International Journal of Medical and Pharmaceutical Research

Online ISSN-2958-3683 | Print ISSN-2958-3675
Frequency: Bi-Monthly
Available online on: https://ijmpr.in/

Original Article

Trimester-Specific Maternal Hemoglobin Levels and Their Association with Neonatal Anthropometric Parameters: A Cross-Sectional Study.

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Received: 15-01-2026
Accepted: 04-02-2026
Available online: 07-03-2026

ABSTRACT

Background: Maternal anemia remains highly prevalent in developing countries and is associated with adverse obstetric and neonatal outcomes. While birth weight has been extensively studied, limited data exist regarding trimester-specific associations between maternal hemoglobin levels and detailed neonatal anthropometric parameters.

Objective : To assess the correlation between maternal hemoglobin levels in the first and third trimesters and neonatal anthropometric measurements, including birth weight, length, and head circumference.

Methods: A cross-sectional study was conducted in a maternity and child hospital from July 2024 to July 2025. A total of 500 term singleton mother–neonate dyads were included. Maternal hemoglobin levels recorded during the first and third trimesters were obtained from antenatal records. Neonatal birth weight, length, and head circumference were measured within 48 hours of birth using standardized techniques. Hemoglobin was analyzed both as a continuous variable and categorized according to severity of anemia. Independent t-test and one-way ANOVA were used for group comparisons. Pearson's correlation coefficient was applied to evaluate associations between maternal hemoglobin and neonatal anthropometry. A p-value <0.05 was considered statistically significant.

Results: Mean maternal hemoglobin increased from 10.58 ±1.13 g/dL in the first trimester to 11.37 ±1.31 g/dL in the third trimester. Neonates born to mothers with moderate anemia had significantly lower birth weight, length, and head circumference in both trimesters ($p < 0.05$). Pearson correlation analysis revealed weak but statistically significant positive correlations between first trimester hemoglobin and neonatal length ($r = 0.098$, $p = 0.033$) and head circumference ($r = 0.106$, $p = 0.018$). Similar associations were observed in the third trimester for length ($r = 0.042$, $p = 0.020$) and head circumference ($r = 0.130$, $p = 0.004$). No significant correlation was found between maternal hemoglobin and birth weight in either trimester.

Conclusion: Maternal hemoglobin levels demonstrate modest but significant associations with neonatal head circumference and length, particularly in late pregnancy, while the relationship with birth weight is less pronounced. These findings highlight the importance of trimester-specific anemia monitoring and management to optimize neonatal growth outcomes.

***Keywords**:* Maternal anemia; Hemoglobin; Neonatal anthropometry; Birth weight; Head circumference; Pregnancy trimesters; Fetal growth.

INTRODUCTION

Anemia in pregnancy remains one of the most prevalent nutritional and hematological disorders worldwide and continues to be a significant public health concern, particularly in low- and middle-income countries. According to the World Health Organization (WHO), anemia affects approximately 36.5% of pregnant women globally [1]. In India, the burden is even higher, with surveys conducted by the Indian Council of Medical Research (ICMR) reporting prevalence rates exceeding 70% among pregnant women [2]. Anemia during pregnancy is diagnosed when hemoglobin (Hb) concentration falls below 11 g/dL as per WHO criteria [3]. Despite ongoing national initiatives such as Anemia Mukt Bharat, maternal anemia remains a persistent challenge with implications extending beyond maternal health to fetal growth and neonatal outcomes.

Physiological changes during pregnancy, including plasma volume expansion and increased iron requirements, result in a relative reduction in hemoglobin concentration. Maternal plasma volume increases by approximately 40–50%, while red blood cell mass rises by only about 20%, leading to physiological hemodilution [4]. However, in many women—especially in resource-constrained settings—this physiological anemia is compounded by true iron deficiency anemia (IDA), which remains the most common cause of anemia in pregnancy [5]. Increased iron demands for fetal growth, inadequate dietary intake, diminished absorption, short interpregnancy intervals, and pre-existing iron deficiency contribute significantly to the development of anemia during gestation [52].

Maternal anemia has been associated with multiple adverse obstetric and neonatal outcomes. These include intrauterine growth restriction (IUGR), preterm birth, low birth weight (LBW), increased risk of infection, prolonged labor, and higher maternal and neonatal morbidity and mortality [4]. A doubling of low birth weight rates and a two- to three-fold increase in perinatal mortality have been reported when maternal hemoglobin levels fall below 8 g/dL [8]. Furthermore, perinatal iron deficiency may adversely affect fetal neural development, with potential long-term consequences including impaired cognitive function, behavioral abnormalities, and increased risk of cardiovascular disease in adult life [9-11].

Iron plays a critical role in fetal organogenesis, particularly in brain development. During late gestation, rapid hippocampal growth and neuronal differentiation require adequate iron availability [12]. Approximately 80% of fetal iron transfer occurs during the third trimester via placental transport mechanisms involving transferrin receptors and ferroportin pathways [13-17]. Although placental adaptations may partially compensate for maternal deficiency, moderate to severe maternal anemia can reduce fetal iron stores at birth, as evidenced by lower cord blood hemoglobin and ferritin levels [18]. Biological mechanisms linking maternal anemia to impaired fetal growth include hypoxia-induced stress responses, increased cortisol production, oxidative damage, and altered insulin-like growth factor pathways, all of which may negatively influence fetal growth trajectories [19-22].

Neonatal anthropometry serves as a simple, reliable, and non-invasive tool for assessing intrauterine growth and fetal well-being. Birth weight, length, and head circumference are widely accepted indicators of neonatal health and predictors of both short-term survival and long-term developmental outcomes [23-26]. While birth weight remains the most commonly used parameter, head circumference and length provide additional diagnostic and prognostic value, particularly in identifying patterns of symmetric or asymmetric growth restriction [27]. In developing countries, intrauterine growth restriction is a predominant contributor to low birth weight, underscoring the importance of maternal nutritional status during pregnancy [28].

Several studies have examined the relationship between maternal hemoglobin and neonatal anthropometry, with varying findings. Some investigators have reported a significant association between maternal anemia and reduced birth weight, length, and head circumference [29-32]. Others have observed trimester-specific variations, suggesting that early pregnancy hemoglobin levels may have a greater influence on fetal growth compared to later gestation [33]. However, inconsistencies remain regarding the strength and significance of these associations, particularly when hemoglobin is analyzed as a continuous variable rather than categorical severity grades.

Given the high burden of maternal anemia and its potential impact on fetal development, it is essential to evaluate trimester-specific hemoglobin levels in relation to neonatal anthropometric outcomes. Most prior studies have focused primarily on birth weight, with limited attention to head circumference and length as independent growth parameters. Furthermore, few studies have simultaneously examined hemoglobin levels in both the first and third trimesters to determine whether the timing of anemia exerts differential effects on neonatal growth.

In this context, the present study was undertaken to assess the correlation between maternal hemoglobin levels in the first and third trimesters and neonatal anthropometric parameters at birth, including birth weight, length, and head circumference. By examining trimester-specific associations using continuous hemoglobin measurements, this study aims to provide a more nuanced understanding of the relationship between maternal hematological status and neonatal growth outcomes, thereby contributing to evidence-based strategies for optimizing antenatal care and improving neonatal health.

MATERIALS AND METHODS

Study Design and Setting: This cross-sectional observational study was conducted in the Department of Paediatrics at Shri Dada Dev Matri Avum Shishu Chikitsalaya, New Delhi, a maternity and child hospital. The study was carried out over a one-year period from July 2024 to July 2025.

Study Population: The study population comprised term neonates admitted in the postnatal wards along with their mothers during the study period. Maternal hemoglobin levels recorded during the first and third trimesters were retrieved from antenatal records.

Inclusion Criteria

- Term neonates (≥37 completed weeks of gestation)
- Singleton pregnancies
- Mothers aged between 21 and 35 years
- Mothers who had documented hemoglobin levels in both the first and third trimesters
- Mothers who provided informed consent

Exclusion Criteria

- Preterm neonates (<37 weeks gestation)
- Multiple gestations
- Neonates with congenital malformations or skeletal deformities
- Neonates born to mothers with chronic medical conditions such as diabetes mellitus, hypertension, thyroid disorders, HIV, syphilis, TORCH infections
- Mothers with a history of smoking or alcohol intake
- Unbooked pregnancies

Sample Size: The sample size was calculated based on the prevalence of anemia among pregnant women (52.2%) as reported under national data. The minimum calculated sample size was 384. To increase statistical power and account for potential data exclusions, a total of 500 mother–neonate dyads were included in the study using random sampling.

Data Collection: After obtaining institutional ethical clearance and written informed consent, data were collected using a pre-tested semi-structured questionnaire and a structured data collection sheet.
Maternal demographic details and antenatal records were reviewed. Hemoglobin values were recorded from laboratory reports documented during routine antenatal visits in:

- First trimester (up to 12 weeks of gestation)
- Third trimester (after 28 weeks of gestation)

Hemoglobin estimation had been performed as part of standard antenatal care using automated hematology analyzers in the hospital laboratory.

Neonatal Anthropometric Measurements: Anthropometric measurements were recorded within the first 48 hours of birth using standardized techniques:

- Birth weight was measured using a calibrated digital weighing scale with 10 g sensitivity.
- Length was measured using an infantometer, with the neonate placed in a supine position and legs fully extended.
- Head circumference was measured using a non-stretchable measuring tape placed over the supraorbital ridge anteriorly and the most prominent part of the occiput posteriorly.

All measurements were recorded to the nearest 0.1 kg (for weight) and 0.1 cm (for length and head circumference).

Study Variables

Independent Variable

- Maternal hemoglobin level in first trimester (continuous, g/dL)
- Maternal hemoglobin level in third trimester (continuous, g/dL)

For secondary analysis, hemoglobin was categorized according to WHO classification:

- Mild anemia: 10.0–10.9 g/dL
- Moderate anemia: 7.0–9.9 g/dL
- No anemia: ≥11 g/dL

Dependent Variables

- Neonatal birth weight (kg)
- Neonatal length (cm)
- Neonatal head circumference (cm)

Statistical Analysis: All data were entered into Microsoft Excel and analyzed using Statistical Package for the Social Sciences (SPSS) version 26.0. Qualitative variables were expressed as frequency and percentage. Quantitative variables were expressed as mean ±standard deviation (SD). For analytical assessment independent *t*-test was used for comparison of means between two groups. One-way Analysis of Variance (ANOVA) was applied to compare anthropometric parameters across categories of anemia severity. Pearson's correlation coefficient was used to assess the relationship between maternal hemoglobin levels (continuous variable) and neonatal anthropometric measurements. A *p*-value of <0.05 was considered statistically significant.

Ethical Considerations: The study was conducted after approval from the Institutional Ethics Committee. Written informed consent was obtained from all participating mothers. Confidentiality of patient information was maintained throughout the study, and data were used strictly for research purposes.

RESULTS

A total of 500 mother–neonate dyads were included in the analysis. Maternal hemoglobin levels in the first and third trimesters were evaluated in relation to neonatal birth weight, length, and head circumference.Nearly 85% of women were below 31 years of age. Two-thirds (66.4%) were multigravida.(Table 1)

Table 1. Baseline Characteristics of Study Participants (n = 500)

Variable	**Category**	**Frequency (n)**	**Percentage (%)**
Maternal Age (years)	21–25	239	47.8
	26–30	188	37.6
	31–35	73	14.6
Gravida	Primigravida	168	33.6
	Multigravida	332	66.4

There was a notable improvement in mean hemoglobin levels from the first to the third trimester.(Table 2)

Table 2. Mean Maternal Hemoglobin Levels in First and Third Trimesters

Trimester	**Mean Hb (g/dL)**	**SD**
First trimester	10.58	1.13
Third trimester	11.37	1.31

Neonates born to mothers with moderate anemia had significantly lower birth weight, length, and head circumference compared to other groups. The differences were statistically significant.(Table 3)

Table 3. Neonatal Anthropometry According to Severity of Maternal Anemia in First Trimester

Severity of Anemia	**Birth Weight (kg) Mean ± SD**	**Length (cm) Mean ± SD**	**Head Circumference (cm) Mean ± SD**
Moderate anemia	2.8 ± 0.4	50.5 ± 1.9	33.4 ± 1.1
Mild anemia	2.9 ± 0.4	50.6 ± 1.5	33.7 ± 0.9
No anemia	2.9 ± 0.4	50.3 ± 1.7	33.6 ± 1.0
ANOVA p-value	**0.006**	**0.004**	**0.018**

A similar pattern was observed in the third trimester. Moderate maternal anemia was associated with lower neonatal anthropometric measurements, with statistically significant differences across all three parameters.(Table 4)

Table 4. Neonatal Anthropometry According to Severity of Maternal Anemia in Third Trimester

Severity of Anemia	**Birth Weight (kg) Mean ± SD**	**Length (cm) Mean ± SD**	**Head Circumference (cm) Mean ± SD**
Moderate anemia	2.8 ± 0.4	50.3 ± 1.9	33.3 ± 1.2

Mild anemia	2.9 ± 0.4	50.4 ± 1.5	33.6 ± 1.1
No anemia	2.9 ± 0.4	50.5 ± 1.7	33.6 ± 1.0
ANOVA p-value	**0.007**	**0.004**	**0.010**

First trimester hemoglobin showed a weak positive but statistically significant correlation with neonatal length and head circumference. No significant correlation was observed with birth weight.(Table 5)

Table 5. Correlation Between First Trimester Maternal Hemoglobin and Neonatal Anthropometric Parameters

Parameter	Pearson Correlation (r)	p-value
Birth weight	0.047	0.294
Length	0.098	0.033
Head circumference	0.106	0.018

Third trimester hemoglobin demonstrated a weak but statistically significant positive correlation with neonatal head circumference and length. The association with birth weight remained statistically non-significant.(Table 6)

Table 6. Correlation Between Third Trimester Maternal Hemoglobin and Neonatal Anthropometric Parameters

Parameter	Pearson Correlation (r)	p-value
Birth weight	0.075	0.095
Length	0.042	0.020
Head circumference	0.130	0.004

DISCUSSION

The present study evaluated the trimester-specific association between maternal hemoglobin levels and neonatal anthropometric parameters in a cohort of 500 mother–neonate dyads. The findings demonstrate that moderate maternal anemia in both the first and third trimesters was associated with significantly lower neonatal birth weight, length, and head circumference. Furthermore, maternal hemoglobin levels showed weak but statistically significant positive correlations with neonatal length and head circumference, whereas the association with birth weight was not statistically significant.

Anemia during pregnancy remains highly prevalent, particularly in developing countries. National surveys indicate that more than half of pregnant women in India are anemic [2], consistent with the high proportion of anemia observed in the first trimester in our study. Although physiological hemodilution occurs during pregnancy due to plasma volume expansion [4], true iron deficiency anemia remains the predominant cause in low-resource settings [5]. The improvement in mean hemoglobin levels from the first to the third trimester observed in our cohort may reflect effective antenatal supplementation programs; however, residual moderate anemia continued to demonstrate measurable effects on neonatal growth.

One of the key findings of this study was that neonates born to mothers with moderate anemia had significantly lower birth weight compared to those with mild or no anemia in both trimesters. This supports previous research demonstrating an association between maternal anemia and reduced fetal growth [7]. A doubling of low birth weight rates has been reported in mothers with severe anemia [8]. However, in our correlation analysis, maternal hemoglobin treated as a continuous variable did not show a statistically significant association with birth weight. This suggests that while categorical severity (particularly moderate anemia) may influence fetal weight, incremental variations in hemoglobin within the observed range may not linearly affect birth weight. Similar inconsistencies have been reported in earlier studies examining trimester-specific hemoglobin concentrations [33].

In contrast, head circumference demonstrated a consistent and statistically significant positive correlation with maternal hemoglobin levels in both trimesters. The correlation was slightly stronger in the third trimester (r = 0.130, p = 0.004), suggesting that late gestational hemoglobin status may have a measurable influence on fetal cranial growth. This finding is biologically plausible. Iron plays a critical role in fetal neurodevelopment, particularly in the rapidly developing hippocampus during late gestation [12]. Approximately 80% of fetal iron transfer occurs during the third trimester via placental transport mechanisms [13-17]. Although placental adaptations may compensate to some extent, moderate maternal anemia can reduce fetal iron endowment at birth [18]. Reduced iron availability may impair neuronal proliferation, myelination, and brain growth, thereby affecting head circumference measurements.

Neonatal length also showed weak but statistically significant positive correlations with maternal hemoglobin in both trimesters. These findings suggest that linear growth may be subtly influenced by maternal hematological status. Experimental evidence supports this association. Maternal anemia can induce fetal hypoxia and activate stress pathways involving corticotropin-releasing hormone and cortisol, potentially impairing longitudinal fetal growth [19-22]. Elevated cortisol levels have been shown to decelerate fetal growth and interfere with insulin-like growth factor pathways, which are critical for skeletal development. Although the correlations observed in our study were weak, their statistical significance indicates that even mild reductions in maternal hemoglobin may exert measurable effects on fetal growth patterns.

Interestingly, the strength of correlation was consistently greater for head circumference than for birth weight. This suggests that maternal anemia may preferentially influence specific aspects of fetal growth rather than overall mass. Neonatal anthropometry is a valuable indicator of intrauterine growth and health status [23-26], and head circumference in particular provides insight into brain development beyond what birth weight alone can capture [27]. The differential pattern observed in this study reinforces the importance of including multiple anthropometric parameters when assessing neonatal outcomes.

While several previous studies have demonstrated significant associations between maternal anemia and all anthropometric parameters [29-32], the magnitude of effect varies across populations. Some investigators have reported stronger associations in early pregnancy [33], whereas others emphasize third trimester hemoglobin levels as more critical determinants of fetal growth [34]. Our findings suggest that both early and late pregnancy hemoglobin levels have modest but measurable effects, with slightly stronger associations observed in the third trimester for cranial growth.
The weak magnitude of correlation coefficients observed in this study indicates that maternal hemoglobin is only one of multiple determinants influencing neonatal anthropometry. Factors such as maternal nutritional status, interpregnancy interval, infections, and socioeconomic conditions also contribute significantly to fetal growth [28]. Nonetheless, the statistically significant associations with head circumference and length underscore the importance of maintaining adequate maternal hemoglobin levels throughout pregnancy.

From a clinical perspective, these findings highlight the need for early detection and effective management of anemia in pregnancy. Although improvements in hemoglobin levels may occur with supplementation, moderate anemia—even when not severe—can still influence neonatal growth parameters. Ensuring adequate iron stores before and during pregnancy may therefore contribute not only to improved birth weight but also to optimal fetal neurodevelopment.

This study demonstrates that trimester-specific maternal hemoglobin levels show weak but significant positive associations with neonatal head circumference and length, while the relationship with birth weight is less pronounced. These findings emphasize the importance of comprehensive antenatal anemia management to optimize neonatal growth outcomes.

CONCLUSION
This study demonstrates that maternal hemoglobin levels in both the first and third trimesters show weak but statistically significant positive associations with neonatal head circumference and length, while the relationship with birth weight remains non-significant when hemoglobin is analyzed as a continuous variable. Moderate maternal anemia was associated with lower neonatal anthropometric measurements, indicating that anemia severity may influence fetal growth patterns. The slightly stronger association observed with third trimester hemoglobin and head circumference suggests that late gestational iron status may play an important role in fetal cranial development. Although the correlations were modest, the findings highlight that maternal hemoglobin is a measurable determinant of specific neonatal growth parameters. These results underscore the importance of early screening, continuous monitoring, and effective management of anemia throughout pregnancy to optimize fetal growth and support neurodevelopmental outcomes. Strengthening trimester-specific antenatal anemia interventions may contribute to improved neonatal health indicators.

DECLARATIONS
Ethical Approval and Consent to Participate
The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Ethical approval was obtained from the Institutional Ethics Committee of Shri Dada Dev Matri Avum Shishu Chikitsalaya, New Delhi, prior to commencement of the study (IEC Letter No.: F.1(15)/DNBcourse/sddmasc/2017-18/Part-IV/1715; Date of Approval: 28/6/24). Written informed consent was obtained from all participating mothers before their inclusion in the study. Confidentiality and anonymity of all participants were strictly maintained throughout the research process.

Availability of Data and Materials

The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Competing Interests

The authors declare that they have no competing interests.

Funding

The study did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Authors 'Contributions

The study was conceptualized and designed as part of postgraduate thesis work. Data collection, statistical analysis, interpretation of results, manuscript drafting, and critical revision were carried out collaboratively by the authors. All authors read and approved the final manuscript.

Acknowledgements

The authors acknowledge the support of the Department of Paediatrics, Shri Dada Dev Matri Avum Shishu Chikitsalaya, New Delhi, for facilitating the conduct of the study. The authors also thank all participating mothers and neonates for their cooperation.

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