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Original Article

Association of Maternal Hemoglobin Concentration With Neonatal Outcomes in Deliveries: A Prospective Cohort Study

Leyla Sahebi; Ph.D.[1], Hossein Dalili; M.D.[1], Mazyar Babagoli; M.D.[1,2], Atefeh Sabbagh; M.D.[1]

1 Maternal-Fetal and Neonatal Research Center, Family Health Research Institute, Imam Khomeini Hospital Complex, Tehran University of Medical Sciences, Tehran, Iran
2 Center for Orthopedic Trans-Disciplinary Applied Research, Tehran University of Medical Sciences, Tehran, Iran

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Abstract

Objective: Maternal hemoglobin concentration during pregnancy is a key indicator of placental–fetal oxygen delivery and may influence neonatal outcomes. Despite existing evidence, prospective cohort data in the Iranian population remain limited. This study aimed to investigate the association between maternal hemoglobin concentration and neonatal outcomes while controlling for potential confounding factors.

Materials and methods: This prospective cohort study was conducted over a six-month period. A total of 263 eligible mother–neonate pairs were included in the analysis. Maternal hemoglobin concentration was measured at 28 weeks of gestation, and participants were categorized into two groups: Hb < 11 g/dL (anemia) and Hb ≥ 11 g/dL. Neonatal outcomes were investigated in two groups. Statistical analyses were performed using independent t-tests, chi-square tests, and univariate and multivariate linear and logistic regression models, adjusting for gestational age, mode of delivery, parity, maternal conditions, and iron supplementation.

Results: The incidence of RDS was calculated 56% (33 neonates) and 26% (48 neonates) in mothers with anemia and normal, respectively. Neonates born to mothers with Hb ≥ 11 g/dL had a significantly lower risk of RDS compared with those born to anemic mothers (adjusted OR = 0.64; $P < 0.01$). No significant association was observed between maternal anemia and either birth weight or birth length in multivariate analysis.

Conclusion: Adequate maternal hemoglobin concentration is associated with a reduced risk of neonatal RDS. Timely screening and appropriate management of maternal anemia may play an important role in improving neonatal respiratory outcomes.

Keywords: Maternal Hemoglobin; Anemia in Pregnancy; Neonatal Outcomes; Birth Weight; Respiratory Distress Syndrome

Introduction

Maternal and neonatal health is considered one of the fundamental indicators of health development in societies and directly reflects the quality of healthcare services, nutritional status, and access to prenatal care. Pregnancy is accompanied by extensive physiological adaptations aimed at providing optimal

Correspondence:
Dr. Atefeh Sabbagh
Email: atefesabagh0049@gmail.com

conditions for fetal growth and development, as well as preparing the maternal body for childbirth. These adaptations include increased blood volume, alterations in nutrient metabolism, and hematological adjustments, any disruption of which may lead to adverse outcomes for both the mother and the newborn. Among these factors, maternal hematological status particularly hemoglobin concentration plays a crucial role in maintaining adequate oxygen delivery to maternal and fetal tissues. Hemoglobin, as the primary oxygen-carrying molecule, is essential for ensuring sufficient oxygen transport to the placenta and the developing fetus. The placenta, which serves as the interface between maternal and fetal circulation, is highly sensitive to changes in maternal hemoglobin levels; abnormal reductions or elevations in hemoglobin concentration may impair placental function and subsequently result in unfavorable pregnancy outcomes (1, 2).

Anemia during pregnancy is the most common hematological disorder in this period and remains a major global public health concern. According to the World Health Organization, approximately 40% of pregnant women worldwide are affected by anemia, with the highest prevalence observed in low- and middle-income countries. Iron deficiency is the leading cause of anemia in pregnancy; however, deficiencies in folate and vitamin B12, chronic diseases, infections, and genetic disorders may also contribute to its development (3, 4). During pregnancy, maternal iron requirements increase substantially due to the expansion of maternal blood volume, fetal and placental growth, and the accumulation of iron stores for the neonatal period. If these increased demands are not adequately met through appropriate dietary intake or iron supplementation, a decline in hemoglobin concentration becomes inevitable. In addition, socioeconomic factors, maternal educational level, interpregnancy intervals, and the quality of prenatal care can directly or indirectly influence maternal hemoglobin status (5, 6).

Scientific evidence indicates that maternal anemia is associated with a wide range of adverse maternal and neonatal outcomes. From a maternal perspective, anemia may increase the risk of severe fatigue, reduced functional capacity, infections, postpartum hemorrhage, and even maternal mortality. From a neonatal standpoint, numerous studies have reported associations between maternal anemia and low birth weight, intrauterine growth restriction, low Apgar scores, increased risk of preterm birth, and a higher need for admission to neonatal intensive care units (7-10). The underlying mechanisms of these associations are not yet fully understood; however, reduced oxygen-carrying capacity of maternal blood, leading to chronic fetal hypoxia, is considered one of the most important explanatory pathways. Chronic hypoxia may impair cellular growth and tissue differentiation and adversely affect the development of vital fetal organs, particularly the lungs and the central nervous system. In addition, anemia-related placental dysfunction may reduce the transfer of essential nutrients to the fetus, resulting in inadequate fetal growth (7, 11).

Nevertheless, focusing solely on low hemoglobin concentrations may not provide a complete picture of this relationship. Some evidence suggests that elevated maternal hemoglobin levels may also be associated with adverse pregnancy outcomes. Abnormally high hemoglobin concentrations are often regarded as indicators of hemoconcentration and reduced plasma volume expansion, a condition that can decrease uteroplacental blood flow and impair the exchange of oxygen and nutrients (12, 13). In this context, several studies have reported a U-shaped relationship between maternal hemoglobin concentration and pregnancy outcomes, whereby both low and high hemoglobin levels are associated with an increased risk of adverse neonatal outcomes (6, 14). Despite the substantial body of research conducted in this field, study findings have not always been consistent. Variations in the timing of hemoglobin measurement (first, second, or third trimester), diagnostic criteria for anemia, study design, and population characteristics are among the factors that may contribute to heterogeneity in results (15). Furthermore, a considerable proportion of existing studies are cross-sectional or retrospective in nature, which imposes limitations on causal inference and adequate control of potential confounding factors.

Moreover, cultural, nutritional, and healthcare system differences may modify the pattern of association between maternal hemoglobin levels and neonatal outcomes across different populations (16, 17). Therefore, the generation of context-specific evidence through well-designed prospective studies appears essential for informing preventive strategies and effective interventions in prenatal care. Considering the high prevalence of anemia during pregnancy, the critical role of maternal

hemoglobin concentration in fetal health, the inconsistent findings of previous studies, and the paucity of prospective research focusing on term deliveries, the present study was designed and conducted to investigate the association between maternal hemoglobin concentration and neonatal outcomes in NICU. It is anticipated that the findings of this study will contribute to a more precise identification of optimal hemoglobin ranges during pregnancy, improved recognition of high-risk mothers, and enhancement of the quality of prenatal care and neonatal outcomes.

Materials and methods

This study was designed as a prospective cohort study conducted over a six-month period from April to September 2024 in the obstetric emergency department of Valiasr Hospital, affiliated with Tehran University of Medical Sciences, Tehran, Iran. The study population consisted of pregnant women admitted for delivery at this center and their newborns. All mothers and neonates were followed for up to 24 hours after birth to assess the neonatal outcomes of interest.

At the outset of the study, predefined inclusion and exclusion criteria were established. Inclusion criteria comprised provision of written informed consent, singleton pregnancy with a gestational age (GA) greater than 14 weeks, a maternal body mass index (BMI) < 35 kg/m², and absence of underlying medical conditions known to affect pregnancy outcomes based on medical records. Exclusion criteria included a history of congenital or acquired maternal anemia requiring specific therapeutic intervention, maternal polycythemia defined as a hemoglobin level > 15 g/dL, unwillingness to continue participation, and maternal or fetal death during the course of the study. Iron supplementation was routinely prescribed from the 16th week of gestation in accordance with standard prenatal care protocols and therefore could not be discontinued. However, initiation of iron supplementation before the 28th week of gestation was documented, and its potential effect was controlled as a confounding variable in the statistical analyses.

During the pilot phase, using a 2:1 allocation ratio, a total of 45 mothers were enrolled, including 15 women with hemoglobin levels < 11 g/dL and 30 women with normal hemoglobin levels. Based on the pilot results, the incidence of neonatal respiratory distress (RDS) syndrome was estimated to be 0.143 in the normal hemoglobin group and 0.418 in the anemic group. The difference in proportions was considered the expected effect size for sample size calculation. Assuming a significance level of 0.05 and a statistical power of 80%, the final sample size was determined to be 83 mothers in the Hb < 11 g/dL group and 166 mothers in the Hb ≥ 11 g/dL group, providing sufficient statistical power for multivariable analyses.

Following approval from the Ethics Committee of Tehran University of Medical Sciences and receipt of the required permissions, written informed consent was obtained from all participants. Venous blood samples were collected from the included mothers to measure hemoglobin concentration, and the results were recorded in their medical records. Based on hemoglobin levels, participants were classified into an exposed group (Hb < 11 g/dL) and an unexposed group (Hb 11–15 g/dL). At the time of admission for delivery, study variables including maternal hemoglobin concentration at delivery and neonatal outcomes were collected. Neonatal outcomes included preterm birth (GA < 37 weeks), RDS diagnosed based on clinical signs, chest radiographic findings, and the need for supplemental oxygen within the first 24 hours after birth, as well as birth weight, height

Checklist data were obtained through direct interviews with the mothers, review of maternal and neonatal medical records, and recording of clinical data by the researcher. To enhance data accuracy and minimize recording errors, all checklists were completed by a single trained researcher. Content validity of the instrument was confirmed by experts in obstetrics and gynecology and neonatology, and its reliability was verified during the pilot phase through assessment of data consistency.

Statistical Analysis: After coding, data were entered into SPSS software version 24 (IBM Corp., Armonk, NY, USA). Continuous variables were summarized as means and standard deviations, while categorical variables were reported as frequencies and percentages. Independent-samples *t* tests were used to compare means between groups, and chi-square tests were applied to compare categorical variables. To control for the effects of confounding variables, multivariate linear regression (for outcomes of GA, birth and height weight), and logistic regression (for outcome of RDS analyses were performed. A two-sided *p* value of less than 0.05 was considered statistically significant.

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Ethics Committee of Tehran University of Medical Sciences (IR.TUMS.IKHC.REC.1403.17). Participation in the study was voluntary, participant information was kept confidential, and study results were reported anonymously. The study received no external financial support, and no conflicts of interest were declared.

Results

The incidence of RDS was calculated 57% (33 neonates) and 26% (48 neonates) in mothers with anemia and normal, respectively. The results of this study showed that maternal hemoglobin level (≥ 11 vs. < 11 g/dL) was not significantly associated with most confounding variables included demographic and clinical variables, including gestational diabetes (GDM), thyroid dysfunction, iron supplementation, history of anemia prior to pregnancy, hypertension, cesarian section, history of abortion, and nulliparity ($P > 0.05$). The only variable that demonstrated a statistically significant association with maternal hemoglobin level was the presence of comorbidities (X^2=4.38, P = 0.036). The incidence of neonatal RDS was higher among mothers with hemoglobin levels < 11 g/dL; and this difference was statistically significant (X^2=18.32, P = 0.033) (Table 1).

No statistically significant differences were observed between maternal hemoglobin levels and quantified demographic variables, including maternal age, height, weight, ferritin level, and mean corpuscular volume (MCV) ($P > 0.05$). In addition, fertility-related indicators such as gravidity, parity, and history of abortion did not differ significantly between the two hemoglobin groups. GA and first-minute Apgar score (Apgar) were the variables that were significantly lower among mothers with hemoglobin levels < 11 g/dL (P = 0.002 and P =0.035, respectively). Other neonatal parameters, including birth weight, birth height, and head circumference at birth, showed no statistically significant differences between the two groups ($P > 0.05$) (Table 2).

Table 1: Demographic characteristics (frequency [%]) of mothers and neonates (categorical variables) according to maternal hemoglobin level (< 11 g/dL vs. ≥ 11 g/dL)

Variables	Subgroup	Hemoglobin ≥ 11 g/dL	Hemoglobin < 11 g/dL	X^2 (P-Value)
GDM	No	118 (64.1)	66 (35.9)	1.66 (0.198)
	Yes	46(73)	17 (27)	
Maternal hyperthyroidism	No	163(66.5)	82(33.5)	1.972 (0.337)
	Yes	0 (0 %)	1 (100)	
Maternal hypothyroidism	No	112 (63.3)	65 (36.7)	2.51 (0.113)
	Yes	51 (73.9)	18 (26.1)	
Maternal comorbidity	No	64 (59.3)	44 (40.7)	4.38 (0.036)
	Yes	100 (71.9)	39 (28.1)	
Maternal hypertension	No	141 (66.5)	71 (33.5)	0.043 (0.836)
	Yes	22 (64.7)	12 (35.3)	
Iron supplement	No	13 (86.7)	2 (13.3)	2.91 (0.088)
	Yes	152 (65.2)	81 (34.8)	
Pre-pregnancy anemia	No	151 (65.4)	80 (34.6)	2.05 (0.152)
	Yes	14 (82.4)	3 (17.6)	
Cesarean section	No	94 (64.4)	52 (35.6)	0.063 (0.80)
	Yes	47 (62.7)	28 (37.3)	
History of miscarriage	No	135 (64.3)	75 (35.7)	0.285 (0.593)
	Yes	5(55.6)	4 (44.4)	
Nulliparity	No	142(64)	80 (36)	0.067 (0.682)
	Yes	1 (50)	1 (50)	
RDS	No	134 (84.3)	25 (15.7)	18.32(0.033)
	Yes	48 (59.3)	33 (40.7)	
Gender	Female	80 (48.2)	86 (51.8)	1.35(0.245)
	Male	44 (53.7)	38(46.3)	

Table 2: Demographic characteristics (mean ± standard deviation) of mothers and neonates (continuous variables) according to maternal hemoglobin level (< 11 g/dL vs. ≥ 11 g/dL)

Variables	Hb > 11; mean (SD)	Hb < 11; mean (SD)	t(P-Value)
Maternal age (yr)	30.43 (6.83)	31.64 (6.162)	-1.35 (0.177)
Maternal height (cm)	161.57 (5.54)	162.51 (5.35)	-1.26 (0.209)
Maternal weight (Kg)	78.37(15.66)	81.06(15.87)	-1.22 (0.225)
Maternal ferritin (ng/ml)	78.52 (47.28)	73.55 (41.20)	0.175 (0.865)
Maternal MCV (fL)	87.73 (6.72)	87.77(7.2)	-0.045 (0.964)
GA (weeks)	37.43(2.07)	36.37(2.71)	3.21 (0.002)
Birth weight (g)	3082.95(645.33)	767.72(86.37)	1.37 (0.172)
Apgar	7.84 (1.50)	7.35(2.06)	2.12 (0.035)
Birth height (cm)	49.28(3.33)	48.53(3.99)	0.124 (0.749)
Head circumference (cm)	34.30(1.97)	34.06(2.2)	0.830 (0.408)
Gravidity*	2 2)	3 (3)	-0.915 (0.360)**
Parity*	1 (1)	1 (3)	-0.977(0.329)**
Abortion*	0 0)	0 (0)	-0.957 (0.339)**

*Given as median and inter-quartile range, **Man-Whitney test

Effect of maternal hemoglobin on birth weight

Univariate Linear regression analysis showed that neonatal birth weight was significantly influenced by maternal hemoglobin level, GA and the Apgar ($P < 0.05$). Other maternal and neonatal variables including ferritin level, maternal age and weight, underlying medical conditions, iron supplementation during pregnancy, cesarian section, and neonatal gender were not significantly associated with birth weight. After adjustment for the effects of other variables, GA remained the most important factor associated with neonatal birth weight ($P < 0.001$). In addition, maternal gravidity showed a statistically significant association with neonatal birth weight ($P = 0.025$). Other variables, including maternal hemoglobin level, maternal weight and height, thyroid disorders, hypertension, and the Apgar, did not demonstrate statistically significant associations with birth weight in the adjusted model (Tables 3 and 4).

Effect of maternal hemoglobin on birth height

Univariate Linear regression analysis no showed relationship between neonatal birth height and maternal hemoglobin level. GA and the Apgar were significantly associated with neonatal birth height ($P < 0.001$) in univariate linear regression.

Table 3: Results of linear regression for the association between independent variables and the dependent variable of birth weight

Variables	β	Standard Error of β	P-Value
Maternal hemoglobin level	52.171	25.269	0.040
Maternal ferritin level	-1.745	5.081	0.738
Maternal age	-3.494	6.482	0.590
Maternal weight at 28w of GA	2.942	2.803	0.295
Maternal height	-17.094	7.870	0.031
GDM	13.222	95.441	0.890
Maternal hyperthyroidism	-545.264	476.527	0.254
Maternal hypothyroidism	-180.593	95.276	0.059
Maternal hypertension	-163.405	116.759	0.163
Iron supplement	-87.656	162.082	0.589
Iron supplement during pregnancy	-31.497	90.680	0.729
Pre-pregnancy anemia	-101.148	175.505	0.565
Cesarian section	158.568	97.607	0.106
Gravidity	59.476	27.834	0.034
GA	203.393	12.803	< 0.001
Gender	-85.937	85.077	0.313
Apgar	172.876	22.350	< 0.001

Table 4: Multivariate regression results to examine the effect of confounding variables on neonatal birth weight

Variables	β	Standard Error of β	P-Value
Maternal hemoglobin level	-5.774	19.827	0.771
GA	191.165	16.878	< 0.001
Maternal weight at 28w of GA	6.207	2.429	0.193
Maternal height	0.717	7.106	0.920
Maternal hyperthyroidism	236.307	442.595	0.596
Maternal hypothyroidism	-108.525	81.928	0.187
Maternal hypertension	-54.569	91.074	0.550
Gravidity	50.720	22.486	0.025
Apgar	29.689	22.708	0.193

Other maternal variables including hemoglobin level, ferritin level, mean corpuscular volume (MCV), maternal age, height, and weight, underlying medical conditions, iron supplement, cesarian section, and gravidity were not significantly associated with birth height. However, after adjusting for potential confounders, maternal hypothyroidism was significantly associated with a reduction in neonatal birth height (P = 0.047). Other variables, such as maternal hemoglobin level, GA, maternal height, ferritin level, MCV, maternal hypertension, and the Apgar, showed no statistically significant association with neonatal birth height (Tables 5 and 6).

Effect of maternal hemoglobin on RDS

Univariate logistic regression analysis demonstrated that maternal hemoglobin levels < 11 g/dL significantly increased the risk of neonatal RDS (P < 0.001). Cesarean delivery was also identified as an independent risk factor associated with higher risk of RDS (P = 0.032). In contrast, higher gestational age had a strong and statistically significant protective effect against the occurrence of RDS (P <0.001). Moreover, maternal height and the neonatal Apgar showed significant inverse associations with the development of RDS (P = 0.024, P < 0.001). Other maternal and neonatal variables did not demonstrate statistically significant associations with RDS (Table 7).

Multivariate logistic regression analysis showed that maternal hemoglobin levels < 11 g/dL were significantly associated with an increased risk of neonatal RDS (P =0.003).

Table 5: Results of linear regression for the association between independent variables and the neonatal height

Variables	β	Standard Error of β	P-Value
Maternal hemoglobin level	0.212	0.129	0.102
Maternal ferritin level	0.027	0.021	0.225
Maternal MCV	-0.041	0.032	0.203
Maternal age	-0.045	0.033	0.170
Maternal weight at 28w of GA	-0.003	0.015	0.831
Maternal height	-0.069	0.041	0.092
GDM	-0.259	0.495	0.602
Maternal hyperthyroidism	-3.943	2.516	0.118
Maternal hypothyroidism	-0.639	0.495	0.197
Mother's hypertension	-0.972	0.596	0.104
Ironsupplement	-1.084	0.847	0.201
Iron supplement during pregnancy	0.041	0.458	0.928
Pre-pregnancy anemia	-0.003	0.894	0.997
Cesarian section	0.400	0.495	0.421
Gravidity	0.134	0.144	0.351
GA	0.989	0.079	< 0.001
Gender	0.271	0.436	0.535
Apgar	0.752	0.124	< 0.001

Table 6: Results of multivariate regression for the dependent variable of neonatal birth height

Variables	β	Standard Error of β	P-Value
Maternal hemoglobin level	3.207	0.269	0.053
GA	-0.946	0.096	0.064
Maternal height	0.182	0.056	0.190
Maternal hypothyroidism	-10.545	0.773	0.047
Maternal hypertension	-7.421	0.645	0.055
Maternal ferritin level	0.058	0.007	0.080
Maternal MCV	-1.059	0.097	0.058
GA	-2.478	0.238	0.061
Apgar	0.688	0.120	0.110

In addition, cesarean delivery was associated with a statistically significant increase in the odds of neonatal RDS (P =0.021). In contrast, higher GA and a higher neonatal Apgar score demonstrated significant protective effects, reducing the risk of developing this syndrome (P =0.013, P =0.011 respectively). Other maternal variables including maternal age, height, highpertension, MCV, and iron supplementation during pregnancy did not show statistically significant associations with neonatal RDS (Table 8).

Effect of maternal hemoglobin on GA

Univariate linear regression analysis showed that maternal hemoglobin level and maternal serum ferritin were positively and significantly associated with neonatal GA (P =0.001, P =0.001). In addition, the neonatal Apgar was significantly associated with GA (P <0.001). Other maternal and neonatal variables including maternal hypertension, MCV, maternal weight, GDM, maternal hyperthyroidism, iron supplementation during pregnancy, cesarean section, gravidity, and neonatal gender did not show statistically significant associations with neonatal GA (Table 9).

Multiple linear regression analysis showed that maternal hemoglobin level and the neonatal Apgar were positively and significantly associated with neonatal GA, such that increases in these variables were accompanied by higher GA at birth (P =0.013, P =0.001 respectively). In contrast, maternal age demonstrated a significant inverse association with neonatal GA, with increasing maternal age being associated with a reduction in GA at birth. Other maternal and neonatal variables including MCV, GDM, maternal hypertension, maternal height, and the presence of underlying comorbid conditions did not show statistically significant associations with neonatal GA (Table 10).

Table 7: Univriate logistic regression analysis of factors associated with neonatal RDS

Variables	OR/B	95% CI of OR (lower – upper)/ SE(B)	P value
Maternal hemoglobin level<11	3.69	1.99-6.82	< 0.001
Maternal MCV	0.05	0.026	0.050
Maternal Age	0.046	0.024	0.117
Maternal Weight at 28w of GA	0.05	0.01	0. 609
Maternal Height	0.069	0.003	0.024
GDM; Yes	0.923	0.483-1.77	0.809
Maternal hyperthyroidism*; Yes	-	-	-
Maternal hypothyroidism; Yes	1.326	0.708-2.483	0.379
Maternal hypertension; Yes	0.523	0.209-1.312	0.167
Maternal iron supplement; Yes	0.830	0.286-2.404	0.731
Maternal iron supplement during Pregnancy; Yes	0.593	0.310-1.135	0.119
Pre-pregnancy Anemia; Yes	1.275	0.436-3.729	0.657
Cesarean section; Yes	1.970	1.062-3.653	0.032
Gravidity	-0.066	0.103	0.406
GA	0.629	0.537-0.736	< 0.001
Neonate's Gender; males	1.064	0.600-1.887	0.831
Apgar	0.639	0.107	< 0.001

*Not valid for analysis

Table 8: Multivariate logistic regression analysis of factors associated with neonatal RDS

Variables	OR/B	95% CI of OR (lower – upper)/ SE(B)	P value
Maternal hemoglobin level<11	4.77	1.69-13.49	0.003
GA	-.306	0.113	0.013
Maternal age	0.024	0.041	0.934
Maternal Height	0.05	0.046	0.197
Maternal hypertension	0.591	0.153-2.284	0.445
Maternal MCV	1.014	0.939-1.095	0.716
Iron supplement during pregnancy	0.441	0.156-1.245	0.122
Cesarean Section; yes	2.992	1.176-7.612	0.021
Apgar	-0.436	0.145	0.011

Discussion

In recent decades, maternal anemia one of the most common disorders during pregnancy has been extensively investigated in relation to neonatal outcomes. However, systematic reviews of the literature indicate that the effects of maternal anemia on neonatal outcomes are not uniform and depend on the specific outcome assessed, as well as the severity, duration, and timing of anemia during pregnancy, in addition to underlying maternal and fetal conditions (13, 18, 19). Among these outcomes, birth weight, as a classical indicator of intrauterine growth, has received the greatest attention. Nevertheless, a substantial body of evidence suggests that the observed association between maternal hemoglobin levels and birth weight is often mediated, attenuated, or even nullified after adjustment for gestational age and the duration of fetal growth. Garcia et al. reported that although severe anemia may increase the risk of low birth weight, this association frequently loses statistical significance in cases of mild to moderate anemia after adjusting for gestational age and maternal nutritional status (20). Similarly, Belte et al. identified gestational age as the strongest predictor of birth weight and demonstrated that the contribution of maternal hemoglobin becomes limited and inconsistent once this factor is controlled for (21). Findings from studies conducted in resource-limited settings further support this pattern; for example, Rahmati et al. showed that the initial association between maternal anemia and birth weight was attenuated to a non-significant level after adjustment for variables such as gestational age, maternal body mass index (BMI), and antenatal care utilization (22). Within this framework, the results of the present study demonstrating no independent association between maternal anemia and birth weight are not only consistent with the existing literature but also align well with the prevailing body of evidence. These findings reinforce the notion that birth weight reflects the duration and quality of intrauterine growth rather than serving as a direct indicator of maternal hematologic status.

Table 9: Multivariate linear regression analysis of predictors of neonatal GA

Variables	B	Standard Error of β	P value
Maternal hemoglobin level	0.318	0.094	0.001
Maternal height	-0.109	0.030	0.001
Maternal hypothyroidism	-10.545	0.773	0.047
Maternal hypertension	-1.112	0.451	0.055
Maternal ferritin level	0.058	0.007	0.014
Materanl MCV	-0.035	0.024	0.148
Apgar	0.793	0.078	<0.001
Maternal weight	-0.003	-0.011	0.758
GDM	-0.503	0.396	0.194
Maternal hyperthyroidism	-1.033	2.418	0.670
Maternal Comorbidity	-0.653	0.330	0.043
Maternal Iron supplement	-0.677	0.711	0.342
Maternal iron supplement during pregnancy	-0.085	0.355	0.812
Cesarean section	-0.068	0.372	0.856
Gravidity	-0.066	0.108	0.540
Gender	0.293	0.329	0.374

Table 10: Multiple linear regression analysis of predictors of neonatal gestational age

Variables	B	Standard Error of β	P value
Maternal hemoglobin level	0.204	0.081	0.013
Apgar	0.696	0.082	0.001
Maternal MCV	-0.027	0.024	0.267
GDM	0.038	0.381	0.921
Maternal hypertension	-0.685	0.413	0.099
Maternal height	-0.046	0.026	0.080
Comorbidity; yes	-0.238	0.347	0.493
Maternal age	-0.063	0.022	0.005

With respect to neonatal birth length, the available evidence is more limited and heterogeneous compared with that for birth weight. Some studies have reported a weak association between maternal hemoglobin levels and fetal linear growth; however, in most cases, this association does not persist after adjustment for confounding factors, including maternal hormonal and metabolic status as well as genetic background (13, 23). In contrast, the role of maternal endocrine disorders particularly hypothyroidism has been consistently and repeatedly documented in the literature. Studies by Zhang et al. (24) and Smith et al. (25) have demonstrated that even subclinical hypothyroidism may be associated with impaired fetal skeletal development and reduced linear growth. The findings of the present study, which showed reduced birth length among neonates born to mothers with hypothyroidism, are fully consistent with these previous reports. At the same time, the lack of an independent association between maternal anemia and neonatal birth length observed in our study is in agreement with the majority of existing evidence. This pattern suggests that fetal linear growth is likely less sensitive to variations in oxygen delivery and more strongly influenced by hormonal and growth-regulatory factors. In our study, maternal hypothyroidism was significantly associated with a reduction in neonatal birth length but, other variables, such as maternal hemoglobin level, gestational age, maternal height, ferritin, MCV, maternal high blood pressure, and the first minute Apgar score, showed no statistically significant association with neonatal birth length.

Compared with anthropometric indicators, the strongest consensus in the scientific literature concerns functional neonatal outcomes, particularly neonatal RDS. Numerous studies have reported that reduced maternal hemoglobin levels are associated with an increased risk of RDS, even in situations where no significant differences in birth weight or birth length are observed between groups (26-28). In a study by Zhang et al., the effect of maternal anemia on the risk of RDS remained independent of birth weight, highlighting the high sensitivity of fetal lung development to intrauterine oxygen availability (29). The proposed underlying mechanisms for this association include chronic fetal hypoxia, delayed maturation of type II pneumocytes, reduced surfactant synthesis, and impaired pulmonary readiness for extrauterine respiration (30, 31). The findings of the present study demonstrating an increased risk of RDS among neonates born to anemic mothers, along with a protective effect of higher maternal hemoglobin levels are fully consistent with this conceptual framework and the existing empirical evidence, thereby reinforcing the position of the current study within the international body of literature.

Beyond maternal hematologic status, gestational age and mode of delivery have been repeatedly confirmed in the literature as key determinants of neonatal RDS. Studies by Belte et al. (21) and Veli et al. (31) have shown that cesarean delivery particularly in the absence of labor is associated with an increased risk of RDS, a phenomenon commonly attributed to delayed clearance of fetal lung fluid and reduced catecholamine release. The findings of the present study, demonstrating an increased risk of RDS following cesarean delivery and a protective effect of advancing gestational age, are fully consistent with this body of evidence. Collectively, these results suggest that the impact of maternal anemia on neonatal respiratory outcomes is likely amplified or attenuated through its interaction with pulmonary maturation and peripartum delivery conditions.

Overall, a critical comparison of the findings of the present study with the existing body of literature

indicates that maternal anemia exerts a more limited influence on structural indicators of neonatal growth, such as birth weight and birth height, while demonstrating a stronger, more consistent, and clinically meaningful association with vital functional outcomes, particularly neonatal RDS. The results of our study can be interpreted within the context of prior evidence and serve to reinforce it, underscoring the notion that an exclusive focus on birth weight may underestimate the true clinical significance of maternal anemia. In contrast, respiratory outcomes appear to represent more sensitive and relevant indicators for assessing the impact of maternal anemia during pregnancy.

One of the main strengths of the present study is its prospective design, which allowed for a robust assessment of the relationships between maternal characteristics and neonatal outcomes. The adequate sample size, along with the use of multivariable statistical models to simultaneously control for key confounding factors, enhanced the internal validity of the findings and improved their statistical reliability. Moreover, the simultaneous evaluation of both structural and functional neonatal outcomes with a particular emphasis on neonatal RDS as a sensitive and clinically relevant endpoint further strengthens the clinical and practical value of the results. Nevertheless, several limitations should be acknowledged. The lack of a comprehensive assessment of maternal nutritional and socioeconomic factors may have influenced the precise interpretation of the effects of hematologic indicators, particularly maternal hemoglobin levels. In addition, the absence of strict control over the timing of hemoglobin measurement across different trimesters of pregnancy may have introduced heterogeneity in estimating the true anemia status of the mothers. Accordingly, future studies are recommended to adopt a longitudinal monitoring approach to maternal hematologic parameters throughout pregnancy, accompanied by detailed documentation of nutritional status, supplement intake, and socioeconomic variables. Such an approach would enable a more accurate elucidation of causal relationships and enhance the generalizability of the findings.

Conclusion

This study demonstrates that maternal hemoglobin levels during pregnancy have differential associations with neonatal outcomes. After adjustment for key confounding factors, maternal hemoglobin was not independently associated with structural growth indicators at birth, including neonatal weight and length. These findings suggest that such anthropometric outcomes are more strongly influenced by broader intrauterine growth dynamics and gestational duration.

In contrast, maternal anemia (Hb < 11 g/dL) showed a significant independent association with neonatal RDS, highlighting the sensitivity of neonatal respiratory outcomes to impaired maternal oxygen-carrying capacity and intrauterine oxygen delivery. Additionally, maternal hemoglobin levels and the first-minute Apgar score were positively associated with gestational age, whereas certain maternal comorbidities, such as hypothyroidism, were linked to shorter gestational duration.Overall, these findings indicate that maternal anemia may exert limited influence on neonatal anthropometric measures but represents an important risk factor for functional neonatal outcomes, particularly respiratory morbidity. These results underscore the importance of early detection and appropriate management of maternal anemia during pregnancy to reduce adverse neonatal respiratory complications.

This article is derived from a subspecialty thesis conducted by Dr. Atefeh Sabbagh and approved by Tehran University of Medical Sciences. The study was carried out in accordance with established ethical standards and the principles of the Declaration of Helsinki, and received approval from the Institutional Review Board of Tehran University of Medical Sciences (Ethics Code: IR.TUMS.IKHC.REC.1403.179). The thesis was formally approved on 1403/04/27.

Conflict of Interests

Authors declare no conflict of interests.

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