

Study Of Maternal Anemia and Anemia-Related Biomarkers During Pregnancy and Their Association with Infant OutcomesShikha¹, Nutan Mandal², Bibha Jha³¹Senior Resident, Department of Obstetrics and Gynecology, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India²Senior Resident, Department of Obstetrics and Gynecology, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India³Associate Professor, Department of Obstetrics and Gynecology, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India

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Abstract:**Background:** Maternal anemia is a major public health concern in low-resource settings like India, contributing to adverse maternal and infant outcomes. Its multifactorial etiology includes micronutrient deficiencies and inflammation.**Aim:** To assess maternal anemia and related biomarkers during pregnancy and examine their association with infant outcomes in Bihar, India.**Methodology:** A hospital-based prospective observational study was conducted among 96 pregnant women at Department of Obstetrics and Gynecology, Darbhanga Medical College and Hospital, Laheriasarai, Darbhanga, Bihar, India. Hemoglobin and biomarkers (serum ferritin, vitamin B12, folate, CRP) were assessed during pregnancy. Infant outcomes, including birth weight, gestational age, and hemoglobin at 6 weeks, were recorded. Statistical analyses included regression and multivariable models.**Results:** Anemia prevalence was high (68.7%), with moderate anemia most common (33.3%). Iron deficiency (41.7%), vitamin B12 deficiency (37.5%), and elevated CRP (39.6%) were frequent. Mean birth weight was 2650 g, with 35.4% low birth weight and 27.1% preterm births. Increasing anemia severity was associated with lower birth weight, higher preterm rates, and reduced infant hemoglobin. Ferritin, vitamin B12, and folate positively influenced outcomes, while CRP showed negative associations.**Conclusion:** Maternal anemia and poor biomarker status significantly worsen infant outcomes, highlighting the need for early detection and nutritional interventions.**Keywords:** Maternal Anemia, Pregnancy, Biomarkers, Infant Outcomes, Birth Weight, Iron Deficiency, Bihar.**DOI:** 10.25258/ijpqa.17.1.73

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Introduction

Anemia is defined as a condition in which the concentration of hemoglobin (Hb) and/or the number of red blood cells are inadequate to meet an individual's physiological needs [1]. The threshold for defining anemia depends on age, sex, altitude, smoking status and pregnancy. As per WHO, nonpregnant women with Hb concentrations of < 12.0 g/dL are considered anemic. Physiological changes during pregnancy with plasma volume expansion require trimester-specific cutoffs. In 2016, anemia in pregnancy was defined as Hb concentration <11.0 g/dL in the first and third trimesters and <10.5 g/dL in the second trimester.

Anemia has a complex and multifactorial etiology, especially in low- and middle-income countries (LMICs), where multiple etiologies frequently co-

exist. Iron deficiency (ID) is well acknowledged to be the most common nutritional cause of anemia globally, accounting for approximately half of all cases [2], and most often due to inadequate dietary intake. However, the percentage of anemia attributable to iron deficiency differs by population characteristics as well as geographic region, infectious disease burden, and other determinants of health. Apart from iron deficiency, other micronutrient deficiencies need to be considered as they have indispensable roles in hemoglobin synthesis and erythropoiesis such as folate and vitamin B12. Besides, non-nutritional conditions like chronic infections, inflammation, impaired nutrient absorption, blood loss disorders and genetic diseases such as sickle-cell disease are also important parameters which cause anemia [3].

Women during their reproductive age were on the list of most vulnerable groups to anemia owing to high iron requirements and physiological needs triggered by menstruation and pregnancy along with exceeding dietary intake. Realizing the severity of the issue, in 2012, the World Health Assembly endorsed Global Nutrition Target 2 to reach a 50% reduction in anemia among women of reproductive age by 2025 [4]. This commitment was further affirmed by the Sustainable Development Goals (SDGs), which comprise a similar standard to be achieved by 2030 [5]. Worldwide, however, anemia continues to be one of the most common global public health issues; approximately 30% of women aged 15–49 years are affected by anemia [1] (representing over half a billion women worldwide). The burden is even greater among pregnant women, with an estimated prevalence of 37%.

India has the largest global burden of anemia in pregnant women, with almost half of this population — around 7.5 million women — affected. However, in 1970, India launched the National Nutritional Anemia Prophylaxis Program to provide iron and folic acid (IFA) supplementation [6]. But there have been several programmatic issues like irregular supply chain, inadequate training of health workers and limited reach of the programme that curtailed its effectiveness. Thus, compliance with IFA supplementation has been poor and declines in anemia have been slow. According to the National Family Health Survey-5 (NFHS-5) only 44% of pregnant women consumed IFA supplements for recommended 100 days [7]. Notably, the prevalence of anemia among pregnant women in India remains relatively unchanged over time with estimates of 58.7% in 2005–2006, 50.4% in 2015–16 and 52.2% (43) from other clinical study conducted during a period of January to December 2019 (which was published during August-2021). These numbers, however, underscore the ongoing and intractable nature of the problem.

The burden of maternal anemia could be particularly high in states such as Bihar, with higher population density, healthcare access issues and socioeconomic challenges. Factors contributing to high anemia prevalence in this region include poor nutritional coverage, frequent infections and limited antenatal care utilization. Yet, there is a dearth of region-specific prospective studies on the temporal changes in anemia and associated biomarkers across pregnancy and their effect(s) on infant health outcomes in Bihar despite national-level data appraisals.

Anemia has an extensive impact beyond the haematological health and influences some aspects of both individual welfare as well as country's socioeconomic progress. Anemia has been linked to poor cognitive performance, lowered educational achievement, impaired work productivity, and poor mental health outcomes among reproductive aged women [8]. The dangers of anemia are especially

severe during pregnancy since it can impact fetal growth and birth outcomes. New evidence indicates that the effects of anemia differ by its etiology and timing in pregnancy.

Multiple literature has shown significant association of maternal anaemia with adverse pregnancy outcomes, from systematic reviews to meta-analysis. These effects consist of obstetrical complications such as impaired fetal growth, high risk of low birth weight (LBW), preterm labor, reduced neonatal iron kinetic stores and a possible long-term infantile developmental delay [9]. It is worth noting that there is also an increased risk of adverse outcomes associated with high iron levels during pregnancy, which suggests a U-shaped relationship between iron status and birth outcomes. This highlights the need to maintain good, and not just higher, micronutrient status during pregnancy. Moreover, low concentrations of important anemia-related biomarkers such as vitamin B12 and folate have been independently associated with adverse birth outcomes (e.g. LBW and low gestation period).

In an Indian context, little is known about the link between maternal anemia and poor infant outcomes as it has been demonstrated based on primarily retrospective cohort studies with hospital-based data [10]. Although these studies offer the richest datasets available, they cannot capture shifts in anemia status and biomarker levels over the duration of pregnancy. Prospective, community-based studies in population settings especially in resource-constrained countries like rural Bihar remain limited. The dynamic nature of anemia makes such studies crucial to understanding the evolution in underlying determinants of anemia over time and identifying intervention windows.

Because of these gaps, there is a critical need for comprehensive studies evaluating maternal anemia and related micronutrient biomarkers over the course of pregnancy and their association with infant outcomes. Thus, this study aims to examine the association between maternal anemia and anemia-related biomarkers in pregnancy and important infant outcomes like birth weight, gestational age at birth, birth weight-for-gestational-age percentile and infant hemoglobin concentrations at 6 weeks of age in Bihar India. This research aims to produce local evidence when needed is and can increase effectiveness of existing maternal and child health programs in the region.

Methodology

Study Design: This study was a hospital-based prospective observational study conducted to evaluate maternal anemia and anemia-related biomarkers during pregnancy and to determine their association with infant outcomes. The design allowed for longitudinal follow-up of pregnant women from early pregnancy through delivery and the postnatal period,

enabling assessment of temporal relationships between maternal hematological status and neonatal health indicators.

Study Area: The study was conducted in the Department of Obstetrics and Gynecology at Darbhanga Medical College and Hospital (DMCH), Laheriasarai, Darbhanga, Bihar, India.

Study Duration: The study was carried out over a period of nine months from March 2025 to November 2025.

Sample Size: A total of 96 pregnant women were included in the study. The sample size was determined based on feasibility, considering the study duration, patient flow in the antenatal clinic, and available resources. All eligible participants who met the inclusion criteria and consented to participate during the study period were enrolled until the desired sample size was achieved.

Study Population: The study population consisted of pregnant women attending the antenatal clinic (ANC) of the Department of Obstetrics and Gynecology at DMCH. Women were preferably enrolled during the first trimester of pregnancy (before 13 weeks of gestation) to allow early assessment of anemia status and adequate follow-up. These women were monitored throughout pregnancy and after delivery to evaluate maternal biomarkers and infant health outcomes.

Data Collection: Data were collected by trained healthcare personnel using a structured proforma. At the time of enrollment, baseline information including socio-demographic characteristics such as age, education, and socioeconomic status was recorded. Obstetric history, including parity and gravidity, along with anthropometric measurements such as height and weight, were documented. Dietary history focusing on the intake of iron-rich foods and animal products was also obtained. Gestational age was assessed based on the last menstrual period.

Hemoglobin levels were measured using a digital hemoglobinometer through the finger-prick method. Additionally, approximately 5–7 mL of venous blood was collected under aseptic conditions for laboratory investigations. These included complete blood count, serum ferritin, vitamin B12, folate levels, and C-reactive protein (CRP). Standard laboratory methods such as the cyanmethemoglobin method for hemoglobin estimation, immunoassay techniques for micronutrient analysis, and turbidimetric methods for CRP were used.

Participants were followed up during the third trimester (after 27 weeks of gestation), where repeat hemoglobin measurements were taken and information regarding iron-folic acid supplementation and dietary intake was updated. At the time of delivery, infant birth weight was recorded within 24 hours using a calibrated digital weighing scale. A

follow-up visit was conducted at six weeks postpartum, during which infant hemoglobin levels were assessed using the heel-prick method.

Inclusion Criteria

- Pregnant women attending ANC at DMCH
- Gestational age ≤ 13 weeks at enrollment (preferable)
- Willing to provide informed consent
- Planning to deliver at the study hospital or available for follow-up

Exclusion Criteria

- Women with known chronic diseases (e.g., renal disease, malignancy)
- Women with hematological disorders other than nutritional anemia
- Multiple pregnancies (twins or higher order)
- Women unwilling to participate or lost to follow-up

Study Procedure: Eligible pregnant women were identified during their routine antenatal clinic visits. After obtaining informed consent, baseline data and blood samples were collected. Participants were then followed up at specified intervals, including during the third trimester, at delivery, and at six weeks postpartum. Maternal hemoglobin levels and biomarker profiles were assessed at different stages of pregnancy. Infant outcomes, including birth weight, gestational age at birth, and hemoglobin levels at six weeks, were recorded. All data were systematically documented and verified for accuracy.

Statistical Analysis: Data collected during the study were entered into Microsoft Excel and analyzed using appropriate statistical software such as SPSS. Descriptive statistics were used to summarize the data, with continuous variables expressed as mean and standard deviation and categorical variables presented as frequencies and percentages. Inferential statistical tests such as the chi-square test were used to analyze associations between categorical variables, while independent t-tests or ANOVA were used for comparison of means between groups. Correlation analysis was performed to assess relationships between maternal anemia-related biomarkers and infant outcomes. Multivariable regression analysis was conducted to evaluate the independent association between maternal anemia and infant outcomes while adjusting for potential confounding variables. A p-value of less than 0.05 was considered statistically significant.”

Result

Table 1 presents the socio-demographic and obstetric characteristics of 96 study participants, showing that the majority were aged 20–25 years (42; 43.8%), followed by 26–30 years (28; 29.2%), while younger (<20 years) and older (>30 years) groups constituted 14 (14.6%) and 12 (12.5%) respectively.

In terms of education, most participants had secondary education (32; 33.3%), followed by primary (30; 31.3%), while 20 (20.8%) were illiterate and 14 (14.6%) had higher education. Regarding parity, multigravida women (56; 58.3%) outnumbered primigravida (40; 41.7%). Socioeconomically, half of the participants belonged to the low

socioeconomic group (48; 50%), with 34 (35.4%) from the middle class and 14 (14.6%) from the high socioeconomic group. Overall, the table indicates that most participants were young, moderately educated, multigravida women from lower socioeconomic backgrounds.

Variables	Frequency (n)	Percentage (%)
Age Group (years)		
<20	14	14.6
20–25	42	43.8
26–30	28	29.2
>30	12	12.5
Education Status		
Illiterate	20	20.8
Primary	30	31.3
Secondary	32	33.3
Higher	14	14.6
Parity		
Primigravida	40	41.7
Multigravida	56	58.3
Socioeconomic Status		
Low	48	50
Middle	34	35.4
High	14	14.6

Table 2 presents the prevalence and severity of maternal anemia among 96 participants, showing that anemia was common in the study population. Only 30 women (31.3%) had normal hemoglobin levels (≥ 11 g/dL), while the majority exhibited some degree of anemia. Moderate anemia was the most

prevalent, affecting 32 participants (33.3%), followed by mild anemia in 28 (29.2%). Severe anemia was relatively less common, observed in 6 women (6.3%). Overall, nearly two-thirds of the participants were anemic, with moderate anemia constituting the largest proportion.

Hemoglobin Level	Frequency (n)	Percentage (%)
Normal (≥ 11 g/dL)	30	31.3
Mild Anemia (10–10.9 g/dL)	28	29.2
Moderate Anemia (7–9.9 g/dL)	32	33.3
Severe Anemia (< 7 g/dL)	6	6.3

Table 3 shows the distribution of anemia-related biomarkers among 96 study participants, highlighting both mean levels and prevalence of deficiencies. The mean serum ferritin level was 18.5 ± 7.2 $\mu\text{g/L}$, with 40 participants (41.7%) being deficient, indicating a high burden of iron deficiency. Vitamin B12 had a mean of 220 ± 65 pg/mL , with deficiency observed

averaged 4.2 ± 1.5 ng/mL , with comparatively fewer deficiencies (22; 22.9%). The mean CRP level was 6.8 ± 2.3 mg/L , with elevated levels seen in 38 participants (39.6%), suggesting a considerable proportion with underlying inflammation. Overall, iron deficiency and inflammation were the most prevalent abnormalities, followed by vitamin B12 deficiency,

Biomarker	Mean \pm SD	Deficient n (%)
Serum Ferritin ($\mu\text{g/L}$)	18.5 ± 7.2	40 (41.7%)
Vitamin B12 (pg/mL)	220 ± 65	36 (37.5%)
Folate (ng/mL)	4.2 ± 1.5	22 (22.9%)
CRP (mg/L)	6.8 ± 2.3	38 (39.6%)

in 36 participants (37.5%), while folate levels

with folate deficiency being relatively less common.

Table 4 presents the infant outcomes among the study population (N = 96), showing that the mean birth weight was 2650 ± 420 g, with 34 infants (35.4%) classified as low birth weight (<2500 g) and 62 (64.6%) having normal birth weight. The mean gestational age was 37.8 ± 1.9 weeks, with 26 infants (27.1%) born preterm (<37 weeks) and the majority,

70 (72.9%), delivered at term. Additionally, the mean infant hemoglobin level at 6 weeks was 10.8 ± 1.2 g/dL. Overall, the table indicates that while most infants had normal birth weight and term deliveries, a considerable proportion still experienced low birth weight and preterm birth.

Table 4: Infant Outcomes among Study Population (N = 96)

Outcome	Frequency (n)	Percentage (%) / Mean ± SD
Birth Weight (g)		2650 ± 420
Low Birth Weight (<2500 g)	34	35.4
Normal Birth Weight	62	64.6
Gestational Age (weeks)		37.8 ± 1.9
Preterm (<37 weeks)	26	27.1
Term	70	72.9
Infant Hb at 6 weeks (g/dL)		10.8 ± 1.2

Table 5 demonstrates the association between maternal anemia and infant outcomes, showing a clear worsening trend with increasing severity of anemia. Mothers with normal hemoglobin had the highest mean birth weight (2900 ± 350 g), lowest preterm rate (10%), and highest infant hemoglobin levels (11.5 ± 1.0 g/dL). In contrast, mild anemia was associated with a reduction in birth weight (2700 ± 400 g), higher preterm incidence (25%), and lower infant Hb (10.9 ± 1.1 g/dL). This trend continued with

moderate anemia, where birth weight further decreased to 2500 ± 380 g, preterm births increased to 34%, and infant Hb dropped to 10.5 ± 1.2 g/dL. The most adverse outcomes were observed in severe anemia, with the lowest birth weight (2300 ± 300 g), highest preterm rate (50%), and lowest infant Hb (9.8 ± 1.3 g/dL). Overall, the table indicates a dose-response relationship, where increasing severity of maternal anemia is associated with poorer infant outcomes.

Table 5: Association between Maternal Anemia and Infant Outcomes

Maternal Hb Status	Mean Birth Weight (g)	Preterm (%)	Infant Hb (g/dL)
Normal	2900 ± 350	10%	11.5 ± 1.0
Mild Anemia	2700 ± 400	25%	10.9 ± 1.1
Moderate Anemia	2500 ± 380	34%	10.5 ± 1.2
Severe Anemia	2300 ± 300	50%	9.8 ± 1.3

Table 6 presents the regression analysis showing associations between maternal biomarkers and infant outcomes, indicating both positive and negative influences. Serum ferritin was positively associated with birth weight (β = +2.1 ± 0.9), gestational age (β = +0.02 ± 0.01), and infant hemoglobin (β = +0.05 ± 0.02), with statistical significance (p = 0.03). Similarly, vitamin B12 showed positive associations with birth weight (β = +1.5 ± 0.8), gestational age (β = +0.01 ± 0.01), and infant Hb (β = +0.04 ± 0.02) (p = 0.04), while folate also demonstrated modest positive effects across all outcomes (birth weight β =

+1.2 ± 0.7; gestational age β = +0.01 ± 0.01; infant Hb β = +0.03 ± 0.01) with borderline significance (p = 0.05). In contrast, CRP showed negative associations with all outcomes, including birth weight (β = -1.8 ± 0.9), gestational age (β = -0.02 ± 0.01), and infant Hb (β = -0.04 ± 0.02), and was statistically significant (p = 0.02). Overall, the findings suggest that better maternal nutritional status (ferritin, vitamin B12, folate) is associated with improved infant outcomes, whereas inflammation (CRP) is linked to poorer outcomes.

Table 6: Association between Biomarkers and Infant Outcomes (Regression Analysis)

Variable	Birth Weight (β ± SE)	Gestational Age (β ± SE)	Infant Hb (β ± SE)	P-value
Serum Ferritin	+2.1 ± 0.9	+0.02 ± 0.01	+0.05 ± 0.02	0.03
Vitamin B12	+1.5 ± 0.8	+0.01 ± 0.01	+0.04 ± 0.02	0.04
Folate	+1.2 ± 0.7	+0.01 ± 0.01	+0.03 ± 0.01	0.05
CRP	-1.8 ± 0.9	-0.02 ± 0.01	-0.04 ± 0.02	0.02

Table 7 presents the multivariable analysis of maternal anemia and its impact on infant outcomes, showing a significant inverse association between

severity of anemia and birth weight. Compared to normal mothers, mild anemia was associated with a reduction of 150 g in infant weight (Adjusted β =

-150 g; 95% CI: -260 to -40; $p = 0.01$), while moderate anemia showed a greater reduction of 280 g (95% CI: -400 to -120; $p = 0.001$). The most pronounced effect was seen in severe anemia, with a reduction of 420 g in birth weight (95% CI: -600 to

-200; $p < 0.001$). Overall, the findings demonstrate a dose-response relationship, where increasing severity of maternal anemia is significantly associated with progressively lower infant birth weight.

Table 7: Multivariable Analysis of Maternal Anemia and Infant Outcomes

Variable	Adjusted β (95% CI)	P-value
Mild Anemia vs Normal	-150 g (-260, -40)	0.01
Moderate Anemia vs Normal	-280 g (-400, -120)	0.001
Severe Anemia vs Normal	-420 g (-600, -200)	<0.001

Discussion

The current study findings reveal high prevalence (68.7%) of anaemia and their association with adverse birth outcomes, which are largely consistent to existing literature although some differences were observed in magnitude and biomarker associations. The prevalence noted in our study aligns well with reports from other comparable low- and middle-income settings, where anemia during pregnancy continues to pose serious public health challenges. Similarly, in India a cohort study had reported anemia rates as high across pregnancy and upto 71% during later trimesters suggesting that the burden observed in our population is similar to regional trends (Dutta et al., 2023) [11]. However, our overall prevalence was slightly lower, which may be attributed to differences in maternal sample size ($n = 88$), gestational age at the time of assessment and nutritional interventions reported”.

An earlier systematic review and meta-analyses have provided strong evidence for association between maternal anemia and lower birth weight, which is consistent with our findings. A progressive decrease in birth weight with increasing severity of anemia was observed with severe forms being associated to a decline of 420 g, corroborating global evidence that maternal anemia is an important risk factor for low birth weight (LBW) [12]. Likewise, it has been shown that maternal hemoglobin levels during the first trimester are important parameters of fetal growth and development, presumably because of compromised permeability to oxygen along with reduced placental vascularization (Stangret et al., 2017) [13]. Other studies were found to suggest the role of anemia timing on LBW, as they report a stronger association between early pregnancy anemia and LBW than that observed for later detected anemia in the same pregnancy (Dewey & Oaks, 2017) [14]. Although we did not stratify by trimester, the robust overall association strengthens its biological plausibility.

Our data revealed a strong link between maternal anemia and preterm birth, with more than one in ten infants born to non-anemic mothers being premature compared to half of those born to severely anemic mothers. This is comparable to results from studies

on large cohorts in South Asia indicating a higher risk of preterm delivery among anemic mothers: (Parks et al., 2019; Nair et al., 2016) [15,10]. However, there have been several reports of weak or inconsistent association between anemia and gestational age such that it has been suggested that other maternal factors such as nutritional status, infections, among others, including socioeconomic conditions serve to confound this relationship. In the associated discussion, third-trimester maternal anemia was specifically linked to lower gestational age, whereas our results point to a less truncation which occurs more uniformly across anaemia severity levels, reflecting potential variations by population.

When we look at the relationship between hemoglobin and outcomes, an important dichotomy arises. Our findings showed a linear increase in poor outcomes as anemia increased in severity, however prior literature suggests it may be more of a U-shaped relationship with higher and lower levels of hemoglobin associated with worse outcomes (Dewey & Oaks 2017; Young et al., 2023) [14,16]. Abnormally high hemoglobin concentrations have also been associated with increased blood viscosity and impaired placental perfusion, which may lead to preterm birth or fetal growth restriction. We did not observe or evaluate adverse outcomes in women with high hemoglobin levels, which could reflect either the small number of cases or the lower nutritional status of our study population.

The association of anemia-related biomarkers with infant outcomes in our study corroborates previous evidence. Similarly, we observed positive relationships between serum ferritin levels and birth weight and gestational age that were consistent with previous findings suggesting an important role for adequate iron stores in optimal growth among the fetus [17]. Our data similarly show that vitamin B12 deficiency in our study was associated with lower infant hemoglobin levels, which is consistent with findings from Rogne et al. (2017) [18], which proved that low maternal vitamin B12 increases adverse neonatal hematological outcomes. Our study also confirmed the positive association of folate levels with infant outcomes which is consistent with previous studies pointing out its role in DNA synthesis and fetal development (Scholl et al., 1996) [19].

Conversely, our study uniquely emphasized the adverse effect of inflammation, particularly reflected by CRP, on birth outcomes and hemoglobin level in infants. This is consistent with data from the BRINDA project, which highlighted that inflammation must be considered when interpreting iron biomarkers and etiology of anemia (Suchdev et al., 2016) [20]. Although most of the preceding studies were predominantly nutritional deficiency studies, our findings highlight how anemia is multifactorial and that inflammation acts to further restrict iron availability whilst blunting maternal erythropoiesis; both mechanisms contributing to worsening maternal and neonatal outcomes.

Another contrasting finding relates to the interdependence of maternal anemia and other maternal characteristics. Maternal anthropometry and background characteristics are more predictive of infant outcomes than anemia (referenced discussion). Although detailed anthropometric variables were not analyzed in our study, the significant independent effect of maternal anemia from multivariable analysis suggests that anemia per se is an important determinant in our cohort. This difference can be explained by differences in study designs, subject populations or depth of nutritional deficiencies.

The mean infant hemoglobin levels in our study (10.8 ± 1.2 g/dL) were also comparatively low, especially among infants of anemic mothers. In line with indications that maternal iron and micronutrient status directly impact neonatal iron stores and hemoglobin levels during early life (Georgieff, 2020) [21]. Maternal hemoglobin was also associated with lower infant hemoglobin at 6 weeks, suggesting that maternal nutrition has intergenerational influence.

In conclusion, our results corroborate previous reports in the literature on maternal anemia adverse effects on birth weight and gestational age, as well as infant hemoglobin. Our study, however, adds new information regarding the graded relationship between anemia severity and outcomes as well as the joint effect of micronutrient deficiency and inflammation. These results indicate that broader antenatal strategies are needed to enhance maternal and neonatal health, including not just iron deficiency but also other nutritional and inflammatory factors.

Conclusion

The research paper findings support previous evidence of commonality of maternal anemia in pregnancy, particularly among women from lower socioeconomic and educational backgrounds, but also demonstrate that many women experience moderate to severe forms of the condition. Abolition of key anemia-related biomarkers such as iron, vitamin B12 and folate next to elevated inflammatory markers were also common. Among the findings of these maternal nutritional and hematological inadequacies

were closely linked with poor infant outcomes such as low birth weight, premature birth, and less infant hemoglobin bars. In addition, the influence of increasing severity of maternal anemia was in negative relation for all infant health indicators expressing better biomarker status as positively correlated to improved outcomes. In conclusion, the results highlight the need for early detection and management of maternal anemia and associated deficiencies in pregnancy to optimize neonatal health.

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