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RELATIONSHIP BETWEEN MATERNAL HEMOGLOBIN LEVELS WITH BIRTH WEIGHT

Rita Gusmaladewi[1], Nur Indrawaty Lipoeto[2]*, Eka Nofita[1]
[1]Faculty of Medicine, Universitas Andalas, Jl. Lingkar Universitas Andalas, Limau Manis, Pauh, Padang, West Sumatra 25163, Indonesia
[2]Department of Nutrition, Universitas Andalas, Jl. Lingkar Universitas Andalas, Limau Manis, Pauh, Padang, West Sumatra 25163, Indonesia
*indralipoeto@med.unand.ac.id

ABSTRACT
Pregnancy anemia is a global health problem often associated with low birth weight (LBW). The prevalence of anemia among pregnant women in Indonesia was 27.7% in 2023, while West Sumatra reported 11.26% in 2024. Low maternal hemoglobin (Hb) levels are thought to reduce the supply of oxygen and nutrients to the fetus, although the evidence remains inconsistent. This study aimed to determine the relationship between first-trimester maternal Hb levels and birth weight. This retrospective cohort study used secondary medical record data collected in 2019–2021 in Padang Panjang City, Agam Regency, and Tanah Datar Regency, analyzed in 2026. Using total sampling, 80 mother–infant pairs meeting the inclusion criteria were included. Maternal Hb level (anemia <11 g/dL) was the independent variable, birth weight was the dependent variable, controlled for maternal age, education, and occupation. Data were analyzed using the Shapiro–Wilk test, independent t-test, and multiple linear regression (α = 0.05). Of the 80 pregnant women, 37.5% had anemia. The mean birth weight was 3187.06 ± 429.43 grams, with 2.5% classified as LBW. The mean birth weight did not differ significantly between anemic mothers (3195.83 ± 417.24 grams) and non-anemic mothers (3181.80 ± 440.68 grams; p = 0.889). Multiple regression confirmed no significant relationship between Hb and birth weight after adjustment (B = 32.32; p = 0.750); the overall model was not significant (F = 0.907; p = 0.481; adjusted R^2 = −0.006). No significant relationship was found between maternal Hb and birth weight, as most mothers had mild anemia or no anemia and received adequate antenatal care.

Keywords: anemia; birth weight; hemoglobin; low birth weight; pregnancy

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INTRODUCTION

Anemia in pregnancy is defined as a decrease in the blood's oxygen-carrying capacity, caused by a reduction in red blood cell count, low hemoglobin (Hb) concentration, or a combination of both (Farah Paramita, 2019). Iron deficiency is the most common cause, accounting for approximately 10–60% of anemia cases globally (WHO, 2025). According to national guidelines, pregnant women are categorized as anemic if their Hb level is below 11 g/dL in the first and third trimesters, or below 10.5 g/dL in the second trimester (Kemenkes RI, 2021).

Global surveillance data show that 35.5% of pregnant women had anemia in 2023, with the highest burden in the African region (43.0%) and Southeast Asia (42.1%), and the lowest in the Western Pacific (18.6%) (WHO, 2025). In Indonesia, the national prevalence of anemia among pregnant women was reported at 27.7% in 2023 (SKI, 2023), while provincial surveillance in West Sumatra recorded a lower prevalence of 11.26% in 2024 (Dinkes Sumbar, 2024). Contributing factors

include inadequate antenatal care coverage, closely spaced pregnancies, and poor nutritional status (Singal et al., 2018).

Anemia during pregnancy is clinically important because it is associated with impaired fetal growth, fetal death, congenital abnormalities, and low birth weight (LBW), all of which contribute to increased maternal and perinatal mortality (Dinkes Kota Padang, 2021). LBW, defined by WHO as a birth weight below 2500 grams regardless of gestational age, remains a major determinant of neonatal morbidity and mortality and a strong predictor of growth, cognitive development, and the risk of non-communicable disease later in life (Sylvi Maria Fransisca and Elvania Della Tri Widya Listyowati, 2023).

Mechanistically, low maternal Hb levels are thought to impair uteroplacental blood flow, thereby limiting the transfer of oxygen and nutrients to the developing fetus and increasing the risk of LBW (Rina Setyawati, 2022). However, birth weight is a multifactorial outcome, also influenced by disease severity, pregnancy complications, maternal nutritional status, and psychosocial stress, so Hb levels alone may not fully explain variation in fetal growth. Findings in the literature also remain mixed: some studies report a significant relationship between maternal Hb and LBW (Pitriani, Nurvinanda and Lestari, 2023; Rahmawati and Dwi, 2025; Nugraha and Sulastri, 2024), while large-scale meta-analyses show that the strength of this relationship is relatively small and highly dependent on the degree of anemia, the timing of Hb measurement during pregnancy, and the baseline risk of the population (Figueiredo et al., 2018; Young et al., 2023).

Physiologically, the fetoplacental unit functions as an integrated system that must continuously meet the metabolic needs of the growing fetus. Low maternal Hb levels are associated with impaired placental angiogenesis due to oxidative stress, which can further limit oxygen availability to the fetus and contribute to intrauterine growth restriction (Srimani et al., 2025). Infants born to anemic mothers have also been reported to have poorer perinatal outcomes, including prematurity, being small for gestational age, and low iron reserves at birth, making them more susceptible to infection and postnatal growth impairment (Dhole et al., 2022). Anemia is also associated with reduced maternal Insulin-like Growth Factor (IGF) levels, an important mediator of fetal growth hormone signaling, providing an additional biological pathway linking maternal anemia to LBW (Salakory and Wija, 2021). Although this biological plausibility is strong, the epidemiological literature has not consistently shown a significant relationship between Hb and birth weight at the population level, particularly in regions where anemia is generally mild and antenatal care coverage is relatively good.

Given these inconsistencies, and the absence of prior studies specifically examining this relationship using longitudinal cohort data from the antenatal period through delivery in Padang Panjang City, Agam Regency, and Tanah Datar Regency, this study aimed to (1) describe the distribution of maternal Hb levels in the first trimester, (2) describe the distribution of birth weight, and (3) analyze the relationship between maternal Hb levels and birth weight, adjusting for maternal age, education, and occupation. The findings of this study are expected to strengthen the evidence base for antenatal anemia screening policy and clarify whether Hb alone is an adequate predictor of birth weight outcomes in this population.

The proposed hypothesis, consistent with the biological pathways described above, is that lower maternal Hb levels in the first trimester will be associated with lower birth weight, and that this relationship will remain significant after controlling for maternal age, education, and occupation. The null hypothesis states that no such relationship exists.

METHOD

This observational analytic study with a retrospective cohort design relied on secondary data from February 2019–June 2021 sourced from community health centers (puskesmas) and private midwifery practices in Padang Panjang City, Agam Regency, and Tanah Datar Regency, West Sumatra, with the analysis conducted in January–February 2026. Using a total sampling technique, 80 mother–infant pairs were selected from an initial population of 120 based on inclusion criteria (first-trimester Hb examination and a full-term singleton delivery) and completeness of medical record data. Data were collected using a structured observation sheet after obtaining ethical clearance and research permit approval. Data processing was univariate descriptive statistical tests, bivariate tests (independent t-test or Mann-Whitney, $p < 0.05$) to compare mean birth weight between anemic and non-anemic maternal groups, and multivariate multiple linear regression analysis to control for confounding variables such as maternal age, education, and occupation.

RESULT

3.1 Characteristics of Study Respondents

Of the 80 pregnant women included, the majority (90.0%) were in the not-at-risk age category (20–35 years), 63.8% had a high level of education, and 91.3% were not employed (Table 1).

Table 1. Characteristics of Study Respondents (n = 80)

Characteristic	n	%
Maternal age		
At risk (<20 or >35 years)	8	10.0
Not at risk (20–35 years)	72	90.0
Maternal education		
Low	9	11.3
Moderate	20	25.0
High	51	63.8
Maternal occupation		
Employed	7	8.8
Not employed	73	91.3

3.2 Distribution of Maternal Hemoglobin Levels

Of the 80 respondents, 30 (37.5%) were classified as anemic (Hb <11 g/dL) and 50 (62.5%) were non-anemic (Table 2). Descriptively, the non-anemic group had a mean Hb of 11.997 ± 1.013 g/dL (median 12.0; range 11.0–15.2 g/dL), while the anemic group had a mean Hb of 10.075 ± 0.741 g/dL (median 10.2; range 8.2–10.9 g/dL).

Table 2. Distribution of Maternal Hemoglobin Levels (n = 80)

Hemoglobin category	n	%
Anemic (<11 g/dL)	30	37.5
Non-anemic (≥11 g/dL)	50	62.5
Total	80	100.0

3.3 Distribution of Birth Weight

Only 2 infants (2.5%) were classified as LBW (<2500 grams); the remaining 78 infants (97.5%) had a birth weight ≥2500 grams (Table 3). The overall mean birth weight of the sample was 3187.06 ± 429.43 grams (range 2100–4300 grams; 95% CI: 3091.50–3282.63 grams) (Table 4).

Table 3. Distribution of Birth Weight (n = 80)

Birth weight category	n	%
LBW (<2500 grams)	2	2.5
Non-LBW (≥2500 grams)	78	97.5
Total	80	100.0

Table 4. Descriptive Statistics of Birth Weight (n = 80)

Variable	Mean	SD	Min	Max	95% CI

Birth weight (g)	3187.06	429.43	2100	4300	3091.50–3282.63

3.4 Relationship between Maternal Hemoglobin Levels and Birth Weight (Bivariate Analysis)

The mean birth weight of infants born to anemic mothers was 3195.83 ± 417.24 grams, compared with 3181.80 ± 440.68 grams for non-anemic mothers — a difference of only 14.03 grams (Table 5). The independent t-test showed no statistically significant difference between the groups (p = 0.889), indicating no significant relationship between maternal Hb level and birth weight in this cohort.

Table 5. Relationship between Maternal Hemoglobin Levels and Birth Weight

Hb category	Mean (g)	SD	SE	n	p-value
Anemic	3195.83	417.24	76.17	30	0.889
Non-anemic	3181.80	440.68	62.32	50	

3.5 Multivariate Analysis

Multiple linear regression was performed to assess the independent contribution of Hb level, age, education, and maternal occupation to birth weight. The overall model showed a weak correlation (R = 0.240) and explained only 5.8% of the variation in birth weight (R^2 = 0.058; adjusted R^2 = −0.006; SE = 430.70 grams), indicating very limited explanatory value after adjusting for the number of predictor variables (Table 6). The overall model was not statistically significant (F(5,74) = 0.907; p = 0.481), indicating that Hb level, age, education, and maternal occupation, taken together, did not significantly predict birth weight (Table 7).

Table 6. Summary of the Multiple Linear Regression Model

R	R^2	Adjusted R^2	SE
0.240	0.058	−0.006	430.701

Table 7. Regression Model Fit Test Results (ANOVA)

Source	df	F	p-value
Regression	5	0.907	0.481
Residual	74		
Total	79		

In the analysis of coefficients for each variable (Table 8), Hb level was not a significant predictor of birth weight (B = 32.32; SE = 101.20; β = 0.037; t = 0.319; p = 0.750), nor were maternal age (B = 77.76; p = 0.638), occupation (B = 64.98; p = 0.709), moderate education (B = −14.80; p = 0.933), or high education (B = −207.64; p = 0.190) compared with the low-education reference category. These results indicate that the lack of a significant relationship between Hb and birth weight remained consistent even after statistical adjustment for the confounding variables examined.

Table 8. Results of Multiple Linear Regression Analysis of Factors Associated with Birth Weight

Variable	B	SE	Beta	t	p-value
Constant	3297.55	151.91	-	21.71	<0.001
Hemoglobin	32.32	101.20	0.037	0.32	0.750
Maternal age	77.76	164.36	0.055	0.47	0.638
Occupation	64.98	173.39	0.043	0.38	0.709
Education (moderate)	-14.80	174.63	-0.015	-0.09	0.933
Education (high)	-207.64	156.94	-0.234	-1.32	0.190

DISCUSSION

4.1 Respondent Characteristics

The majority of respondents (90.0%) were within the optimal reproductive age range of 20–35 years, a period generally associated with mature reproductive organ function, lower rates of

obstetric complications, and better physiological capacity to support fetal growth compared with extreme ages (Cunningham et al., 2022). This distribution is consistent with IDHS-based analyses in Indonesia showing that most deliveries occur within this age range, although extreme maternal age remains an independent contributor to adverse outcomes when accompanied by inadequate antenatal visits or nutritional deficits (Safitri et al., 2022; Nurwati et al., 2023).

The majority of respondents (63.8%) had a high level of education. Higher maternal education is generally associated with better health literacy, more consistent use of antenatal care, and healthier dietary and lifestyle patterns during pregnancy (Asefa et al., 2020), and low maternal education has previously been associated with an increased risk of LBW in IDHS-based studies in Indonesia (Safitri et al., 2022; Nurwati et al., 2023). Most respondents (91.3%) were not employed outside the home; although heavy physical workloads and long working hours have been associated with adverse pregnancy outcomes (Cai et al., 2020), several studies in Indonesia show that employment status itself is not always consistently associated with LBW once household income, antenatal care quality, and nutritional status are taken into account (Siramaneerat, Agushybana and Meebunmak, 2018; Sekriptini, Handayani and Haryono, 2026).

4.2 Distribution of Maternal Hemoglobin Levels

Slightly more than a third of respondents (37.5%) had anemia — a proportion still above Indonesia's national anemia reduction target of 26% for 2025–2029 (Kemenkes RI, 2026), although lower than the 61.5% reported by Damayanti et al. (2022) and comparable to the 38% reported among third-trimester mothers by Andriani et al. (2025). Hb levels during pregnancy are influenced by physiological plasma volume expansion (hemodilution), iron status, the timing of measurement during pregnancy, and overall maternal health (Young et al., 2019). The relatively high proportion of non-anemic mothers in this cohort likely reflects adequate antenatal iron supplementation and routine Hb screening, consistent with findings that iron supplementation adherence and antenatal care quality are major determinants of maternal Hb status (Quezada-Pinedo et al., 2021; Pramita and Fatmaningrum, 2021). Nevertheless, the persistence of anemia in more than a third of respondents indicates that anemia control efforts — including adherence to iron tablet consumption, nutrition education, and periodic screening — remain necessary, given that anemia during pregnancy is known to be multifactorial and influenced by maternal age, parity, infection, socioeconomic status, and access to health services (Fite, Assefa and Mengiste, 2021).

4.3 Distribution of Birth Weight

The overall mean birth weight (3187.06 ± 429.43 grams) fell within the WHO normal range (2500–4000 grams), and only 2.5% of infants were classified as LBW. This finding indicates generally good intrauterine growth in this cohort and is consistent with previous reports that full-term birth weight typically ranges from 3000–3400 grams when maternal health status, including Hb level, is adequate (Young et al., 2019). Systematic reviews in Indonesia also confirm that birth weight is shaped by the interaction of various maternal, fetal, and antenatal care factors, rather than by a single determinant (Nurwati et al., 2023).

4.4 Relationship between Maternal Hemoglobin Levels and Birth Weight

This study found no statistically significant difference in mean birth weight between anemic and non-anemic mothers ($p = 0.889$), a finding that remained consistent after multivariate analysis ($p = 0.750$). This result is consistent with Damayanti et al. (2022), who likewise found no significant relationship between maternal anemia and LBW ($p = 0.886$) and attributed LBW occurrence to socioeconomic status, nutritional intake, and adherence to iron supplementation. This finding is also consistent with the broader literature emphasizing that the strength of the relationship between Hb and birth weight is highly dependent on the degree of anemia, the timing of Hb measurement during pregnancy, and the mother's baseline risk profile (Young et al., 2023).

This finding differs from several international meta-analyses reporting a significant, albeit small, relationship between maternal anemia and LBW after controlling for confounders such as maternal age, education, hypertensive disorders, and gestational age (Figueiredo et al., 2018), as well as studies from Sub-Saharan Africa where the prevalence and severity of anemia are far higher than in this cohort (Belete, Belete and Assefa, 2025). This difference may be explained by several factors specific to the study population: most anemic respondents likely had mild anemia (Hb 8.2–10.9 g/dL, close to the diagnostic threshold), which may still be sufficient to maintain adequate oxygen supply to the fetus; respondents appear to have received routine antenatal care and iron supplementation, which may have mitigated adverse effects on fetal growth; and birth weight is a multifactorial outcome in which maternal nutritional status, gestational weight gain, placental function, and pregnancy complications may have a greater influence than first-trimester Hb level alone (Young et al., 2023; Seid et al., 2023).

4.5 Multivariate Findings

The overall regression model was not statistically significant ($F = 0.907$; $p = 0.481$), and none of the confounding variables — maternal age, education, or occupation — significantly altered the null relationship between Hb and birth weight, indicating that these variables did not act as confounders in this dataset. This is consistent with reports that the relationship between maternal Hb and birth weight is nonlinear and highly sensitive to the timing of Hb measurement relative to physiological hemodilution during pregnancy (Xiong et al., 2023). The low adjusted R^2 value (-0.006) also indicates that unmeasured factors — such as pre-pregnancy nutritional status, gestational weight gain, adherence to iron supplementation, comorbidities, and placental function — likely account for a much larger portion of birth weight variation than the variables examined in this study (Nurwati et al., 2023).

4.6 Clinical and Public Health Implications

Although this study found no statistically significant relationship between first-trimester Hb level and birth weight, this should not be interpreted as meaning that anemia screening or iron supplementation is unimportant. Anemia during pregnancy carries risks beyond birth weight alone, including postpartum hemorrhage, increased susceptibility to infection, reduced work capacity, and, in more severe cases as documented in other populations, preterm birth and intrauterine growth restriction (Daru, 2019; Young et al., 2023). The relatively favorable birth weight outcomes in this cohort likely partly reflect the benefits of an antenatal care system that has implemented routine Hb screening and iron supplement distribution; weakening of these services could plausibly shift the population toward more severe anemia and stronger, more detectable effects on fetal growth. Antenatal care providers in Padang Panjang City, Agam Regency, and Tanah Datar Regency should therefore continue to prioritize anemia screening across all trimesters — not only the first trimester — accompanied by structured counseling on dietary iron intake, adherence to iron tablet consumption, and early detection of other maternal risk factors such as suboptimal gestational weight gain, hypertensive disorders, and infection, which may have a more direct influence on birth weight than first-trimester Hb level alone.

4.7 Strengths of the Study

This study has the strength of using a cohort design that links antenatal hemoglobin measurements with actual delivery outcomes, rather than a mere cross-sectional comparison, thereby strengthening temporal inference between exposure and outcome. The total sampling approach minimized selection bias within the eligible population, and the inclusion of multivariate analysis allowed the researchers to assess whether commonly cited sociodemographic confounders could alter the observed relationship. Nevertheless, these strengths should be considered alongside the limitations outlined below.

CONCLUSION

In this retrospective cohort involving 80 mother–infant pairs from Padang Panjang City, Agam Regency, and Tanah Datar Regency, 37.5% of pregnant women had anemia, the mean birth weight was within the normal range (3187.06 ± 429.43 grams), and no statistically significant relationship was found between first-trimester maternal hemoglobin level and birth weight, either before ($p = 0.889$) or after ($p = 0.750$) adjustment for maternal age, education, and occupation. These findings suggest that in this cohort — most of whom had mild anemia and appeared to have received adequate antenatal care birth weight is more likely to be influenced by factors beyond first-trimester Hb level alone.

This study contributes new evidence from a geographic region Padang Panjang City, Agam Regency, and Tanah Datar Regency that had not previously been examined with respect to the relationship between maternal Hb and birth weight, and was conducted using cohort data linking the antenatal period with delivery, rather than a mere cross-sectional design. These findings therefore add a locally grounded data point to the global literature, in which the strength of this relationship is known to vary considerably depending on the population, degree of anemia, and antenatal care context.

Nevertheless, given the risks of moderate-to-severe anemia demonstrated in other populations, antenatal care services should continue to maintain routine anemia screening, iron supplementation, and nutritional counseling, along with monitoring of other maternal factors known to affect fetal growth.

DECLARATIONS

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Ethical approval: This study used secondary data from medical records and was conducted after obtaining ethical clearance and research permit approval

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Data Availability Statement: The data analyzed in this study were obtained from secondary medical records of community health centers and private midwifery practices. The anonymized dataset is available from the corresponding author (Nur Indrawaty Lipoeto, indralipoeto@med.unand.ac.id) upon reasonable request, subject to institutional and ethical permissions.

Author Contributions: Rita Gusmaladewi: conceptualization, methodology, data collection, formal analysis, and writing of the original draft. Nur Indrawaty Lipoeto: conceptualization, supervision, validation, and writing, review, and editing. Eka Nofita: methodology, supervision, validation, and writing, review, and editing. All authors have read and approved the final manuscript.

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