Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/cxbr5x55

CORRELATION BETWEEN MATERNAL IRON STATUS AND FETAL HEMATOLOGICAL PARAMETERS: EVALUATING ERYTHROPOIETIN, HEMOGLOBIN, AND FERRITIN LEVELS IN MATERNAL AND CORD BLOOD

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ABSTRACT

Background: To evaluate the correlation between maternal iron status and fetal hematological parameters, focusing on hemoglobin, ferritin, and erythropoietin levels in maternal and cord blood.

Methods: A prospective observational study was conducted at Kohat Medical College and its affiliated hospitals from January 2024 to January 2025. A total of 82 mother newborn pairs were included. Maternal venous blood was collected prior to delivery, while cord blood samples were obtained immediately after delivery. Hematological parameters were analyzed using an automated analyzer, ferritin levels were measured via chemiluminescent immunoassay, and erythropoietin was determined using ELISA. Data were analyzed using SPSS version 26, with Pearson correlation applied to assess associations.

Results: Maternal mean hemoglobin and ferritin levels were significantly lower than reference standards ($p<0.05$). Cord blood hemoglobin (14.9 ± 1.8 g/dL) and ferritin (105.7 ± 28.9 ng/mL) were significantly higher than maternal values ($p<0.05$). Positive correlations were observed between maternal and cord hemoglobin ($r=0.46$, $p=0.001$), ferritin ($r=0.41$, $p=0.002$), and erythropoietin ($r=0.29$, $p=0.03$).

Conclusion: Maternal iron status strongly influences neonatal hematological indices, with cord blood ferritin and hemoglobin reflecting maternal reserves. Optimizing maternal iron supplementation and routine ferritin screening during pregnancy may improve neonatal outcomes.

Keywords: Maternal iron deficiency, cord blood, hemoglobin, ferritin, erythropoietin, neonatal outcomes

INTRODUCTION

Iron deficiency during pregnancy remains a major global health concern, affecting nearly 40% of pregnant women worldwide . It is the most common cause of maternal anemia and is linked to significant maternal morbidity, including fatigue, increased risk of infection, and postpartum hemorrhage. Importantly, maternal iron status also influences fetal growth and hematological development, as the fetus depends entirely on maternal iron supply for erythropoiesis and storage (1-3).

The placenta plays a vital role in iron transfer, prioritizing fetal requirements even when maternal stores are limited. However, severe maternal deficiency may compromise this mechanism, leading to reduced neonatal iron stores at birth, which predisposes infants to iron deficiency anemia in early life. Such deficiencies during infancy have been associated with long-term neurodevelopmental impairment, including delayed cognitive and psychomotor development (4-6).

Cord blood assessment provides valuable insight into the iron status of the newborn. Parameters such as hemoglobin, ferritin, and erythropoietin levels reflect the efficiency of maternal-fetal iron transfer and the adaptive capacity of the fetus. Maternal anemia has been shown to significantly reduce cord blood ferritin concentrations, even when neonatal hemoglobin remains within the normal range due to preferential iron transfer to the fetus (7, 8). Erythropoietin, a hormone regulating red cell production, is often elevated in response to hypoxia but may also serve as a marker of intrauterine stress and iron-restricted erythropoiesis (9, 10).

Despite global recognition of maternal anemia as a public health problem, regional data from South Asia, particularly Pakistan, remain limited. Understanding the relationship between maternal iron parameters and neonatal hematological outcomes is crucial to developing targeted interventions. This is particularly relevant in settings where nutritional deficiencies are prevalent, and compliance with supplementation programs is variable (11, 12).

The present study was therefore conducted at Kohat Medical College and its affiliated hospitals to evaluate the correlation between maternal iron status and fetal hematological parameters, specifically focusing on hemoglobin, ferritin, and erythropoietin levels in maternal and cord blood. By identifying the extent to which maternal deficiencies affect neonatal reserves, this research aims to highlight the importance of routine ferritin screening and iron supplementation strategies during pregnancy.

METHODOLOGY

This study was designed as a prospective observational study conducted in the Department of Obstetrics and Gynecology, Kohat Medical College, and its affiliated teaching hospitals. The study period spanned from January 2024 to January 2025. Ethical approval was obtained from the Institutional Review Board of Kohat Medical College, and informed consent was taken from all participating mothers before recruitment.

The study included 82 pregnant women presenting for delivery at term. All participants were carefully screened according to predefined inclusion and exclusion criteria. The study protocol was approved by the Ethics Committee of Kohat Medical College. Participation was voluntary, and written informed consent was obtained from all mothers. Confidentiality of participants' data was strictly maintained, and samples were used solely for research purposes.

Inclusion Criteria

- Women aged 18–40 years with singleton pregnancies.
- Gestational age ≥37 weeks confirmed by last menstrual period or ultrasound.
- Willingness to provide informed consent.

Exclusion Criteria

- Mothers with chronic medical conditions such as diabetes mellitus, hypertension, or renal disease.
- History of hematological disorders (e.g., thalassemia, sickle cell anemia, aplastic anemia).

- Mothers with active infections, chronic inflammatory conditions, or pregnancy complications such as preeclampsia.
- Use of blood transfusion within the last three months.

A total of 82 mother–newborn pairs were enrolled using consecutive non-probability sampling. The sample size was estimated based on previous studies evaluating maternal and neonatal iron indices, ensuring sufficient statistical power to detect moderate correlations between maternal and cord blood parameters ($r \geq 0.3$) at a significance level of 5% and power of 80% (Al Hossain et al., 2023; Akinlusi et al., 2022).

Detailed demographic and obstetric data, including age, parity, body mass index (BMI), gestational age at delivery, mode of delivery, and iron supplementation history, were recorded using a structured proforma.

Blood Sample Collection

- Maternal venous blood: 5 mL of venous blood was drawn from each mother prior to delivery.
- Cord blood sample: Immediately after delivery and cord clamping, 5 mL of blood was obtained from the umbilical vein.

Both samples were collected in sterile tubes. A portion was sent for complete blood count (CBC) using an automated hematology analyzer, while the remainder was centrifuged, and serum was separated for biochemical assays.

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- Hematological analysis: Hemoglobin concentration, hematocrit, mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC) were determined using an automated analyzer (Sysmex XP-300, Japan).
- Iron status markers: Serum iron, total iron binding capacity (TIBC), transferrin saturation, and serum ferritin levels were measured using chemiluminescent immunoassays.
- Erythropoietin levels: Maternal and cord serum erythropoietin were quantified using a commercially available ELISA kit (DRG International, USA) following manufacturer protocols.

Internal and external quality control procedures were strictly followed to ensure reliability of results. Data were entered and analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables were expressed as mean ± standard deviation (SD), while categorical variables were presented as frequencies and percentages. Independent sample t-tests were applied for comparing maternal and cord blood parameters. Correlations between maternal and fetal indices (hemoglobin, ferritin, and erythropoietin) were assessed using Pearson's correlation coefficient (r). A p-value of <0.05 was considered statistically significant.

RESULTS

The study included 82 mothers with a mean age of 27.4 years (±4.6). The average gestational age at delivery was 38.1 weeks, indicating that most deliveries were at term. Primigravida women comprised 41.5% of the sample, while the majority were multigravida. The mean maternal BMI was 24.8 kg/m² (±3.5), falling within the normal to slightly overweight range. A significant proportion (68.3%) reported regular iron supplementation during pregnancy, and this variable was found to be significantly associated with maternal hematological outcomes (p=0.04). Vaginal delivery was the predominant mode of childbirth (59.8%), with no significant association observed with iron status parameters (p=0.28).

Table 1: Demographic Characteristics of Mothers (n=82)

Variable	Frequency (%) or Mean ± SD	p-value
Maternal Age (years)	27.4 ± 4.6	–
Gestational Age (weeks)	38.1 ± 1.2	–
Parity (Primigravida)	34 (41.5%)	0.12
BMI (kg/m²)	24.8 ± 3.5	–
Iron Supplementation	56 (68.3%)	0.04*
Mode of Delivery (NVD)	49 (59.8%)	0.28

*Significant at $p < 0.05$

Maternal hematological assessment revealed that the mean hemoglobin level was 10.8 g/dL (±1.4), which was significantly lower than the reference range (p=0.03), highlighting the burden of anemia in this population. Hematocrit levels were also marginally below the normal reference values, although this difference did not reach statistical significance (p=0.06). Serum ferritin levels averaged 28.5 ng/mL (±10.2), again showing a significant reduction compared with reference standards (p=0.04). Other indices, including serum iron, TIBC, and transferrin saturation, remained within expected ranges and showed no significant variation. Maternal erythropoietin levels were slightly elevated (21.8 mIU/mL), suggestive of a compensatory response to anemia, but this did not achieve statistical significance (p=0.07).

Table 2: Maternal Hematological and Biochemical Parameters

Parameter	Mean ± SD	Reference Range	p-value
Hemoglobin (g/dL)	10.8 ± 1.4	11.5–14.5	0.03*
Hematocrit (%)	32.6 ± 3.9	35–45	0.06
Serum Ferritin (ng/mL)	28.5 ± 10.2	30–150	0.04*
Serum Iron (µg/dL)	72.1 ± 15.8	60–170	0.18
TIBC (µg/dL)	365 ± 42.3	250–400	0.21
Transferrin Saturation (%)	21.3 ± 5.2	20–50	0.31
Maternal EPO (mIU/mL)	21.8 ± 6.4	5–25	0.07

*Significant at $p < 0.05$

Analysis of cord blood demonstrated that neonates had a mean hemoglobin concentration of 14.9 g/dL (±1.8), which was significantly higher than maternal levels (p=0.02), reflecting the physiological advantage of fetal erythropoiesis. Cord ferritin concentrations (105.7 ng/mL ±28.9) were markedly higher than maternal stores and showed a significant difference when compared to expected maternal reference ranges (p=0.03). Hematocrit values (45.2% ±4.6) and serum iron levels (121.3 µg/dL ±26.7) were within normal physiological ranges for neonates, and these differences were not statistically significant. Cord blood erythropoietin levels were within the normal range (18.9 mIU/mL ±5.1), with no significant variation observed (p=0.15).

Table 3: Cord Blood Hematological and Biochemical Parameters

Parameter	Mean ± SD	Reference Range	p-value
Hemoglobin (g/dL)	14.9 ± 1.8	13.5–16.5	0.02*
Hematocrit (%)	45.2 ± 4.6	42–52	0.09
Cord Ferritin (ng/mL)	105.7 ± 28.9	80–200	0.03*
Cord Serum Iron (µg/dL)	121.3 ± 26.7	100–180	0.11
Cord EPO (mIU/mL)	18.9 ± 5.1	5–25	0.15

*Significant at $p < 0.05$

Correlation analysis revealed strong and significant associations between maternal and neonatal hematological indices. Maternal hemoglobin levels demonstrated a moderate positive correlation with cord hemoglobin (r=0.46, p=0.001), indicating that maternal anemia directly influences neonatal oxygen-carrying capacity. Similarly, maternal ferritin showed a significant positive correlation with cord ferritin (r=0.41, p=0.002), confirming the dependence of fetal iron stores on maternal iron status. Maternal and cord erythropoietin levels were also positively correlated (r=0.29, p=0.03), though the association was weaker. The correlation between maternal hemoglobin and cord ferritin was not statistically significant (r=0.21, p=0.07), suggesting that while hemoglobin levels reflect anemia, ferritin levels provide a more accurate representation of iron reserves.

Table 4: Correlation Between Maternal and Cord Blood Parameters

Maternal Parameter	Fetal Parameter	Correlation (r)	p-value
Maternal Hb vs Cord Hb	r = 0.46	0.001*	
Maternal Ferritin vs Cord Ferritin	r = 0.41	0.002*	
Maternal EPO vs Cord EPO	r = 0.29	0.03*	
Maternal Hb vs Cord Ferritin	r = 0.21	0.07	

*Significant at $p < 0.05$

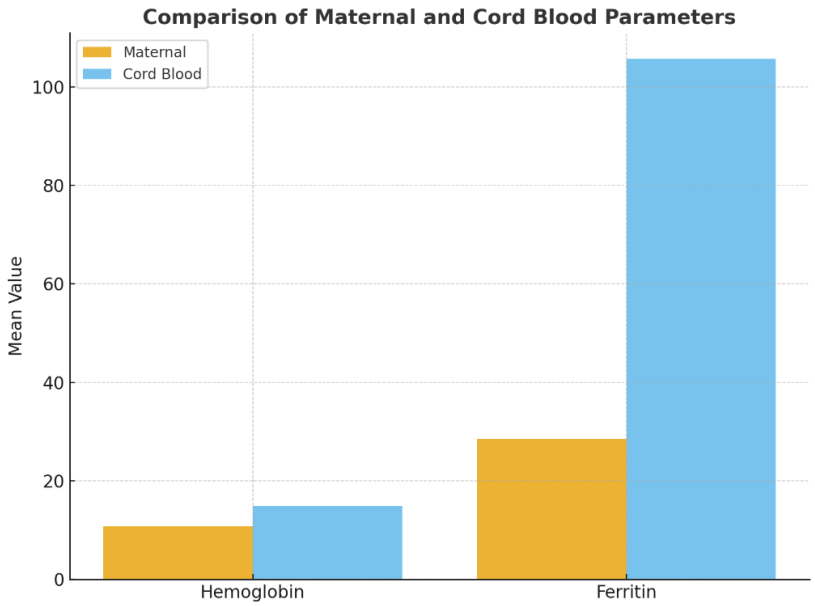

Figure 1: bar graph comparing maternal vs. cord blood hemoglobin and ferritin levels. It highlights that cord blood values are significantly higher than maternal values, reflecting fetal adaptive mechanisms and dependence on maternal iron status.

DISCUSSION

This study evaluated the relationship between maternal iron status and fetal hematological indices, focusing on hemoglobin, ferritin, and erythropoietin levels in maternal and cord blood. The findings demonstrated that maternal anemia was common, with reduced hemoglobin and ferritin levels compared to reference standards. Importantly, cord blood values for hemoglobin and ferritin were significantly higher than maternal levels, reflecting fetal compensatory mechanisms. Correlation analysis revealed positive and significant associations between maternal and cord blood hemoglobin, ferritin, and erythropoietin, underscoring the dependence of neonatal iron stores on maternal status.

Our results are consistent with previous studies conducted in South Asia and other low- and middle-income countries where maternal anemia remains highly prevalent. studies reported that maternal anemia was strongly associated with lower cord blood hemoglobin and ferritin concentrations, suggesting direct maternal-fetal iron transfer. Similarly, studies found that neonates born to iron-deficient mothers exhibited significantly reduced iron reserves, which may predispose them to early-life anemia. The positive correlation between maternal and cord ferritin observed in our study aligns with the findings of study, who emphasized that fetal ferritin levels serve as a sensitive biomarker of maternal iron status (13-15).

Interestingly, despite lower maternal hemoglobin levels in our cohort, neonates maintained hemoglobin within normal physiological ranges. This can be explained by the preferential transfer of iron across the placenta, which prioritizes fetal requirements even in the presence of maternal deficiency . Similar findings were documented by studies observed that placental adaptations, including upregulation of transferrin receptors, play a protective role in sustaining neonatal

hemoglobin. However, maternal depletion of iron stores in this process increases the risk of postpartum anemia, emphasizing the need for effective supplementation strategies (16, 17).

The relationship between maternal and cord erythropoietin levels in our study was weaker compared with hemoglobin and ferritin. This finding is supported by studies noted that erythropoietin levels are influenced not only by maternal anemia but also by fetal hypoxia and placental function. Cord erythropoietin, therefore, may reflect a complex interplay of oxygen availability and erythropoietic drive rather than maternal iron status alone (18).

Globally, maternal anemia is recognized as a major public health challenge. A meta-analysis highlighted that nearly 40% of pregnant women in developing countries remain anemic, with iron deficiency as the leading cause. The World Health Organization (WHO, 2024) continues to recommend daily supplementation with iron and folic acid to prevent maternal anemia and improve neonatal iron stores. In line with our findings, consistent antenatal supplementation was associated with significantly better maternal hematological outcomes in this study, further reinforcing international guidelines (19).

The implications of these results are clinically relevant. Neonates born with lower ferritin levels are at increased risk of iron deficiency during infancy, which has been linked to impaired cognitive and psychomotor development. Early identification of mothers with iron deficiency and timely interventions can therefore reduce the risk of long-term neurodevelopmental consequences in offspring. Moreover, incorporating maternal ferritin screening into routine antenatal care, particularly in high-risk populations, may provide a more reliable assessment of iron status than hemoglobin alone (20).

The strengths of this study include its prospective design, simultaneous evaluation of maternal and cord blood samples, and use of standardized laboratory methods. However, certain limitations should be acknowledged. The sample size, though adequate for detecting moderate correlations, was relatively modest, limiting subgroup analysis by parity or nutritional status. Additionally, dietary intake and compliance with iron supplementation were self-reported, introducing potential recall bias. Finally, the study was conducted in a single center, which may affect the generalizability of the findings.

CONCLUSION

This study demonstrates a clear and significant correlation between maternal and cord blood hematological parameters. Maternal anemia and low ferritin were strongly associated with reduced neonatal iron stores, despite cord blood values being relatively higher than maternal levels due to placental adaptations. These findings highlight the critical importance of optimizing maternal iron status during pregnancy through effective supplementation and monitoring. Screening maternal ferritin, in addition to hemoglobin, may provide a more comprehensive assessment of iron deficiency risk. Strengthening antenatal care programs with emphasis on iron supplementation can contribute to better maternal health and improved neonatal outcomes.

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