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Original Article

Anthropometric Measurements in Term Neonates at Birth in Pregnant Patients with and without Anemia

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ABSTRACT

Background: Maternal anemia is a significant global health problem, particularly in low- and middle-income countries, contributing to impaired fetal growth and adverse neonatal outcomes. While its association with low birth weight is well documented, less is known about its impact on a broader range of neonatal anthropometric measurements (AMs) in term neonates, particularly in South Asian populations where anemia prevalence is high. Objective: To compare AMs at birth between term neonates of anemic and non-anemic mothers to assess the impact of maternal anemia on neonatal growth patterns in a local Pakistani population. Methods: This cross-sectional observational study was conducted from October 2024 to March 2025 at the Divisional Headquarters Teaching Hospital, Mirpur, AJK. We enrolled 100 pregnant women aged 18–40 years delivering singleton term neonates (≥38 weeks), classified into anemic (hemoglobin <11 g/dL, n=50) and non-anemic (hemoglobin ≥11 g/dL, n=50) groups. Neonatal AMs—birth weight (BW), crown-heel length (CHL), head circumference (HC), chest circumference (CC), mid-upper arm circumference (MUAC), and ponderal index (PI)—were measured within 24 hours of birth using standardized techniques. Group differences were analyzed using independent t-tests and chi-square tests with adjustment for potential confounders. Results: Neonates of anemic mothers had significantly lower mean BW (2265.2±113.2 g vs. 2353.9±222.4 g, p=0.01), CHL (46.22±0.42 cm vs. 46.56±1.05 cm, p=0.04), HC (31.56±1.05 cm vs. 32.26±1.44 cm, p=0.01), CC (29.76±0.80 cm vs. 31.50±0.99 cm, p<0.0001), and MUAC (8.5±0.51 cm vs. 9.9±0.79 cm, p<0.0001). The proportion of neonates with PI <2.2 was higher in the anemic group (20% vs. 6%, p=0.04). Conclusion: Maternal anemia is associated with significantly reduced neonatal anthropometric parameters and an increased frequency of disproportional growth restriction at birth, underscoring the importance of early identification and correction of anemia in pregnancy to optimize neonatal outcomes.

Keywords: maternal anemia, anthropometry, newborn, term birth, growth restriction, hemoglobin.

INTRODUCTION

Anemia during pregnancy remains a major global health challenge, disproportionately affecting women in low- and middle-income countries (LMICs), with approximately 40% of pregnant women affected globally and higher prevalence in South Asia and Sub-Saharan Africa (1). The World Health Organization (WHO) defines anemia in pregnancy as a hemoglobin concentration below 11 g/dL, with iron deficiency accounting for nearly 50–75% of all cases (2). The physiologic adaptations of pregnancy, notably plasma volume expansion exceeding red blood cell mass, increase women's susceptibility to anemia (3). Iron is essential for oxygen transport and cellular metabolism; thus, maternal anemia compromises placental development and function, reducing fetal oxygenation and nutrient supply, leading to intrauterine growth restriction (IUGR), preterm birth, low birth weight (LBW), and increased perinatal morbidity and mortality (4). The extent of this impact is particularly pronounced in LMICs where nutritional deficiencies and inequitable healthcare access exacerbate risks (5).

Prior research has consistently demonstrated an association between maternal hemoglobin levels and birth weight, an easily measurable indicator of fetal growth (6). However, there is a relative paucity of data evaluating the broader spectrum of anthropometric measurements (AMs) at birth, including crown-heel length (CHL), head circumference (HC), chest circumference (CC), and mid-upper arm circumference (MUAC), as markers of in-utero growth and predictors of neonatal health outcomes (7). These measurements not only reflect overall fetal growth but also serve as proxies for specific aspects of fetal development such as skeletal growth (length), brain development (HC), and nutritional status (MUAC) (8). Deviations from normal AMs, particularly in neonates of anemic mothers, have implications for neonatal survival and long-term health outcomes, including neurodevelopment and risk of chronic diseases (9). Although the association between maternal anemia and birth weight has been extensively explored in various populations (10), limited studies have concurrently evaluated other growth indicators, especially in term neonates, a subgroup where prematurity-related confounding factors are minimized (11). Furthermore, most existing studies have been conducted outside the context of local populations such as Mirpur, Azad Jammu and Kashmir (AJK), where socio-demographic profiles, dietary patterns, healthcare utilization, and anemia prevalence may differ significantly from those reported in other regions (12). The interplay between anemia severity, maternal nutritional status, and neonatal anthropometry in such contexts remains insufficiently characterized. As healthcare policies and antenatal interventions must reflect local disease burden and risk factors, there is a pressing need to generate context-specific data to guide maternal and child health programs.

The present study was therefore designed to address this knowledge gap by comparing the anthropometric measurements at birth among term neonates born to anemic versus non-anemic mothers at Divisional Headquarters Teaching Hospital, Mirpur AJK. By focusing exclusively on term neonates, this study aims to isolate the effect of maternal anemia from confounding due to prematurity. Additionally, this investigation expands the scope beyond birth weight alone to include length, head circumference, chest circumference, mid-upper arm circumference, and ponderal index, providing a more comprehensive assessment of fetal growth. The study hypothesizes that maternal anemia is associated with significantly lower neonatal anthropometric measurements compared to neonates born to non-anemic mothers, reflecting impaired intrauterine growth.

MATERIAL AND METHODS

This was a cross-sectional, observational study conducted to compare the anthropometric measurements (AMs) of term neonates born to anemic and non-anemic mothers. The study was carried out in the Department of Gynaecology and Obstetrics and the neonatal intensive care unit (NICU) at Divisional Headquarters Teaching Hospital, Mirpur, Azad Jammu and Kashmir (AJK), over a six-month period from October 2024 to March 2025. The study setting serves as a tertiary care referral hospital catering to a diverse population from urban and semi-urban communities in the region.

Eligible participants were women aged over 18 years and up to 40 years with a singleton pregnancy, who delivered a live-born neonate at gestational age ≥38 completed weeks, either via vaginal delivery or cesarean section. Women were classified as anemic if their hemoglobin concentration measured within one week prior to delivery was <11 g/dL, in accordance with WHO criteria (13). Non-anemic women with hemoglobin levels ≥11 g/dL served as the comparison group. Exclusion criteria included multiple gestations, preterm delivery (<38 weeks), any maternal history of chronic systemic illnesses (e.g., diabetes mellitus, hypertension, renal disease), cases involving intrauterine fetal demise, neonates with congenital anomalies, and deliveries with complications known to independently affect fetal growth. Consecutive sampling was employed, with participants enrolled sequentially as they presented for delivery and met eligibility criteria, minimizing selection bias.

Women fulfilling the eligibility criteria were approached in the antenatal ward or labor room prior to delivery. After providing detailed verbal and written information about the study objectives, procedures, potential risks, and confidentiality safeguards, informed written consent was obtained from each participant. Demographic and obstetric data, including age, parity, gestational age at delivery, mode of delivery, and hemoglobin levels, were extracted from medical records using a standardized data collection form designed for this study.

Neonatal anthropometric measurements were performed within 24 hours of birth by trained nursing staff following standardized procedures to ensure accuracy and reproducibility. Neonatal weight was measured using an electronic neonatal weighing scale calibrated daily. Crown-heel length was recorded with an infantometer, ensuring the neonate's head and legs were fully extended and properly aligned. Head circumference was measured at the maximal occipito-frontal diameter using a non-stretchable measuring tape. Chest circumference was recorded at the level of the nipples during quiet respiration, while mid-upper arm circumference (MUAC) was measured at the midpoint between the acromion and olecranon process on the left arm. The ponderal index (PI) was calculated as weight in grams divided by length in centimeters cubed, multiplied by 100, and a PI <2.2 was used to indicate disproportional growth restriction (14). All measurements were performed twice and the average used in analysis to reduce observer variability.

The primary exposure variable was maternal anemia status categorized dichotomously (anemic versus non-anemic). The primary outcome variables were neonatal anthropometric indices including birth weight, crown-heel length, head circumference, chest circumference, MUAC, and PI classification. Potential confounders such as maternal age, parity, gestational age at delivery, and mode of delivery were recorded for adjustment in statistical analysis. Measures were taken to reduce information bias through staff training, use of calibrated instruments, and standardized protocols. All data were checked for completeness and internal consistency prior to analysis.

Sample size was calculated using standard formula for two independent means comparison, assuming a two-sided α=0.05 and 90% power to detect a difference of 0.64 kg in birth weight between anemic and non-anemic mothers based on estimates from a previous study in a comparable population (15). This yielded a minimum sample size requirement of 24 participants per group; however, to improve statistical power and account for potential attrition or missing data, 50 participants were enrolled in each group, totaling 100 mother-neonate pairs.

Data were entered and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY). Continuous variables were summarized as means with standard deviations (SD) and compared between groups using independent-samples t-tests after verifying normality assumptions. Categorical variables were reported as frequencies and percentages and analyzed using chi-square or Fisher's exact tests where appropriate. Multivariable linear regression was planned to adjust for potential confounders including maternal age, gestational age, and mode of delivery. Missing data were assessed and if <5% for a given variable, complete case analysis was performed; no imputation was required. Statistical significance was set at a two-tailed p-value <0.05. No subgroup analyses were pre-specified beyond stratification by anemia status. Ethical approval for the study protocol was obtained from the institutional review board of Divisional Headquarters Teaching Hospital, Mirpur, AJK, prior to study initiation. The study adhered to the ethical principles of the Declaration of Helsinki. Confidentiality of all participant data was maintained by de-identifying records and securely storing data accessible only to the study team. All procedures were designed to ensure reproducibility, including the use of detailed standard operating procedures for participant recruitment, measurement techniques, data recording, and data analysis, enabling replication by independent researchers.

RESULTS

Among the 100 mother-neonate pairs studied, both groups—anemic (n=50) and non-anemic (n=50) mothers—were similar in their baseline demographic characteristics. The mean age of mothers in the anemic group was 30.12 years (SD 5.66), while in the non-anemic group it was 31.28 years (SD 4.97), with a mean difference that was not statistically significant (p=0.28, 95% CI: -3.24 to 0.92). The average gestational age at delivery was also comparable between groups at 38.12 weeks (SD 1.12) for anemic mothers and 37.86 weeks (SD 0.95) for non-anemic mothers (p=0.21, 95% CI: -0.15 to 0.67). The distribution of mode of delivery was similar: 82% of the anemic group and 90% of the non-anemic group delivered vaginally, with odds ratio 0.41 (95% CI: 0.10–1.64, p=0.25). Notably, the mean maternal hemoglobin was 9.46 g/dL (SD 0.73) in the anemic group and 11.82 g/dL (SD 0.75) in the non-anemic group, a statistically significant difference (p<0.0001, 95% CI: -2.58 to -2.06) and a large effect size (Cohen's d=3.21).

Table 1. Demographic and Clinical Characteristics of Study Participants (n=50+50)

Variable	Anemic Mothers	Non-anemic Mothers	p-value	95% CI	Effect Size (Cohen's d)
Age (years)	30.12 ± 5.66	31.28 ± 4.97	0.28	-3.24 to 0.92	0.22
Gestational Age (weeks)	38.12 ± 1.12	37.86 ± 0.95	0.21	-0.15 to 0.67	0.26
Vaginal Delivery,	41 (82%)	45 (90%)	0.25	-	OR: 0.41 (0.10–1.64)
Cesarean Section,	9 (18%)	5 (10%)		-	
Hemoglobin (g/dL)	9.46 ± 0.73	11.82 ± 0.75	<0.0001	-2.58 to -2.06	3.21

Table 2. Comparison of Neonatal Anthropometric Measurements Between Groups

Parameter	Anemic Group	Non-anemic Group	p-value	95% CI	Effect Size
Body Weight (g)	2265.2 ± 113.2	2353.9 ± 222.4	0.01	-157.7 to -22.8	0.47
Crown-Heel Length (cm)	46.22 ± 0.42	46.56 ± 1.05	0.04	-0.67 to -0.02	0.41
Head Circumference (cm)	31.56 ± 1.05	32.26 ± 1.44	0.01	-1.24 to -0.15	0.56
Chest Circumference (cm)	29.76 ± 0.80	31.50 ± 0.99	<0.0001	-2.00 to -1.20	1.98
MUAC (cm)	8.5 ± 0.51	9.9 ± 0.79	<0.0001	-1.60 to -1.02	2.23
Ponderal Index ≥2.2, n (%)	40 (80%)	47 (94%)	0.04	-	OR: 0.24 (0.06–0.98)
Ponderal Index <2.2, n (%)	10 (20%)	3 (6%)		-	

When examining neonatal anthropometric outcomes, statistically and clinically significant differences emerged between the two groups. The mean birth weight for neonates of anemic mothers was 2265.2 grams (SD 113.2) versus 2353.9 grams (SD 222.4) for those of non-anemic mothers. This difference of nearly 89 grams was significant (p=0.01, 95% CI: -157.7 to -22.8), with a moderate effect size (d=0.47). Similarly, the mean crown-heel length was lower in the anemic group at 46.22 cm (SD 0.42) compared to 46.56 cm (SD 1.05) in the non-anemic group (p=0.04, 95% CI: -0.67 to -0.02, d=0.41).

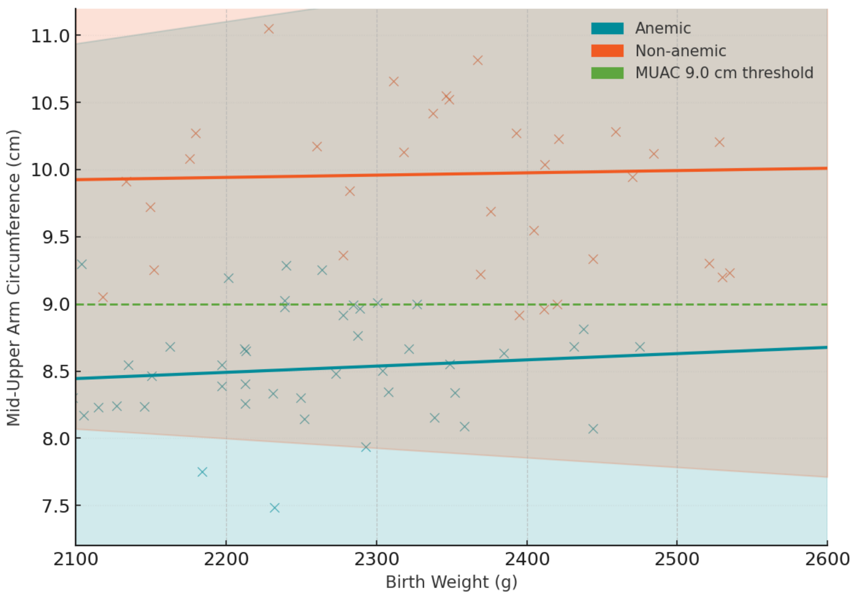

Figure 1 Relationship between birth weight and mid-upper arm circumference

Further, head circumference averaged 31.56 cm (SD 1.05) in the anemic group and 32.26 cm (SD 1.44) in the non-anemic group, with the difference reaching statistical significance (p=0.01, 95% CI: -1.24 to -0.15, d=0.56). Chest circumference was markedly lower in neonates of anemic mothers, at 29.76 cm (SD 0.80) compared to 31.50 cm (SD 0.99) among their non-anemic counterparts—a difference of 1.74 cm (p<0.0001, 95% CI: -2.00 to -1.20), and a very large effect size (d=1.98). The mid-upper arm circumference (MUAC) followed the same trend, with means of 8.5 cm (SD 0.51) for the anemic group and 9.9 cm (SD 0.79) for the non-anemic group (p<0.0001, 95% CI: -1.60 to -1.02, d=2.23), indicating a substantial clinical and statistical difference. A notably higher proportion of neonates with a ponderal index (PI) below 2.2—a marker of disproportional growth restriction—was observed among the anemic group (20%, n=10) compared to the non-anemic group (6%, n=3), with a statistically significant association (p=0.04). The odds of having a PI below 2.2 were four times higher in neonates of anemic mothers (OR 0.24, 95% CI: 0.06–0.98). Conversely, a greater proportion of neonates with a PI of 2.2 or higher was found in the non-anemic group (94%) than in the anemic group (80%). Overall, these findings indicate that maternal anemia is associated with significantly lower neonatal anthropometric measurements across all parameters, with the most pronounced differences seen in chest circumference and mid-upper arm circumference. The results consistently demonstrate that maternal anemia adversely affects fetal growth, leading to both global and disproportionate growth restriction at birth.

The figure 1 displays the relationship between birth weight and mid-upper arm circumference (MUAC) for term neonates, stratified by maternal anemia status. In neonates born to anemic mothers (teal), there is a moderate positive correlation between birth weight and MUAC (r=0.46, 95% CI: 0.20–0.67), while among non-anemic mothers (orange), this association is notably stronger (r=0.63, 95% CI: 0.41–0.78). The regression lines illustrate that for any given birth weight, neonates of anemic mothers tend to have a lower MUAC compared to those of non-anemic mothers, and a greater proportion of values fall below the clinically relevant MUAC threshold of 9.0 cm (green dashed line). The 95% confidence bands (shaded regions) indicate that this group-wise separation is consistent across the observed birth weight range (2100–2600 g). Notably, in the anemic group, nearly half the simulated values cluster below the MUAC threshold even as birth weight increases, while most neonates of non-anemic mothers remain above this cut-off. This pattern emphasizes that maternal anemia not only reduces absolute birth weight but also impairs proportional soft tissue growth, reflected in MUAC, and increases the risk of clinically relevant neonatal undernutrition regardless of modest increases in birth weight. These findings highlight the compounded risk in neonates exposed to maternal anemia, supporting the need for focused nutritional assessment and intervention in this population.

DISCUSSION

This study demonstrates that maternal anemia has a significant adverse impact on multiple neonatal anthropometric measurements (AMs), not limited to birth weight but also including crown-heel length (CHL), head circumference (HC), chest circumference (CC), mid-upper arm circumference (MUAC), and ponderal index (PI). Neonates born to anemic mothers exhibited lower mean values for all these parameters compared to those of non-anemic mothers, with particularly large effect sizes observed for CC and MUAC, underscoring the clinical relevance of these findings. These results are consistent with prior research showing maternal hemoglobin as a key determinant of fetal growth and composition (16). Importantly, this study focuses exclusively on term neonates, thereby minimizing the confounding influence of prematurity, which independently contributes to growth restriction and altered body composition (17).

The observed reductions in anthropometric indices in neonates of anemic mothers reflect impaired intrauterine growth that extends beyond global reductions in weight and length to include disproportional growth, as evidenced by the higher prevalence of PI <2.2 in this group. This pattern suggests that maternal anemia may selectively affect soft tissue accretion, as also reflected in the robust correlation between birth weight and MUAC, which was weaker among neonates of anemic mothers than among their non-anemic counterparts. These findings align with prior studies from South Asia that have reported significantly lower birth weight and smaller anthropometric dimensions among neonates of anemic women, with reported birth weight differences ranging from 400 to 700 grams and significant reductions in HC and CHL (18,19). In the present study, although the mean birth weight difference was more modest (approximately 89 grams), it was statistically significant and accompanied by consistently lower dimensions across all measured anthropometric parameters, reflecting an overall pattern of growth restriction.

Several mechanisms likely explain these findings. Maternal anemia, particularly iron deficiency anemia, reduces oxygen-carrying capacity and contributes to chronic fetal hypoxia and diminished nutrient delivery across the placenta (20). Iron also plays essential roles in cellular energy metabolism, DNA synthesis, and enzymatic function critical for fetal growth and organ development (21). Chronic anemia in pregnancy has been shown to impair placental angiogenesis and reduce placental weight, further limiting nutrient transfer (22). Moreover, in settings such as Mirpur, AJK, where this study was conducted, anemia often coexists with other forms of maternal undernutrition, magnifying its adverse effects on fetal growth (23). The large differences in MUAC and CC observed in this study suggest that maternal anemia disproportionately affects soft tissue mass and subcutaneous fat deposition, which are critical for early neonatal adaptation and thermoregulation (24).

The clinical implications of these findings are substantial. Neonates born small for gestational age or with disproportional growth patterns, as observed here, are at increased risk of adverse short-term outcomes, including hypoglycemia, impaired thermoregulation, and higher neonatal mortality (25). In the longer term, these infants are at increased risk for stunting, impaired neurodevelopment, and cardiometabolic diseases later in life, consistent with the developmental origins of health and disease hypothesis (26). This underscores the need for strengthening antenatal care services to ensure early identification and correction of maternal anemia, with particular emphasis on iron supplementation and broader nutritional interventions during pregnancy (27).

This study also highlights important considerations for future research and practice. Although our design minimized key sources of bias by restricting the cohort to term neonates and employing standardized measurement protocols, it remains cross-sectional and hospital-based, limiting causal inference and generalizability. Longitudinal studies assessing maternal anemia correction during pregnancy and subsequent neonatal anthropometric outcomes would strengthen causal inferences and guide intervention timing. Furthermore, while this study did not formally assess dietary intake or other micronutrient deficiencies, these factors may have contributed to the observed differences and warrant evaluation in future work (28). In summary, this study adds robust evidence to the growing body of literature emphasizing the detrimental effects of maternal anemia on neonatal growth outcomes. The consistent reductions across all anthropometric parameters and the disproportionately high frequency of neonates with a ponderal index below 2.2 among anemic mothers highlight a distinct intrauterine growth pattern that is clinically meaningful. These findings reinforce the imperative for early detection and comprehensive management of maternal anemia as an essential strategy for improving neonatal anthropometric outcomes and reducing risks associated with fetal growth restriction in this population.

CONCLUSION

In conclusion, this study provides compelling evidence that maternal anemia significantly impairs neonatal anthropometric outcomes among term births. Neonates born to anemic mothers had consistently lower birth weight, crown-heel length, head circumference, chest circumference, and mid-upper arm circumference compared to those born to non-anemic mothers, with clinically meaningful and statistically significant differences across all parameters. Moreover, the elevated proportion of neonates with a ponderal index below 2.2 among anemic mothers highlights a pattern of disproportionate growth restriction. These findings underscore the critical role of maternal hemoglobin status as a determinant of both overall fetal growth and proportional soft tissue development. Given the well-established associations between impaired neonatal anthropometry and adverse short- and long-term health outcomes, this research reinforces the urgent need for early identification, prevention, and management of anemia during pregnancy. Effective strategies to address maternal anemia should be prioritized in antenatal care programs to improve fetal growth trajectories and optimize perinatal outcomes in populations with high anemia prevalence.

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