subsistence farming and consume food from their own farm. However, the reason for the probability of having less newborn weight in *Janjaati* ethnic group compared with the *Brahamin/Chhetri* ethnic group needs further research.

This study has some limitations. First, the cross-sectional design of the study confined the ability to establish a robust causal pathway. Second, this study relied on hemoglobin as the measure of anemia; further studies should consider other red blood cell indices [57]. In this study, only hemoglobin level was measured therefore we could not assess the other differentiation of anemia or underlying cause of anemia, such as iron deficiency, nutritional, genetic, and infectious anemia. Third, we were unable to take hemoglobin levels in the first and second trimesters since most pregnant women visiting the health center at the study site had their first ANC visits during the second trimester. Also, there was a possibility of losing follow-up until the third trimester if we had limited the criteria to enrol only in the first and second trimesters. Fourth, income level, frequency of antenatal visits, and micronutrient supplementation were not measured. Despite these limitations, this study has an ample sample size from a tertiary care center, which is the largest medical academic institution in Nepal.

5. Conclusions

There are many factors that cause low newborn weight. Our study concludes that mothers having low hemoglobin as well as high hemoglobin levels can contribute to LBW. Programs and health authorities can benefit by revising their policy focus to explore the association of maternal Hb level with newborn weight. More research is essential to build on the evidence from this study.

Declarations

Author contribution statement

Sandeep Kumar Sah, Dev Ram Sunuwar: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Devendra Raj Singh, Narendra Kumar Chaudhary: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Josie R. Barala, Geeta Gurunga: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data used in the study is available from the corresponding author upon request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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References

[1] C.L. Cutland, E.M. Lackritz, T. Mallett-Moore, A. Bardají, R. Chandrasekaran, C. Lahariya, M.I. Nisar, M.D. Tapia, J. Pathirana, S. Kochhar, F.M. Muñoz, T.B.C.L.B.W.W. Group, Low birth weight: case definition & guidelines for data collection, analysis, and presentation of maternal immunization safety data, Vaccine 35 (2017) 6492.

[2] C.T., A. Kiserud, K. Benachi, R.G. Hecher, J.,P.G. Perez, L.D. Piaggio, The World Health Organization fetal growth charts: concept, findings, interpretation, and application, Am. J. Obstet. Gynecol. 218 (2018) S619–S629.

[3] P.M. Hays, D.P. Cruikshank, L.J. Dunn, Plasma volume determination in normal and preeclamptic pregnancies, Am. J. Obstet. Gynecol. 151 (1985) 958–966.

[4] P. Whittaker, S. Macphail, T. Lind, Serial hematologic changes and pregnancy outcome, Obstet. Gynecol. 88 (1996) 33–39.

[5] R.A. Mahumud, M. Sultana, A.R. Sarker, Distribution and determinants of low birth weight in developing countries, J. Prev. Med. Public Health 50 (2017) 18.

[6] M. Zulyniak, R. de Souza, M. Shaikh, D. Desai, D. Lefebvre, M. Gupta, J. Wilson, G. Wahi, P. Subbarao, A. Becker, P. Mandhane, S. Turvey, J. Beyene, S. Atkinson, K. Morrison, S. McDonald, K. Teo, M. Sears, S. Anand, Does the impact of a plant-based diet during pregnancy on birth weight differ by ethnicity? A dietary pattern analysis from a prospective Canadian birth cohort alliance, BMJ Open 7 (2017).

[7] A. Zerbeto, F. Cortelo, É.C. Filho, Association between gestational age and birth weight on the language development of Brazilian children: a systematic review, J. Pediatr. (Rio. J). 91 (2015) 326–332.

[8] M.M. Rahman, S.K. Abe, M.S. Rahman, M. Kanda, S. Narita, V. Bilano, E. Ota, S. Gilmour, K. Shibuya, Maternal anemia and risk of adverse birth and health outcomes in low- and middle-income countries: systematic review and meta-analysis, Am. J. Clin. Nutr. 103 (2016) 495–504.

[9] M.A. Rahman, M.N. Khan, M.M. Rahman, Maternal anaemia and risk of adverse obstetric and neonatal outcomes in South Asian countries: a systematic review and meta-analysis, Publ. Health Pract. 1 (2020) 100021.
[10] D.R. Sunuwar, D.R. Singh, N.K. Chaudhary, P.M.S. Pradhan, P. Rai, K. Tiwari, Prevalence and factors associated with anemia among women of reproductive age in seven South and Southeast Asian countries: evidence from nationally representative surveys, PLoS One 15 (2020), e0236449.
[11] World Health Organization (WHO), Haemoglobin Concentrations for the Diagnosis of Anaemia and Assessment of Severity, Geneva, 2011. https://www.who.int/vmnis/indicators/haemoglobin.pdf. (Accessed 17 July 2021).
[12] D.R. Sunuwar, R.K. Sangroula, N.S. Shakya, R. Yadav, N.K. Chaudhary, P.M.S. Pradhan, Effect of nutrition education on hemoglobin level in pregnant women: a quasi-experimental study, PLoS One 14 (2019).
[13] V. Shrestha, R. Paudel, D.R. Sunuwar, A.L.T. Lyman, S. Manohar, A. Amatya, Factors associated with dietary diversity among pregnant women in the western hill region of Nepal: a community based cross-sectional study, PLoS One 16 (2021).
[14] A.C.M.G. Figueiredo, I.S. Gomes-Filho, R.B. Silva, P.P.S. Pereira, F.A.F. Da Mata, A.O. Lyrio, E.S. Souza, S.S. Cruz, M.G. Pereira, Maternal anemia and low birth weight: a systematic review and meta-analysis, Nutrients 10 (2018) 601.
[15] P. Steer, M.A. Alam, J. Wadsworth, A. Welch, Relation between maternal haemoglobin concentration and birth weight in different ethnic groups, BMJ Br. Med. J. 310 (1995) 489.
[16] S. Rahmati, A. Delpishe, M. Azami, M.R.H. Ahmadi, K. Sayehmiri, Maternal Anemia during pregnancy and infant low birth weight: a systematic review and Meta-analysis, Int. J. Reprod. Biomed. 15 (2017) 125. http://pmc/articles/PMC5447828. (Accessed 16 July 2021).
[17] M. Bakacak, F. Avci, O. Ercan, B. Köstü, S. Serin, G. Kiran, M.S. Bostanci, Z. Bakacak, The effect of maternal hemoglobin concentration on fetal birth weight according to trimesters, J. Matern. Fetal Neonatal Med. 28 (2014) 2106–2110.
[18] M.F. Young, B.M. Oaks, S. Tandon, R. Martorell, K.G. Dewey, A.S. Wendt, Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis, Ann. N. Y. Acad. Sci. 1450 (2019) 47.
[19] S.C. Jwa, T. Fujiwara, Y. Yamanobe, K. Kozuka, H. Sago, Changes in maternal hemoglobin during pregnancy and birth outcomes, BMC Pregnancy Childbirth 151 (2015) 1–10.
[20] S.R. Sharma, S. Giri, U. Timalsina, S.S. Bhandari, B. Basyal, K. Wagle, L. Shrestha, Low birth weight at term and its determinants in a tertiary hospital of Nepal: a case-control study, PLoS One 10 (2015), e0123962.
[21] A.K. Koirala, D.N. Bhatta, Low-birth-weight babies among hospital deliveries in Nepal: a hospital-based study, Int. J. Womens. Health 7 (2015) 581–585.
[22] R. Lamichhane, Y. Zhao, S. Paudel, E.O. Adewuyi, Factors associated with infant mortality in Nepal: a comparative analysis of Nepal demographic and health surveys (NDHS) 2006 and 2011, BMC Publ. Health 17 (2017).
[23] S.C. Chang, K.O. O'Brien, M.S. Nathanson, J. Mancini, F.R. Witter, Hemoglobin concentrations influence birth outcomes in pregnant African-American adolescents, J. Nutr. 133 (2003) 2348–2355.
[24] D. Liu, S. Li, B. Zhang, Y. Kang, Y. Cheng, L. Zeng, F. Chen, B. Mi, P. Qu, D. Zhao, Z. Zhu, H. Yan, D. Wang, S. Dang, Maternal hemoglobin concentrations and birth weight, low birth weight (LBW), and small for gestational age (SGA): findings from a prospective study in Northwest China, Nutrients 14 (2022).
[25] D. Sharma, K. Amgain, P.P. Panta, B. Pokhrel, Hemoglobin levels and anemia evaluation among pregnant women in the remote and rural high lands of mid-western Nepal: a hospital based study, BMC Pregnancy Childbirth 20 (2020) 1–7.
[26] S. Gautam, H. Min, H. Kim, H.-S. Jeong, Determining factors for the prevalence of anemia in women of reproductive age in Nepal: evidence from recent national survey data, PLoS One 14 (2019).
[27] D.R. Sunuwar, D.R. Singh, B. Adhikari, S. Shrestha, P.M.S. Pradhan, Factors affecting anaemia among women of reproductive age in Nepal: a multilevel and spatial analysis, BMJ Open 11 (2021).
[28] Ministry of Health and Population, New ERA, The DHS Program ICF, Nepal Demographic and Health Survey 2016, Ministry of Health, Nepal, Kathmandu, Nepal, 2016. https://www.dhsprogram.com/pubs/pdf/FR336/FR336.pdf. (Accessed 11 July 2019).
[29] Government of Nepal, National Planning Comission Central Bureau of Statistics, United Nations Children's Fund, Nepal Multiple Indicator Cluster Survey 2019, 2020. https://www.unicef.org/nepal/media/11081/file/Nepal MICS 2019_Final Report.pdf.
[30] S.A. Ali, S.S. Tikmani, S. Saleem, A.B. Patel, P.L. Hibberd, S.S. Goudar, S. Dhaded, R.J. Derman, J.L. Moore, E.M. McClure, R.L. Goldenberg, Hemoglobin concentrations and adverse birth outcomes in South Asian pregnant women: findings from a prospective Maternal and Neonatal Health Registry, Reprod. Health 17 (2020) 1–13.
[31] Tribhuvan University Teaching Hospital, T.U., Teaching hospital | institute of medicine website (n.d.), http://www.iom.edu.np/?page_id=182. (Accessed 30 June 2021).
[32] N.P. Deputy, P.H. Nguyen, H. Pham, S. Nguyen, L. Neufeld, R. Martorell, U. Ramakrishnan, Validity of gestational age estimates by last menstrual period and neonatal examination compared to ultrasound in Vietnam, BMC Pregnancy Childbirth 17 (2017).
[33] J.F. Hair, W.C. Black, B.J. Babin, R.E. Anderson, R.L. Tatham, Multivariate Data Analysis, Prentice Hall Upper, Saddle River, NJ, 1998.
[34] S.S. Rana, S. Sharma, A. Chand, R. Malla, Relationship between maternal haemoglobin and fetal weight, Nepal J. Obstet. Gynaecol. 8 (2013) 37–40.
[35] L. Sekhavat, R. Davar, S. Hosseinidezoki, Relationship between maternal hemoglobin concentration and neonatal birth weight, Hematology 16 (2011) 373–376.
[36] B. Bhagat, D. Jha, Maternal hemoglobin concentration in relation to neonatal birth weight, Int. Arch. Integr. Med. 4 (2017). http://iaimjournal.com/. (Accessed 12 July 2021).
[37] A. Ahankari, J. LeonardiBee, Maternal hemoglobin and birth weight: systematic review and meta-analysis, Int. J. Med. Sci. Publ. Health 4 (2015) 435.
[38] A. Pal, S. Manna, B. Das, P.C. Dhara, The risk of low birth weight and associated factors in West Bengal, India: a community based cross-sectional study, Egypt, Pediatr. Assoc. Gaz. 681 (2020) 1–11.
[39] A. Stangret, A. Wnuk, G. Szewczyk, M. Pyzlak, D. Szukiewicz, Maternal hemoglobin concentration and hematocrit values may affect fetus development by influencing placental angiogenesis, J. Matern. Fetal Neonatal Med. 30 (2017) 199–204.
[40] M. Cordina, S. Bhatti, M. Fernandez, A. Syngelaki, K. Nicolaides, N. Kametas, Association between maternal haemoglobin at 27-29weeks gestation and intrauterine growth restriction, Pregnan. Hypert. 5 (2015) 339–345.
[41] P.J. Steer, Maternal hemoglobin concentration and birth weight, Am. J. Clin. Nutr. 71 (2000).
[42] K.S. Scanlon, R. Yip, L.A. Schieve, M.E. Cogswell, High and low hemoglobin levels during pregnancy: differential risks for preterm birth and small for gestational age, Obstet. Gynecol. 96 (2000) 741–748.
[43] H.A. Zondervan, F.J. Voorhorst, E.A. Robertson, P.H.J. Kurver, C. Massen, Is maternal whole blood viscosity a factor in fetal growth? Eur. J. Obstet. Gynecol. Reprod. Biol. 20 (1985) 145–151.
[44] H.A. Zondervan, J. Oosting, M.R. Hardeman, M.E. Smorenberg-schoorl, P.E. Treffers, The influence of maternal whole blood viscosity on fetal growth, Eur. J. Obstet. Gynecol. Reprod. Biol. 25 (1987) 187–194.
[45] S.D. McDonald, Z. Han, S. Mulla, J. Beyene, Overweight and obesity in mothers and risk of preterm birth and low birth weight infants: systematic review and meta-analyses, BMJ 341 (2010) 187.
[46] A.A. Ju, M. Heyman, A. Garber, J. Wojcicki, Maternal obesity and risk of preterm birth and low birthweight in Hawaii PRAMS, 2000-2011, Matern. Child Health J. 22 (2018) 893–902.
[47] E. Ota, H. Hori, R. Mori, R. Tobe-Gai, D. Farrar, Antenatal dietary education and supplementation to increase energy and protein intake, Cochrane Database Syst. Rev. 2015 (2015).
[48] S. Hinkle, P. Albert, P. Mendola, L. Sjaarda, E. Yeung, N. Boghossian, S. Laughon, The association between parity and birthweight in a longitudinal consecutive pregnancy cohort, Paediatr. Perinat. Epidemiol. 28 (2014) 106–115.
[49] F. Lei, L. Zhang, Y. Shen, Y. Zhao, Y. Kang, P. Qu, B. Mi, S. Dang, H. Yan, Association between parity and macrosomia in Shaanxi Province of Northwest China, Ital. J. Pediatr. 46 (2020) 1–7.
[50] S. Wang, L. Yang, L. Shang, W. Yang, C. Qi, L. Huang, G. Xie, R. Wang, M.C. Chung, Changing trends of birth weight with maternal age: a cross-sectional study in Xi'an city of Northwestern China, BMC Pregnancy Childbirth 20 (2020) 1–8.
[51] A. Guimarães, H. Bettiol, L. Souza, R. Gurgel, M. Almeida, E. Ribeiro, M. Goldaniv, M. Barbieri, Is adolescent pregnancy a risk factor for low birth weight? Rev. Saude Publica 47 (2013) 11–19.
[52] Y. Chen, X.-P. Zhang, J. Yuan, B. Cai, X.-L. Wang, X.-L. Wu, Y.-H. Zhang, X.-Y. Zhang, T. Yin, X.-H. Zhu, Y.-J. Gu, S.-W. Cui, Z.-Q. Lu, X.-Y. Li, Association of body mass index and age with incident diabetes in Chinese adults: a population-based cohort study, BMJ Open 8 (2018), e021768.
[53] R. Gul, S. Iqbal, Z. Anwar, S.G. Ahdi, S.H. Ali, S. Pirzada, Pre-pregnancy maternal BMI as predictor of neonatal birth weight, PLoS One 15 (2020).
[54] G. Iltaf, B. Shahid, M. Khan, Incidence and associated risk factors of low birth weight babies born in Shaikh Khalifa Bin Zayad Al-Nayan Hospital Muzaffarabad, Azad Jammu and Kashmir, Pakistan J. Med. Sci. 33 (2017) 626–630.
[55] R. Miller, M. Karra, Birth spacing and child health trajectories, Popul. Dev. Rev. 46 (2020) 347–371.
[56] R.A., R. Goldberg, J. Kane, Racial and ethnic patterning of low birth weight, normal birth weight, and macrosomia, Prev. Med. (Baltim). 118 (2019) 196–204.
[57] P.A.M. Ntenda, K.Y. Chuang, F.N. Tiruneh, Y.C. Chuang, Multilevel analysis of the effects of individual and community-level factors on childhood anemia, severe anemia, and hemoglobin concentration in Malawi, J. Trop. Pediatr. 64 (2018) 267–278.