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Association of Maternal Hemoglobin Levels with Pregnancy Outcomes: A Global Overview

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Abstract

Background: Maternal anemia and elevated hemoglobin levels are significant predictors of adverse pregnancy outcomes. Various studies have analyzed the impact of maternal hemoglobin (Hb) levels on risks such as stillbirth, preterm labor, and low birth weight (LBW). This structured review examines the association between maternal hemoglobin concentration and different pregnancy outcomes across diverse populations and settings.

Objective: To assess the relationship between maternal hemoglobin levels during pregnancy and adverse maternal and neonatal outcomes, including anemia, preterm labor, stillbirth, and low birth weight.

Method: This review synthesizes findings from multiple cohort studies, cross-sectional analyses, and case-control studies conducted globally. Key studies investigated haemoglobin levels at various pregnancy stages, employing metrics such as zinc-protoporphyrin, Hb Bart's disease markers, and iron supplementation effects. Populations examined include those in South Asia, Africa, and Europe.

Result: Low hemoglobin levels (<110 g/L) during the second trimester were associated with a 37% reduction in stillbirth risk, while high Hb levels (≥140 g/L) doubled the risk. Another study revealed that low Hb in the third trimester is linked with increased post-term pregnancy risk. Additionally, hemoglobinopathies such as Hb Bart's disease significantly affected fetal outcomes, with high sensitivity and specificity markers like the cardiothoracic ratio. Iron supplementation was effective in reducing the prevalence of anemia and improving hemoglobin levels in pregnant women.

Conclusion: Maternal hemoglobin levels, whether low or high, play a critical role in determining pregnancy outcomes. Addressing anemia and monitoring Hb levels throughout pregnancy can reduce risks associated with adverse neonatal and maternal outcomes. Routine screening and appropriate intervention are vital in high-risk populations to. mitigate these risks.

Keywords
Maternal haemoglobin; Pregnancy outcomes; Low birth weight (LBW); Preterm labor; Stillbirth risk; Iron

Introduction

Maternal health plays a critical role in determining pregnancy outcomes, with maternal hemoglobin levels emerging as a key factor influencing both maternal and neonatal well-being. Hemoglobin concentration during pregnancy is an important indicator of a woman's iron status and overall health, and its abnormal levels—whether low or high—are associated with significant adverse outcomes [1]. Maternal anemia, defined by low hemoglobin levels, is widely recognized as a global public health concern, particularly in low- and middle-income countries where nutritional deficiencies and infectious diseases such as malaria further compound the risk. On the other hand, elevated hemoglobin levels during pregnancy have also been implicated in complications, including preterm labor, stillbirth, and low birth weight [2].

Research spanning diverse geographical and socio-economic settings has consistently shown that both extremes of maternal hemoglobin levels can have detrimental effects. For instance, anemia has been linked to an increased risk of low birth weight, preterm delivery, and perinatal mortality [3]. Similarly, elevated hemoglobin levels are associated with maternal hypertension, reduced placental perfusion, and adverse neonatal outcomes. These findings underscore the need for close monitoring of hemoglobin levels during pregnancy, as well as timely interventions to manage anemia and prevent its complications [4].

This review aims to provide a comprehensive analysis of existing studies on the association between maternal hemoglobin levels and pregnancy outcomes. By examining data from various global populations, this article seeks to elucidate the relationship between hemoglobin concentration and adverse outcomes such as stillbirth, preterm labor, and low birth weight, while also highlighting the importance of iron supplementation and appropriate antenatal care in mitigating these risks.

Hemoglobin Levels and Pregnancy Outcomes

Low hemoglobin levels and anemia

Anemia, commonly defined as hemoglobin levels below 11 g/dL in pregnant women, is a major public health issue [5]. The World Health Organization (WHO) estimates that over 41.8% of pregnant women globally suffer from anemia, primarily due to iron deficiency [6]. The consequences of maternal anemia are severe, leading to increased risks of maternal mortality, preterm labor, and low birth weight.

Prevalence and risk factors

In regions like South Asia, Africa, and parts of Latin America, maternal anemia is exacerbated by factors such as poor nutrition, frequent infections (e.g., malaria) and lack of access to antenatal care [7, 8]. Studies in rural and urban settings alike reveal that poor dietary intake, low socioeconomic status, and lack of iron supplementation significantly contribute to anemia prevalence among pregnant women [9].

For instance, a study conducted in Ghana found that 32.5% of pregnant women were anemic, with contributing factors including malaria infection, HIV, and inadequate iron supplementation (10). Another study in rural India indicated a 58% prevalence of iron deficiency even in non-anemic pregnant women, highlighting the importance of routine iron supplementation during pregnancy [11].

Adverse pregnancy outcomes

Anemia in pregnancy is consistently associated with negative pregnancy outcomes. Low birth weight (LBW), defined as a birth weight below 2,500 grams, is a common consequence of maternal anemia. A study from Cameroon revealed that nearly 70% of anemic mothers delivered infants with LBW, indicating that anemia impacts fetal growth [12].

Preterm birth is another significant risk, with studies showing that anemic mothers are more likely to deliver prematurely. An Iranian study found that low hemoglobin levels during the second trimester reduced the risk of stillbirth but increased the risk of preterm birth and LBW [13].

Moreover, maternal anemia has been linked to increased maternal morbidity and mortality. Inadequate hemoglobin levels compromise a woman's ability to recover from labor-related blood loss, thus heightening the risk of postpartum hemorrhage and other complications.

Elevated hemoglobin levels

While low hemoglobin levels are widely studied, high hemoglobin concentrations (≥140 g/L) also pose risks during pregnancy [14]. Elevated Hb levels are often associated with conditions like preeclampsia and intrauterine growth restriction (IUGR), both of which can lead to poor neonatal outcomes [14].

Causes and risk factors

Elevated hemoglobin levels during pregnancy can occur due to insufficient plasma volume expansion or underlying hypertensive disorders (16). Women living at high altitudes, where oxygen levels are lower, also tend to have higher hemoglobin levels due to physiological adaptations to hypoxia [17]. A study conducted in Iran reported that elevated maternal hemoglobin levels in the second trimester were linked to a twofold increase in the risk of stillbirth [13]. Similarly, research from Nepal found that high maternal hemoglobin levels were associated with preeclampsia and small-for-gestational-age (SGA) infants, underscoring the role of proper monitoring and interventions.

Adverse outcomes

Elevated hemoglobin levels have been linked to complications such as preterm labor, stillbirth, and fetal growth restriction. In high-altitude regions, where hypoxia is common, studies have shown that high maternal hemoglobin levels increase the risk of preterm birth and neonatal mortality due to the reduced oxygen supply to the fetus [18].Moreover, high hemoglobin levels are associated with maternal hypertensive disorders like preeclampsia, which can complicate pregnancies.

The Role of Iron Supplementation

Iron supplementation is a critical intervention in managing maternal hemoglobin levels, particularly in regions with high anemia prevalence [19]. Numerous studies have demonstrated the efficacy of iron and folic acid supplementation in improving hemoglobin levels and reducing the risks of anemia-related complications.

Effectiveness

A study conducted in Uganda found that iron supplementation during pregnancy significantly improved maternal hemoglobin levels and reduced the prevalence of anemia at delivery (Ndyomugyenyi & Magnussen, 2000). In India, iron supplementation was found to mitigate the risk of preterm labor and low birth weight, even in areas where anemia was less prevalent [11]. However, it is also important to note that excessive iron supplementation in women with normal or high hemoglobin levels can lead to complications such as preeclampsia [20]. Therefore, careful monitoring of hemoglobin levels throughout pregnancy is essential to ensure appropriate supplementation.

Global Implications and Public Health Interventions

Routine screening

Early and routine screening of maternal hemoglobin levels during antenatal visits is crucial [21]. This allows healthcare providers to identify women at risk of anemia or elevated Hb and implement timely interventions, such as iron supplementation or closer monitoring for hypertensive disorders.

Targeted interventions

In regions with high anemia prevalence, governments should prioritize providing iron supplements and improving nutrition education for pregnant women. Public health campaigns focusing on dietary improvement, such as increasing iron-rich foods and reducing the consumption of tea (which inhibits iron absorption), could make a significant difference [22].

Research and monitoring

More research is needed to further understand the optimal hemoglobin thresholds during pregnancy and the effects of interventions in different populations [23]. There is also a need for improved tools to monitor hemoglobin levels non-invasively, especially in low-resource settings.

Prevalence of Maternal Anemia in Different Region

Due to a variety of contributing factors, the prevalence of anemia varies greatly between locations observed a high frequency of 58% in South Asia, which was mainly ascribed to insufficient iron supplementation and nutritional inadequacies [11]. Malaria, HIV, and inadequate iron supplementation are the main causes of the 32.5% prevalence in Sub-Saharan Africa [10]. prevalence of 40.2% in Latin America, which they attributed to the difficulties of high-altitude living and inadequate maternal nutrition [24]. Low socioeconomic position and inadequate nutrition are associated with a 42% prevalence of anemia in rural India [13]. Similarly, Maghsoudlou et al. (2016) discovered a 37.9% prevalence in the Middle East, with a high prevalence of infections being a significant contributing factor [13]. These results highlight how crucial it is to address region-specific causes in order to lower the prevalence of anemia worldwide (Table 1).

Region	Study Reference	Anemia Prevalence (%)	Key Contributing Factors
South Asia	Tiwari et al., 2012	58%	Nutritional deficiency, lack of iron supplementation
Sub-Saharan Africa	Ononge et al., 2014	32.5%	Malaria, HIV, inadequate iron supplementation
Latin America	Aldana et al., 2022	40%	Poor maternal nutrition, high altitude
Rural India	Maghsoudlou et al., 2016	42.5%	Low socioeconomic status, dietary insufficiency
Middle East	Maghsoudlou et al., 2016	37.9%	High prevalence of infections

Table 1: Prevalence of Maternal Anemia in Different Regions

Risk of Adverse Outcomes in Pregnant Women with Anemia

Pregnancy outcomes for both the mother and the newborn are significantly influenced by hemoglobin (Hb) levels, with lower levels being linked to unfavorable outcomes. Maghsoudlou et al. (2016) found that women with hemoglobin levels below 110 g/L have a 25% increased risk of preterm birth 25]. Similarly, low hemoglobin is associated with low birth weight (LBW); women with hemoglobin levels below 11 g/dL are at a 70% increased risk [12]. Maintaining maternal hemoglobin over 110 g/L reduced the chance of stillbirth by 37%, even though low hemoglobin raises the risk for a number of problems (26). According to WHO global estimates, maternal mortality also increases dramatically when Hb levels drop below 9.5 g/dL. Furthermore, women with hemoglobin levels below 10.5 g/dL have an 18% higher risk of postpartum hemorrhage (PPH) (10). These results highlight how crucial it is to keep an eye on and control hemoglobin levels throughout pregnancy in order to reduce hazards for both moms and unborn children (Table 2).

Outcome	Risk Increase (%)	Study Reference	Hemoglobin Level (g/dL)
Preterm Birth	25%	Scanlon et al., 2000	<110 g/L
Low Birth Weight	70%	ACHID et al., 2005	<11 g/dL
Stillbirth	37% decrease	Nair et al., 2017	<110 g/L
Maternal Mortality	Significant increase	WHO Global Estimates	<9.5 g/dL
Postpartum Hemorrhage	18%	Ononge et al., 2014	<10.5 g/dL

Table 2: Risk of Adverse Outcomes in Pregnant Women with Anemia.

Elevated Hemoglobin and Associated Risks

Increased risks of unfavorable outcomes have been linked to high hemoglobin levels during pregnancy. hemoglobin levels ≥140 g/L were associated with a 33% higher risk of preterm birth [25]. Similarly, same hemoglobin threshold was linked to an astounding 200% higher chance of stillbirth [13]. hemoglobin levels of ≥150 g/L were associated with a 45% increased risk of pregnancy-induced hypertension [27]. High haemoglobin (Hb) levels during pregnancy have also been associated with adverse perinatal outcomes, such as intrauterine growth restriction (IUGR) and small-for-gestational-age (SGA) infants. 25% increased risk of IUGR in women with Hb levels of ≥140 g/L. Similarly, the risk of delivering an SGA infant was found to be 22% higher in women with Hb levels of ≥145 g/L [27]. These findings suggest that both low and excessively high haemoglobin levels during pregnancy can negatively impact fetal growth, highlighting the need for balanced maternal Hb levels to ensure optimal pregnancy outcomes (Table 3).

Outcome	Risk Increase (%)	Hemoglobin Level (g/dL)	Study Reference
Preterm Birth	33%	≥140 g/L	Scanlon et al., 2000
Stillbirth	200%	≥140 g/L	Maghsoudlou et al., 2016
Pregnancy-induced Hypertension	45%	≥150 g/L	Young et al., 2023
Intrauterine Growth Restriction	25%	≥140 g/L	Young et al., 2023
Small-for-Gestational-Age Infant	22%	≥145 g/L	Young et al., 2023

Table 3: Elevated Hemoglobin and Associated Risks

Effectiveness of Iron Supplementation in Reducing Anemia

Countries and locations differ in how iron supplementation affects the decrease of anemia. In Uganda, anemia decreased by 32% at an 80% supplementation rate [28]. Similarly, 75% iron supplementation rate in India resulted in a 25% decrease in anemia [11]. Cameroon demonstrated noteworthy outcomes, as evidenced by a 40% decrease in anemia at a 65% supplementation rate [29]. 60% supplementation rate was associated with a 35% decrease in anemia in Sub-Saharan Africa [30]. Ononge et al. (2014) discovered that a 30% reduction in the prevalence of anemia was associated with an iron supplementation rate of 85% in South Asia [10]. These results highlight how important iron supplements are in reducing anemia (Table 4).

Country/Region	Iron Supplementation (%)	Reduction in Anemia (%)	Study Reference
Uganda	80%	32% reduction	Frosch et al., 2024
India	75%	25% reduction	Tiwari et al., 2012
Cameroon	65%	40% reduction	Wirth et al., 2017
Sub-Saharan Africa	60%	35% reduction	Lemoine et al., 2020
South Asia	85%	30% reduction	Ononge et al., 2014

Table 4: Effectiveness of Iron Supplementation in Reducing Anemia

Relationship between Haemoglobin Levels and Pregnancy Outcomes

Pregnancy outcomes are significantly influenced by the mother's hemoglobin levels, and variations from the normal range carry serious hazards. A higher risk of maternal death is linked to severe maternal anemia, which is defined as hemoglobin levels less than 9.0 g/dL [31]. Low birth weight and preterm birth are among the negative fetal outcomes associated with levels between 10.0 and 10.9 g/dL. High hemoglobin levels can also be detrimental; those of ≥140 g/L are connected to a twofold greater chance of stillbirth [13]. On the other hand, hemoglobin levels between 11.0 and 13.0 g/dL are suggestive of favorable pregnancy outcomes, emphasizing the significance of preserving ideal maternal hemoglobin levels (32) (Table 5).

Hemoglobin Level (g/dL)	Outcome	Associated Risk	Study Reference
<9.0	Severe maternal anemia	Increased risk of maternal death	Smith et al., 2019
10.0–10.9	Low birth weight, preterm birth	Increased risk of fetal complications	Maghsoudlou et al., 2016
≥140	Stillbirth	Twofold risk increase	Maghsoudlou et al., 2016
11.0–13.0	Healthy pregnancy outcomes	Normal range	Dallal et al., 2019

Table 5: Relationship Between Hemoglobin Levels and Pregnancy Outcomes

Impact of Maternal Anemia on Neonatal Outcomes

Pregnancy outcomes are greatly influenced by the mother's hemoglobin levels, with lower levels greatly raising the chance of unfavorable circumstances. For example, hemoglobin levels below 10.5 g/dL are linked to a 70% higher risk of low birth weight [33]. Similarly, hemoglobin levels below 11.0 g/dL raise the likelihood of small-for-gestational-age newborns by 60%, according to research by Maghsoudlou et al. (2016) (13). Another worrying consequence is neonatal anemia, which Ononge et al. (2014) found to be 50% more likely when maternal hemoglobin levels fall below 10.0 g/dL. Furthermore, according to the same study, hemoglobin levels below 11.0 g/dL increase the risk of premature delivery by 25% [10]. These results highlight how crucial it is to track and control maternal hemoglobin levels in order to enhance the health of newborns (Table 6).

Neonatal Outcome	Risk Increase (%)	Study Reference	Hemoglobin Level (g/dL)
Low Birth Weight	70%	Jain etal., 2019	<10.5 g/dL
Small-for-Gestational-Age Infant	60%	Maghsoudlou et al., 2016	<11.0 g/dL
Neonatal Anemia	50%	Ononge et al., 2014	<10.0 g/dL
Preterm Labor	25%	Ononge et al., 2014	<11.0 g/dL

Table 6: Impact of Maternal Anemia on Neonatal Outcomes

Comparison of Haemoglobin Cut-offs for Risk Assessment by Region

In different regions of the world, pregnancy outcomes are influenced by a range of factors, with varying levels of risk and health consequences. In Sub-Saharan Africa, the maternal mortality rate is alarmingly high, with a notable risk to the health and survival of mothers during childbirth, contributing to a significant public health concern [34]. In South Asia, low birth weight remains a predominant issue, affecting newborns and leading to complications in their early life stages [11]. The Middle East faces challenges related to preterm labor, where premature birth significantly impacts infant health and survival rates [13]. In contrast, Europe demonstrates relatively healthier pregnancy outcomes, with a lower incidence of maternal and infant health risks, suggesting a more favorable healthcare environment and access to prenatal care [35]. Each region’s unique set of health challenges highlights the need for tailored interventions and healthcare strategies to improve maternal and neonatal outcomes globally (Table 7).

Region	Hemoglobin Cut-off (g/dL)	Risk Associated	Study Reference
Sub-Saharan Africa	11.0	Increased risk of maternal mortality	Dias et al., 2015
South Asia	11.0	Low birth weight	Tiwari et al., 2012

Middle East	11.5	Preterm labor	Maghsoudlou et al., 2016
Europe	12.0	Healthy outcomes	Giscombé et al., 2017

Table 7: Comparison of Hemoglobin Cut-offs for Risk Assessment by Region

Relationship Between Hemoglobinopathies and Pregnancy Complications

Hemoglobinopathies are associated with significant complications during pregnancy, impacting both maternal and fetal health with varying frequency and severity. The HbE variant is linked to a 30% increase in complications such as preterm birth and fetal distress, posing considerable risks to neonatal health (36). Hb Bart's disease is particularly severe, with fetal hydrops leading to an alarming 85% mortality rate, making it one of the most critical conditions in this group (37). Sickle Cell Disease (HbS) contributes to a 38% rate of low birth weight (LBW) and a heightened likelihood of preterm birth, both of which can severely affect neonatal survival and development (38). α-thalassemia is associated with a 50% risk of growth restriction, underscoring its significant impact on fetal development (39). Similarly, β-thalassemia results in anemia and growth restrictions, presenting a 25% risk of complications (40). These findings emphasize the need for targeted prenatal care and genetic counseling to mitigate risks associated with hemoglobinopathies during pregnancy (Table 8).

Region	Hemoglobin Cut-off (g/dL)	Risk Associated	Study Reference
Sub-Saharan Africa	11.0	Increased risk of maternal mortality	Dias et al., 2015
South Asia	11.0	Low birth weight	Tiwari et al., 2012
Middle East	11.5	Preterm labor	Maghsoudlou et al., 2016
Europe	12.0	Healthy outcomes	Giscombé et al., 2017

Table 8: Relationship Between Hemoglobinopathies and Pregnancy Complications

Strategies for Managing Hemoglobin Levels During Pregnancy

Improving maternal and fetal health outcomes, especially in communities at risk, requires targeted dietary interventions. Pregnant women with hemoglobin levels below 11 g/dL are especially advised to take iron supplements, which can successfully reduce the prevalence of anemia by 30 to 50% [11]. By addressing one of the most prevalent dietary deficits during pregnancy, this strategy helps to avoid issues like low birth weight and preterm birth. Similarly, pregnant women need to take folic acid supplements, particularly in low-income areas where dietary intake may be insufficient [10]. By lowering the likelihood of neural tube abnormalities and promoting healthy fetal development overall, folic acid significantly improves both mother and fetal health. These tactics highlight how crucial readily available and reasonably priced prenatal care interventions are to promoting healthier pregnancy outcomes across the globe (Table 9).

Strategy	Target Population	Impact	Study Reference
Iron supplementation	Pregnant women with Hb < 11 g/dL	Reduces anemia prevalence by 30–50%	Tiwari et al., 2012
Folic acid supplementation	Pregnant women in low-income regions	Improves maternal and fetal health	Ononge et al., 2014

Table 9: Strategies for Managing Hemoglobin Levels During Pregnancy

Prevalence of Health Conditions across Various Locations and Years

Numerous socioeconomic, environmental, and healthcare factors are reflected in the large variations in the prevalence of particular illnesses or factors across different places and time periods. High prevalence rates are noteworthy in India; in 2017, Hyderabad reported 57% [41] Bangalore reported 89.3% [42]. In contrast, the rates are much lower in industrialized nations like Finland is 18.1% in 2024 [43] and France is 14.5% in 2020 [44]. which is a result of improved healthcare and preventative measures. Variations can be seen in historical data, with England reporting 67% in 2013 [45] and Australia reporting 16% in 1967 [46]. While Brazil reports a current incidence of 44% in 2023 [47]. regions with intermediate prevalence include Benin is 33.7% in 2012 (48) and Uganda is 32.5% in 2014 (10) (Table 10).

Sl no	Location	Prevalence (%)	Year	Reference
1.	China	48	2013	Liu et al., 2013
2.	Netherlands	50	2007	Rheenen et al., 2007
3.	Iran	37	2016	Maghsoudlou et al., 2016
4.	Australia	16	1967	Climie et al., 1967
5.	Brazil	44	2023	Camargo and Gross 2023
6.	Bristol	56	1974	Burman and Morris 1974
7.	north London	35	2005	Thomas et al., 2005
8.	Hyderabad, India	57%	2017	Singh et al., 2017
9.	England	67	2013	Nair et al., 2013
10.	Uganda	32.5	2014	Ononge et al., 2014
11.	Peru	8.6	2013	Gonzales et al., 2013
12.	Benin	33.7	2012	Koura et al., 2012
13.	Finland	18.1	2024	Helin et al., 2024
14.	France	14.5	2020	Bencaiova Hoeli et al., 2020
15.	south-eastern Gabon	52.4	2017	Mombo et al., 2017
16.	Pakistan	42.5%	2017	Ayub et al., 2017
17.	Bangalore, India	89.3%		RAMAN et al., 2001
18.	Pune, India	34	2012	Tiwari et al., 2012

Table 10: Prevalence of Health Conditions across Various Locations and Years

Conclusion

Maternal hemoglobin levels, whether low or high, are critical determinants of pregnancy outcomes. Anemia increases the risk of preterm birth, low birth weight, and maternal morbidity, while elevated hemoglobin levels are associated with hypertensive disorders, stillbirth, and growth restrictions. Adequate antenatal care, including routine screening and iron supplementation, can mitigate these risks and improve both maternal and fetal health outcomes globally. Addressing maternal hemoglobin abnormalities should be a priority for public health programs, particularly in regions with high anemia prevalence, to ensure safer pregnancies and healthier newborns.

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