Int. J. Curr. Res. Med. Sci. (2026). 12(3): 8-22

International Journal of Current Research in Medical Sciences

ISSN: 3107-3743 (Print), ISSN: 2454-5716 (Online)

(A Peer Reviewed, Indexed and Open Access Journal)

www.ijcrims.com

Review Article

Volume 12, Issue 3 -2026

DOI: http://dx.doi.org/10.22192/ijcrms.2026.12.03.002

Hemoglobin Dynamics in Pregnancy: Implications for Maternal and Fetal Health in Global Public Health

***Emmanuel Ifeanyi Obeagu[1,2] and Angela Amarachi Obeagu[3]**

[1]Division of Haematology, Department of Biomedical and Laboratory Science, Africa University, Zimbabwe.

[2]Department of Molecular Medicine and Haematology, School of Pathology, Faculty of Health Sciences, University of the Witwatersrand, Johannesburg, South Africa

[3]Department of Human Nutrition and Dietetics, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria

*Corresponding author: Emmanuel Ifeanyi Obeagu, Department of Biomedical and Laboratory Science, Africa University, Zimbabwe,

ORCID: 0000-0002-4538-0161

emmanuelobeagu@yahoo.com

Abstract

Hemoglobin dynamics during pregnancy reflect a delicate balance between normal physiological adaptation and pathological influences that vary across populations and health system contexts. While plasma volume expansion naturally lowers hemoglobin concentrations, excessive declines remain highly prevalent worldwide and are strongly associated with adverse maternal and fetal outcomes. This narrative review synthesizes current evidence on the physiological basis of hemoglobin changes, examines global patterns and key determinants, and explores their implications for maternal and neonatal health from a public health perspective. Nutritional deficiencies, infectious and parasitic diseases, high reproductive burden, and inequities in access to quality antenatal care are primary drivers of adverse hemoglobin trajectories, particularly in low- and middle-income countries. Understanding hemoglobin dynamics across gestation is essential for designing integrated, context-specific public health strategies aimed at reducing maternal anemia, improving pregnancy outcomes, and addressing global health disparities

Keywords: Hemoglobin dynamics, Pregnancy, Maternal health, Fetal outcomes, Global public health.

Introduction

Hemoglobin concentration is a key indicator of maternal health during pregnancy, serving as a marker for oxygen-carrying capacity, nutritional status, and overall physiological adaptation. During gestation, maternal hemoglobin undergoes dynamic changes to support fetal growth and development, ensure adequate placental perfusion, and maintain maternal homeostasis [1-2]. These changes are the result of complex hematological adaptations, including plasma volume expansion and increased erythropoiesis, which are essential for meeting the metabolic and oxygen demands of both mother and fetus. While some reduction in hemoglobin concentration is considered physiologically normal, excessive declines—manifesting as anemia—remain a significant global public health concern [3-4].Globally, anemia affects approximately one-third of pregnant women, representing one of the most common and preventable complications of pregnancy. The burden of low hemoglobin levels is disproportionately concentrated in low- and middle-income countries (LMICs), particularly in sub-Saharan Africa and South Asia, where prevalence rates frequently exceed 40–50%. In these regions, hemoglobin deficits are often the result of cumulative nutritional deficiencies, high fertility rates, infectious and parasitic disease burdens, and limited access to quality antenatal care. In contrast, high-income countries report lower prevalence, generally below 15%, reflecting better nutritional status, effective public health programs, and robust health system capacity for antenatal care, supplementation, and disease prevention [5-8].

The clinical and public health significance of hemoglobin changes in pregnancy is profound. Low maternal hemoglobin is associated with increased risk of maternal morbidity and mortality, including postpartum hemorrhage, infections, and impaired physical capacity. For the fetus, maternal anemia is strongly linked to preterm birth, low birth weight, intrauterine growth restriction, stillbirth, and long-term neurodevelopmental deficits. These outcomes not only affect individual health but also have intergenerational consequences, influencing child survival, growth, and cognitive development, and contributing to cycles of poor health and socioeconomic disadvantage [9-10].

Hemoglobin dynamics are influenced by a wide range of factors that extend beyond physiological adaptation [11]. Nutritional determinants, particularly iron, folate, and vitamin B12 deficiencies, are among the most significant contributors globally. Infectious and parasitic diseases, including malaria, hookworm, HIV, and tuberculosis, further exacerbate hemoglobin decline through mechanisms such as hemolysis, chronic inflammation, and impaired erythropoiesis [12]. Reproductive factors—including high parity, short interpregnancy intervals, and adolescent pregnancy—also increase susceptibility to low hemoglobin by depleting maternal nutrient stores. Socioeconomic determinants, such as poverty, low educational attainment, and gender inequities, indirectly shape hemoglobin levels by influencing dietary quality, health-seeking behavior, and exposure to infections. Environmental factors, including limited access to safe water, sanitation, and climate-related food insecurity, compound these risks. Finally, health system performance—including access to early antenatal care, screening, supplementation programs, and infection control—plays a critical role in moderating hemoglobin trajectories [13-14].This narrative review aims to synthesize current evidence on the physiological, epidemiological, and public health aspects of hemoglobin dynamics in pregnancy, highlighting the implications for maternal and fetal health and informing integrated, context-specific public health strategies.

Aim

The aim of this narrative review is to critically synthesize current evidence on hemoglobin dynamics throughout pregnancy and to examine their physiological basis, global epidemiological patterns, and key determinants, with particular emphasis on the implications for maternal and fetal health from a global public health perspective.

Methods

This narrative review was conducted through a comprehensive and integrative appraisal of the published literature examining hemoglobin dynamics during pregnancy and their implications for maternal and fetal health. Peer-reviewed articles, authoritative reviews, clinical guidelines, and global health reports were identified through systematic searches of major biomedical databases, including PubMed, Scopus and Web of Science. Key search terms and combinations included hemoglobin, anemia in pregnancy, physiological hemodilution, maternal outcomes, fetal outcomes, and global public health.Priority was given to studies published in English that addressed physiological changes in hemoglobin across gestation, epidemiology and determinants of anemia and hemoconcentration in pregnancy, and associations with maternal, perinatal, and neonatal outcomes. Both observational and interventional studies were considered, alongside reports from international organizations such as the World Health Organization. Evidence from low-, middle-, and high-income settings was intentionally included to capture global variation and health inequities.Selected literature was narratively synthesized rather than quantitatively pooled, allowing integration of mechanistic insights, clinical observations, and population-level data. Findings were organized thematically around physiological mechanisms, global patterns, determinants, and public health implications. This approach enabled a contextual interpretation of hemoglobin changes in pregnancy and their relevance to maternal–fetal health across diverse health systems and socioeconomic environments.

Physiological Basis of Hemoglobin Dynamics in Pregnancy

Pregnancy induces profound and highly coordinated physiological changes in the maternal hematological system, which are essential to support the metabolic demands of the developing fetus, the placenta, and the maternal body. Among these changes, hemoglobin dynamics—defined as the fluctuations in hemoglobin concentration across gestation—represent a key adaptation that reflects the balance between oxygen-carrying capacity, plasma volume expansion, and red blood cell production [15]. From the earliest stages of pregnancy, hormonal changes, particularly the rise in estrogen and progesterone, stimulate cardiovascular and renal adaptations that result in a progressive increase in plasma volume. By mid-pregnancy, plasma volume typically expands by 40–50% above pre-pregnancy levels. This expansion is necessary to meet the increased metabolic demands of maternal tissues and the developing fetus, ensure adequate placental perfusion, and prepare the maternal circulation for the hemodynamic stress of childbirth. In contrast, red blood cell mass increases more modestly, usually by 15–30%, even in women with adequate iron stores. The disproportionate increase in plasma volume relative to red blood cell mass produces a physiological decline in hemoglobin concentration, commonly referred to as hemodilution or "physiological anemia of pregnancy [16-17]."

This physiological reduction in hemoglobin is most pronounced during the second trimester, when plasma expansion peaks, and typically partially recovers in the third trimester as erythropoietin-driven red blood cell production accelerates. These changes are adaptive: reduced blood viscosity enhances uteroplacental blood flow, promoting efficient delivery of oxygen and nutrients to the fetus, while minimizing the risk of maternal vascular complications [18].Erythropoiesis during pregnancy is stimulated by increased oxygen demand and elevated erythropoietin levels, but effective red blood cell production depends critically on adequate availability of iron, folate, and vitamin B12. Iron requirements rise significantly—approximately 1,000 mg over the course of pregnancy—to support expansion of maternal red cell mass, fetal growth, and placental development. Folate and vitamin B12 are essential for DNA synthesis and erythrocyte maturation. When these micronutrients are sufficient, hemoglobin declines remain within physiological limits, and maternal adaptation proceeds without adverse consequences.

Conversely, deficiencies in these nutrients constrain compensatory erythropoiesis, increasing the risk of pathological anemia even in otherwise healthy pregnancies [19-20].

Physiological hemoglobin dynamics are also influenced by maternal baseline characteristics and genetic factors. Pre-pregnancy hemoglobin levels, parity, age, body mass index, and preexisting anemia all modulate the magnitude of hemoglobin change. Women entering pregnancy with low iron stores or marginal nutritional status are particularly susceptible to excessive hemoglobin decline. Additionally, genetic conditions such as thalassemia and sickle cell trait can affect baseline hemoglobin levels and the trajectory of changes during gestation [21].Recognition of normal physiological hemoglobin changes is essential for accurate diagnosis and management. The World Health Organization recommends a hemoglobin threshold of 11.0 g/dL for defining anemia in pregnancy, with recognition that mild reductions below this level may be physiological, especially during the second trimester. Failure to account for these gestational changes may lead to misdiagnosis, over-treatment, or under-treatment, with implications for both maternal and fetal outcomes(Table 1) [22].

Table 1: Physiological Basis of Hemoglobin Dynamics in Pregnancy

Physiological Process	Gestational Timing	Mechanism	Effect on Hemoglobin Concentration	Clinical Relevance
Plasma volume expansion	Begins first trimester; peaks second trimester	Estrogen- and renin–angiotensin–aldosterone–mediated sodium and water retention	Dilutional decrease (physiological anemia)	Normal adaptation; misinterpretation may lead to overdiagnosis of anemia
Increased erythropoiesis	Throughout pregnancy	Elevated erythropoietin production stimulating red cell synthesis	Partial compensation for plasma expansion	Requires adequate iron, folate, and vitamin B12
Increased iron demand	Progressive across gestation	Iron utilization for maternal erythropoiesis, placenta, and fetal growth	Decline if intake or stores are inadequate	Major contributor to iron deficiency anemia
Placental iron transfer	Second and third trimesters	Active transport of iron from maternal to fetal circulation	Maternal hemoglobin may fall	Prioritizes fetal needs over maternal reserves
Hemodilution nadir	24–32 weeks' gestation	Maximal plasma volume expansion relative to red cell mass	Lowest hemoglobin levels	Critical period for anemia screening
Late gestational stabilization	Third trimester	Plateau of plasma expansion with continued erythropoiesis	Slight hemoglobin rise or stabilization	Reflects adequate physiological adaptation
Blood loss at delivery	Peripartum	Placental separation and obstetric bleeding	Acute postnatal hemoglobin reduction	Exacerbates pre-existing anemia
Postpartum hemoconcentration	Early postpartum	Rapid plasma volume contraction	Relative increase in hemoglobin	Important for postpartum interpretation of values

Global Patterns of Hemoglobin Levels in Pregnancy

Hemoglobin levels during pregnancy exhibit substantial variation across regions, populations, and socioeconomic contexts, reflecting differences in nutrition, disease burden, reproductive patterns, and health system capacity. While physiological hemodilution occurs universally during pregnancy, the degree to which hemoglobin declines translate into clinically significant anemia varies markedly, revealing persistent global inequities in maternal health [23].Globally, anemia in pregnancy remains a major public health challenge, affecting approximately one-third of pregnant women. However, this global estimate conceals pronounced regional disparities. The highest prevalence is observed in low- and middle-income countries (LMICs), particularly in sub-Saharan Africa and South Asia, where anemia prevalence among pregnant women often exceeds 40–50%. Contributing factors include pre-existing maternal nutritional deficiencies, high fertility rates, infectious and parasitic disease burdens, and limited access to quality antenatal care. In these regions, malaria, hookworm, schistosomiasis, and other endemic infections exacerbate hemoglobin decline through hemolysis, blood loss, and impaired erythropoiesis, while chronic undernutrition further limits compensatory adaptation [23-24].

By contrast, high-income countries report substantially lower prevalence of anemia in pregnancy, generally below 15%. Improved dietary diversity, widespread iron and folic acid supplementation, fortified foods, and lower infectious disease burdens contribute to more favorable hemoglobin profiles. Moreover, robust antenatal care systems facilitate early detection, timely intervention, and close monitoring of hemoglobin levels throughout gestation, mitigating the risk of severe anemia [25].Middle-income regions, including Latin America, parts of Southeast Asia, and North Africa, exhibit intermediate patterns, with considerable heterogeneity both between and within countries. Urban populations and women of higher socioeconomic status often have higher hemoglobin concentrations compared with rural residents, marginalized communities, and women experiencing food insecurity. These intra-country disparities highlight the influence of social determinants, such as income, education, and gender equity, on maternal hematological outcomes [27].

Temporal trends in hemoglobin levels suggest modest global improvements over the past two decades, largely due to expanded antenatal care coverage, iron and folic acid supplementation programs, and increased public health attention to maternal nutrition. However, progress has been uneven. While some regions, particularly parts of East Asia and Latin America, have achieved meaningful reductions in anemia prevalence, sub-Saharan Africa has seen limited gains. Factors such as rapid population growth, persistent poverty, climate-related food insecurity, and weak health systems continue to constrain improvements in high-burden areas [28-29].Within countries, hemoglobin patterns also vary according to maternal age, parity, and reproductive history. Adolescent pregnant women and those with closely spaced pregnancies often exhibit lower hemoglobin levels due to limited time for replenishment of nutrient stores. Women with low educational attainment or restricted access to health information are less likely to seek timely antenatal care or adhere to supplementation regimens, compounding the risk of anemia [30].

Methodological variations in measurement and reporting further shape the apparent global patterns of hemoglobin in pregnancy. Differences in hemoglobin cutoffs, laboratory techniques, timing of assessment, and gestational age at measurement complicate cross-study comparisons. Additionally, population-based surveys frequently lack longitudinal data, limiting insight into trimester-specific hemoglobin trajectories. Data from marginalized, conflict-affected, or remote populations remain scarce, potentially underrepresenting the most vulnerable groups in global estimates [31].From a public health perspective, these patterns underscore the need for context-specific strategies to address hemoglobin deficits during pregnancy. Universal approaches are insufficient to tackle the diverse drivers of maternal anemia across settings. Effective interventions must account for regional disease profiles, nutritional environments, health system capacities, and social determinants to ensure equitable improvements in maternal and fetal health outcomes worldwide [32].

Determinants of Hemoglobin Dynamics During Pregnancy

Hemoglobin dynamics during pregnancy are shaped by a complex interplay of biological, nutritional, infectious, reproductive, socioeconomic, environmental, and health system factors. While physiological hemodilution is a universal adaptation, the magnitude and clinical significance of hemoglobin decline are strongly influenced by these interacting determinants, which often coexist and amplify vulnerability in certain populations. Understanding these determinants is essential for designing effective public health interventions to prevent anemia and optimize maternal and fetal outcomes (Table 2) [33].

Table 2: Determinants of Hemoglobin Dynamics During Pregnancy

Determinant Category	Specific Determinants	Mechanism Affecting Hemoglobin	Typical Impact on Hemoglobin Levels	Public Health Relevance
Nutritional factors	Low dietary iron intake, poor iron bioavailability, folate and vitamin B12 deficiency	Impaired erythropoiesis and reduced hemoglobin synthesis	Decreased hemoglobin; iron deficiency anemia	Central target for supplementation and food fortification programs
Infectious diseases	Malaria, hookworm infection, schistosomiasis, HIV, chronic inflammation	Hemolysis, blood loss, inflammation-mediated iron sequestration	Moderate to severe anemia	High burden in LMICs; requires integrated infection control
Genetic conditions	Sickle cell disease, thalassemias, other hemoglobinopathies	Reduced hemoglobin production or increased red cell destruction	Chronically low baseline hemoglobin	Important for screening and individualized antenatal care
Physiological adaptation	Degree of plasma volume expansion	Hemodilution relative to red cell mass	Physiological decline or, if inadequate, elevated hemoglobin	Distinguishes normal adaptation from pathology
Socioeconomic status	Poverty, food insecurity, low maternal education	Limited access to nutritious foods and healthcare	Persistent low hemoglobin	Driver of global and within-country inequities
Health system factors	Late antenatal booking, inadequate screening, poor supplementation adherence	Delayed detection and management of anemia	Worsening anemia across gestation	Reflects quality and accessibility of antenatal care

Reproductive factors	High parity, short interpregnancy intervals, adolescent pregnancy	Depleted maternal iron stores	Lower hemoglobin at conception and during pregnancy	Highlights need for preconception and interpregnancy care
Environmental exposures	Indoor air pollution, heavy metals, petrochemical pollutants	Oxidative stress and impaired hematopoiesis	Reduced hemoglobin or functional anemia	Emerging concern in environmental and occupational health
Inflammatory states	Obesity, chronic disease, infections	Hepcidin-mediated iron restriction	Functional iron deficiency	Limits effectiveness of iron supplementation alone
Geographic context	Rural residence, malaria-endemic regions	Combined nutritional and infectious risks	Marked regional hemoglobin variation	Guides context-specific public health interventions

Nutritional Determinants

Nutritional status is the most significant driver of hemoglobin changes during pregnancy. Iron deficiency accounts for the majority of anemia cases globally, arising from inadequate dietary intake, poor absorption of non-heme iron, and increased iron requirements during gestation. Folate and vitamin B12 deficiencies further impair erythropoiesis, while chronic energy deficiency and protein malnutrition exacerbate hemoglobin decline. In regions with limited access to micronutrient-rich foods, these nutritional deficits are often compounded by food insecurity and seasonal scarcity [34].

Infectious and Parasitic Determinants

Infectious and parasitic diseases significantly contribute to reductions in hemoglobin levels. Malaria remains a major cause of maternal anemia in endemic regions due to hemolysis and placental sequestration of infected red blood cells. Soil-transmitted helminths, including hookworm and schistosomiasis, lead to chronic blood loss, while chronic infections such as HIV and tuberculosis impair erythropoiesis through inflammation and immune-mediated pathways. Coexisting infections frequently exacerbate hemoglobin decline, particularly in resource-limited settings [35].

Reproductive and Biological Determinants

Reproductive history strongly influences hemoglobin dynamics. High parity and short interpregnancy intervals limit the maternal body's ability to replenish iron and micronutrient stores, increasing susceptibility to anemia. Adolescent pregnancy presents a unique risk due to the concurrent nutritional demands of maternal growth and fetal development. Pre-existing anemia or chronic conditions prior to conception further increase vulnerability, as does the presence of genetic hemoglobinopathies, including sickle cell disease and thalassemia, which can modify baseline hemoglobin levels and the trajectory of change during gestation [36].

Socioeconomic and Environmental Determinants

Socioeconomic conditions indirectly shape hemoglobin dynamics by influencing access to nutrition, healthcare, and exposure to infectious diseases. Poverty, low educational attainment, and gender inequality are consistently associated with lower hemoglobin concentrations. Rural residence and geographic isolation often exacerbate these disadvantages by limiting access to quality antenatal care, supplementation programs, and health education. Environmental factors, such as inadequate water, sanitation, and hygiene (WASH) conditions, increase susceptibility to infections and parasitic infestations, further affecting hemoglobin levels. Climate-related food insecurity and seasonal variability in food availability can also contribute to fluctuations in maternal hemoglobin status [37-38].

Health System and Policy Determinants

The performance of health systems is critical in moderating hemoglobin changes during pregnancy. Timely initiation of antenatal care, routine hemoglobin screening, consistent iron and folic acid supplementation, malaria prophylaxis, and deworming programs are central to maintaining adequate maternal hemoglobin. Weak health systems—characterized by stock-outs, inadequate workforce training, poor monitoring, and limited integration of nutrition and infection control services—reduce the effectiveness of these interventions. Even in countries with national guidelines for anemia prevention, gaps in implementation and coverage can limit impact [39].

Interaction of Determinants

These factors rarely operate in isolation. Nutritional deficiencies, infections, high reproductive demand, and social disadvantage often coexist, producing synergistic effects that amplify hemoglobin decline during pregnancy. This multidimensional interplay explains why certain populations—particularly women in LMICs, adolescents, and marginalized groups—experience disproportionately severe anemia despite similar physiological adaptations [40].From a public health perspective, addressing hemoglobin dynamics during pregnancy requires comprehensive, multisectoral interventions. Strategies must simultaneously target nutrition, infectious disease control, reproductive health, health system strengthening, and social determinants to effectively mitigate anemia and its associated maternal and fetal risks [41].

Implications for Maternal Health

Hemoglobin dynamics during pregnancy have profound implications for maternal health, as low hemoglobin concentrations—whether resulting from physiological adaptation or pathological anemia—can significantly increase maternal morbidity and mortality. Maternal anemia reduces the oxygen-carrying capacity of the blood, which can compromise the mother's ability to tolerate the physiological stress of pregnancy and childbirth. Women with moderate to severe anemia are at higher risk of complications such as postpartum hemorrhage, infections, fatigue, and impaired recovery after delivery. Even mild anemia can reduce physical capacity, productivity, and quality of life, particularly in settings where women perform physically demanding tasks while pregnant [42].Low maternal hemoglobin also interacts with obstetric complications, amplifying their severity. For example, women with anemia who experience hemorrhage during delivery are at higher risk of hypovolemic shock and require more frequent blood transfusions. Chronic anemia can exacerbate cardiovascular strain, contributing to conditions such as preeclampsia or cardiac failure in severe cases. Additionally, repeated pregnancies without adequate recovery of iron and micronutrient stores increase cumulative maternal risk, particularly in high-parity populations [43].

From a public health perspective, maternal anemia reflects broader structural and systemic issues, including poor nutrition, high infectious disease burden, limited access to quality antenatal care, and socioeconomic disadvantage. Addressing maternal anemia, therefore, is not only a clinical concern but also a marker for inequities in healthcare access, nutrition, and social determinants of health. Interventions that maintain adequate hemoglobin levels—such as early antenatal care, iron and folic acid supplementation, deworming, and malaria prophylaxis—are essential to reducing maternal morbidity and mortality, improving birth outcomes, and promoting long-term maternal well-being [44].Improving maternal hemoglobin status has cascading benefits, enhancing resilience to obstetric complications, reducing healthcare costs, and contributing to healthier reproductive trajectories. In high-burden settings, strategies must integrate nutrition, infection control, and health system strengthening to ensure sustainable improvements in maternal health outcomes [45].

Implications for Fetal and Neonatal Health

Maternal hemoglobin dynamics during pregnancy have critical implications for fetal and neonatal health, as hemoglobin levels directly influence oxygen and nutrient delivery to the developing fetus. Low maternal hemoglobin, particularly when indicative of anemia, compromises placental oxygenation and nutrient transfer, increasing the risk of adverse fetal outcomes. Studies consistently associate maternal anemia with preterm birth, low birth weight, intrauterine growth restriction (IUGR), and stillbirth, outcomes that contribute substantially to neonatal morbidity and mortality worldwide [46].In addition to immediate perinatal effects, maternal anemia can have long-term consequences for child development. Insufficient oxygen and nutrient delivery during critical periods of fetal growth may impair neurodevelopment, cognitive function, and immune competence. Infants born to anemic mothers are also at higher risk of neonatal anemia, which can further compromise growth, increase susceptibility to infections, and affect early developmental milestones [47].

The timing and severity of maternal hemoglobin decline are important determinants of fetal risk. Severe anemia in the first and second trimesters is associated with higher rates of miscarriage and preterm labor, while anemia in late pregnancy can impair fetal growth and increase the likelihood of perinatal complications. Chronic or recurrent maternal anemia across pregnancies compounds these risks, particularly in high-parity populations and low-resource settings [48].From a public health perspective, optimizing maternal hemoglobin status is essential for improving fetal and neonatal outcomes. Interventions such as iron and folic acid supplementation, malaria prevention, deworming, and nutrition programs during pregnancy not only protect maternal health but also enhance fetal growth, reduce preterm birth and low birth weight, and improve neonatal survival. Ensuring adequate hemoglobin levels in pregnant women therefore represents a critical strategy for breaking intergenerational cycles of poor health, enhancing early childhood development, and achieving broader maternal and child health targets at the population level [49].

Public Health Strategies and Policy Implications

Addressing hemoglobin dynamics during pregnancy requires comprehensive public health strategies that extend beyond individual supplementation to target the multiple determinants of maternal anemia. Effective interventions must integrate nutrition, infection control, reproductive health services, health system strengthening, and social determinants to reduce the prevalence of low hemoglobin and improve maternal and fetal outcomes [50].

Nutritional Interventions

Iron and folic acid supplementation during pregnancy remains the cornerstone of anemia prevention and management. Ensuring adequate supply, early initiation, and adherence is critical. In addition, broader nutrition-sensitive strategies—including promotion of dietary diversity, fortification of staple foods with iron and other micronutrients, and targeted supplementation for high-risk groups—address underlying nutritional deficiencies that contribute to hemoglobin decline. Maternal nutrition programs should also incorporate counseling and education to improve dietary practices and adherence to supplementation [51-52].

Infection Control

Infectious and parasitic diseases such as malaria, HIV, and helminthiasis significantly exacerbate maternal anemia, particularly in LMICs. Public health strategies must include malaria prevention through insecticide-treated bed nets, intermittent preventive treatment, and vector control; deworming programs; and timely diagnosis and treatment of chronic infections. Integrating infection control with antenatal care services ensures that these measures are accessible and effective [53].

Strengthening Antenatal Care Services

Early and regular antenatal care is essential for monitoring hemoglobin levels, identifying at-risk women, and providing timely interventions.

Health systems should ensure adequate laboratory capacity for hemoglobin assessment, availability of supplements, trained healthcare personnel, and effective follow-up. Community-based outreach programs can improve access for rural, marginalized, and hard-to-reach populations, increasing early engagement with antenatal care services [54].

Addressing Social Determinants and Equity

Socioeconomic and environmental factors strongly influence hemoglobin dynamics. Public health policies should address poverty, food insecurity, gender inequity, and education to reduce structural barriers to maternal nutrition and health care. Social protection programs, conditional cash transfers, and educational initiatives for girls and women can enhance access to nutrition and health services, thereby mitigating the broader determinants of anemia in pregnancy [55].

Policy and Surveillance

Robust health policy and surveillance frameworks are essential to guide evidence-based interventions. Governments should establish national guidelines for anemia prevention and management, integrate hemoglobin monitoring into routine maternal health programs, and implement trimester-specific thresholds for intervention. Strengthening data systems to capture population-level and longitudinal trends in hemoglobin can inform resource allocation, program design, and evaluation [56-57].

Multisectoral and Integrated Approaches

Given the multifactorial determinants of maternal anemia, multisectoral collaboration is critical. Coordination between nutrition, maternal health, infectious disease control, education, and social welfare sectors ensures comprehensive interventions that address both proximal and structural determinants of hemoglobin decline. Integrated approaches are particularly important in high-burden settings, where overlapping risk factors exacerbate maternal and fetal vulnerability [57].

Conclusion

Hemoglobin dynamics during pregnancy reflect a delicate balance between physiological adaptation and multiple interacting determinants, including nutrition, infections, reproductive factors, socioeconomic conditions, and health system capacity. While moderate declines in hemoglobin are a normal feature of gestation, excessive reductions—manifesting as maternal anemia—remain a major global public health challenge, particularly in low- and middle-income countries. Persistent disparities in maternal hemoglobin levels highlight the influence of structural and contextual factors that extend beyond individual clinical care. Maternal anemia has profound implications for both maternal and fetal health, contributing to increased risks of morbidity, mortality, preterm birth, low birth weight, intrauterine growth restriction, and long-term developmental deficits in children. Addressing these risks requires integrated, multisectoral strategies that combine nutritional interventions, infection control, strengthened antenatal care, and policies targeting social determinants of health.

Abbreviations

ANC – Antenatal Care
B12 – Vitamin B12 (Cobalamin)
BMI – Body Mass Index
Hb – Hemoglobin
Hct – Hematocrit
HIV – Human Immunodeficiency Virus
IDA – Iron Deficiency Anemia
IUGR – Intrauterine Growth Restriction
LMICs – Low- and Middle-Income Countries
MCH – Mean Corpuscular Hemoglobin
MCV – Mean Corpuscular Volume
RBC – Red Blood Cell
SDGs – Sustainable Development Goals
SGA – Small for Gestational Age
WHO – World Health Organization

References

1. Liu D, Li S, Zhang B, Kang Y, Cheng Y, Zeng L, Chen F, Mi B, Qu P, Zhao D, et al. Maternal Hemoglobin Concentrations and Birth Weight, Low Birth Weight (LBW), and Small for Gestational Age (SGA): Findings from a Prospective Study in Northwest China. Nutrients. 2022; 14(4):858. https://doi.org/10.3390/nu14040858
2. Young MF, Oaks BM, Tandon S, Martorell R, Dewey KG, Wendt AS. Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. Ann N Y Acad Sci. 2019;1450(1):47-68. doi: 10.1111/nyas.14093.
3. Obeagu EI, Obeagu GU. Protecting maternal health: Strategies against HIV and malaria in pregnancy. Medicine (Baltimore). 2024;103(36): e39565. doi: 10.1097/MD.0000000000039565.
4. Obeagu GU, Altraide BO, Obeagu EI. Iron deficiency anemia in pregnancy and related complications with specific insight in Rivers State, Nigeria: a narrative review. Ann Med Surg (Lond). 2025;87(6):3435-3444. doi: 10.1097/MS9.0000000000003224.
5. Araujo Costa E, de Paula Ayres-Silva J. Global profile of anemia during pregnancy versus country income overview: 19 years estimative (2000-2019). Ann Hematol. 2023;102(8):2025-2031. doi: 10.1007/s00277-023-05279-2.
6. Mbowe F, Darboe KS, Sanyang AM, Barrow A. Prevalence and determinants of anemia among pregnant women attending maternal and child health clinics at Sukuta Health Center, The Gambia: An institutional-based cross-sectional study. Womens Health (Lond). 2025; 21:17455057251338380. doi: 10.1177/17455057251338380.
7. Obeagu GU, Obeagu EI. Complications of anemia in pregnancy: An updated overview for healthcare professionals. Medicine (Baltimore). 2025;104(35): e44246. doi: 10.1097/MD.0000000000044246.
8. Obeagu EI. Climate change and red blood cell disorders: A review of risks and adaptations for pregnant women and children. Medicine (Baltimore). 2025;104(40): e45129. doi: 10.1097/MD.0000000000045129.
9. Edelson PK, Cao D, James KE, Ngonzi J, Roberts DJ, Bebell LM, Boatin AA. Maternal anemia is associated with adverse maternal and neonatal outcomes in Mbarara, Uganda. J Matern Fetal Neonatal Med. 2023;36(1):2190834. doi: 10.1080/14767058.2023.2190834.
10. Jung J, Rahman MM, Rahman MS, Swe KT, Islam MR, Rahman MO, Akter S. Effects of hemoglobin levels during pregnancy on adverse maternal and infant outcomes: a systematic review and meta-analysis. Ann N Y Acad Sci. 2019;1450(1):69-82. doi: 10.1111/nyas.14112.
11. Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in low- and middle-income countries. Ann N Y Acad Sci. 2019 Aug;1450(1):15-31. doi: 10.1111/nyas.14092.
12. Shaw JG, Friedman JF. Iron deficiency anemia: focus on infectious diseases in lesser developed countries. Anemia. 2011; 2011:260380. doi: 10.1155/2011/260380.
13. O'Mahony D, Mabunda SA, Mntonintshi M, Iruedo J, Kaswa R, Blanco-Blanco E, Ogunsanwo B, Namugenyi KAF, Vasaikar S, Yogeswaran P. Causes of Moderate and Severe Anaemia in a High-HIV and TB-Prevalent Adult Population in the Eastern Cape Province, South Africa. International Journal of Environmental Research and Public Health. 2023; 20(4):3584. https://doi.org/10.3390/ijerph20043584
14. Obeagu EI, Obeagu GU. An update on factors affecting umbilical cord care among mothers: A review. Medicine (Baltimore). 2024;103(28): e38945. doi: 10.1097/MD.0000000000038945.

15. Chandra S, Tripathi AK, Mishra S, Amzarul M, Vaish AK. Physiological changes in hematological parameters during pregnancy. Indian J Hematol Blood Transfus. 2012;28(3):144-6. doi: 10.1007/s12288-012-0175-6.
16. Soma-Pillay P, Nelson-Piercy C, Tolppanen H, Mebazaa A. Physiological changes in pregnancy. Cardiovasc J Afr. 2016;27(2):89-94. doi: 10.5830/CVJA-2016-021.
17. Filipec M, JadanecĐurin M. Cardiovascular and Respiratory Adaptations During Pregnancy and Exercise in Pregnancy. Physiologia. 2025; 5(3):30. https://doi.org/10.3390/physiologia5030030
18. Aguree S, Gernand AD. Plasma volume expansion across healthy pregnancy: a systematic review and meta-analysis of longitudinal studies. BMC Pregnancy Childbirth. 2019;19(1):508. doi: 10.1186/s12884-019-2619-6.
19. Vega-Sánchez R, Tolentino-Dolores MC, Cerezo-Rodríguez B, Chehaibar-Besil G, Flores-Quijano ME. Erythropoiesis and Red Cell Indices Undergo Adjustments during Pregnancy in Response to Maternal Body Size but not Inflammation. Nutrients. 2020;12(4):975. doi: 10.3390/nu12040975.
20. Teramo KA, Klemetti MM, Widness JA. Robust increases in erythropoietin production by the hypoxic fetus is a response to protect the brain and other vital organs. Pediatr Res. 2018;84(6):807-812. doi: 10.1038/s41390-018-0054-4.
21. Liu L, Li X. Predictive Value of Dynamic Changes in Hemoglobin Levels During Early Pregnancy for the Development of Anemia During Pregnancy. Int J Womens Health. 2025; 17:1829-1835. doi: 10.2147/IJWH.S530428.
22. Obianeli C, Afifi K, Stanworth S, Churchill D. Iron Deficiency Anaemia in Pregnancy: A Narrative Review from a Clinical Perspective. Diagnostics (Basel). 2024;14(20):2306. doi: 10.3390/diagnostics14202306.
23. Sun M, Gu T, Wu T, Gong X, Li X, Huang J, Li Y, Zhao Y, Shi H, Wei Y. Variation Patterns of Hemoglobin Levels by Gestational Age during Pregnancy: A Cross-Sectional Analysis of a Multi-Center Retrospective Cohort Study in China. Nutrients. 2023;15(6):1383. doi: 10.3390/nu15061383.
24. Araujo Costa E, de Paula Ayres-Silva J. Global profile of anemia during pregnancy versus country income overview: 19 years estimative (2000-2019). Ann Hematol. 2023;102(8):2025-2031. doi: 10.1007/s00277-023-05279-2.
25. Konje ET, Ngaila BV, Kihunrwa A, Mugassa S, Basinda N, Dewey D. High Prevalence of Anemia and Poor Compliance with Preventive Strategies among Pregnant Women in Mwanza City, Northwest Tanzania: A Hospital-Based Cross-Sectional Study. Nutrients. 2022; 14(18):3850. https://doi.org/10.3390/nu14183850
26. Safiri S, Kolahi AA, Noori M, Nejadghaderi SA, Karamzad N, Bragazzi NL, Sullman MJM, Abdollahi M, Collins GS, Kaufman JS, Grieger JA. Burden of anemia and its underlying causes in 204 countries and territories, 1990-2019: results from the Global Burden of Disease Study 2019. J Hematol Oncol. 2021;14(1):185. doi: 10.1186/s13045-021-01202-2.
27. Valladolid-Sandoval LAM, Vásquez-Romero LEM, Loayza-Castro JA, Mayely Sanchez-Tamay N, Coronel AC, Zuzunaga-Montoya FE, De Carrillo CIG, Vera-Ponce VJ. Trends and disparities in the coexistence of anemia and obesity among Peruvian women aged 20-49 years: doubling prevalence in two decades of National surveillance. Int J Equity Health. 2025;24(1):200. doi: 10.1186/s12939-025-02576-2.
28. Fekadie A, Teketelew BB, Aynalem M, Yalew A. Hemoglobin response to iron-folic acid supplementation and associated factors among anemic pregnant women attending the University of Gondar Comprehensive Specialized Hospital ANC

ward Northwest, Ethiopia 2023: A longitudinal follow up study. PLoS One. 2025;20(9): e0331599. doi: 10.1371/journal.pone.0331599.

29. Stevens GA, Finucane MM, De-Regil LM, Paciorek CJ, Flaxman SR, Branca F, Peña-Rosas JP, Bhutta ZA, Ezzati M; Nutrition Impact Model Study Group (Anaemia). Global, regional, and national trends in haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995-2011: a systematic analysis of population-representative data. Lancet Glob Health. 2013;1(1): e16-25. doi: 10.1016/S2214-109X (13)70001-9.
30. Young MF, Oaks BM, Tandon S, Martorell R, Dewey KG, Wendt AS. Maternal hemoglobin concentrations across pregnancy and maternal and child health: a systematic review and meta-analysis. Ann N Y Acad Sci. 2019;1450(1):47-68. doi: 10.1111/nyas.14093.
31. Peng Z, Si S, Cheng H, Zhou H, Chi P, Mo M, Zhuang Y, Liu H, Yu Y. The Associations of Maternal Hemoglobin Concentration in Different Time Points and Its Changes during Pregnancy with Birth Weight Outcomes. Nutrients. 2022; 14(12):2542. https://doi.org/10.3390/nu14122542
32. Loechl CU, Datta-Mitra A, Fenlason L, Green R, Hackl L, Itzkowitz L, Koso-Thomas M, Moorthy D, Owino VO, Pachón H, Stoffel N, Zimmerman MB, Raiten DJ. Approaches to Address the Anemia Challenge. J Nutr. 2023;153 Suppl 1(Suppl 1): S42-S59. doi: 10.1016/j.tjnut.2023.07.017.
33. Kuma MN, Tamiru D, Belachew T. Hemoglobin Level and Associated Factors among Pregnant Women in Rural Southwest Ethiopia. Biomed Res Int. 2021; 2021:9922370. doi: 10.1155/2021/9922370.
34. Gibore NS, Ngowi AF, Munyogwa MJ, Ali MM. Dietary Habits Associated with Anemia in Pregnant Women Attending Antenatal Care Services. Curr Dev Nutr. 2020;5(1): nzaa178. doi: 10.1093/cdn/nzaa178.
35. Achidi EA, Kuoh AJ, Minang JT, Ngum B, Achimbom BM, Motaze SC, Ahmadou MJ, Troye-Blomberg M. Malaria infection in pregnancy and its effects on haemoglobin levels in women from a malaria endemic area of Fako Division, South West Province, Cameroon. J ObstetGynaecol. 2005;25(3):235-40. doi: 10.1080/01443610500060628.
36. Wong MF, Jetly K, Ismail Bukhary NBB, K Krishnan V, Chandrakant JA, Tham SW. Risk Factors for Anemia in Adolescent Pregnancies: Evidence from the Lembah Pantai Urban Health District in Malaysia. Cureus. 2024;16(8): e68094. doi: 10.7759/cureus.68094.
37. Alemu TG, Fentie EA, Belay DG, Asmamaw DB, Shewarega ES, Negash WD, Eshetu HB, Aragaw FM, Fetene SM, Teklu RE. Socioeconomic inequality in the co-occurrence of anemia and stunting among adolescent girls aged 15-19 years in Sub-Saharan African countries: a decomposition analysis. BMC Public Health. 2025;25(1):573. doi: 10.1186/s12889-025-21841-1.
38. McLaren SW. The Relationship between Hemoglobin Level and Socio-economic Indicators among Women of Childbearing Age in South Africa: A Secondary Analysis of DHS Data. Ecol Food Nutr. 2022;61(1):56-63. doi: 10.1080/03670244.2021.1954510.
39. Fekadie A, Teketelew BB, Aynalem M, Yalew A. Hemoglobin response to iron-folic acid supplementation and associated factors among anemic pregnant women attending the University of Gondar Comprehensive Specialized Hospital ANC ward Northwest, Ethiopia 2023: A longitudinal follow up study. PLoS One. 2025;20(9): e0331599. doi: 10.1371/journal.pone.0331599.
40. Alem AZ, Efendi F, McKenna L, Felipe-Dimog EB, Chilot D, Tonapa SI, Susanti IA, Zainuri A. Prevalence and factors associated with anemia in women of reproductive age across low- and

middle-income countries based on national data. Sci Rep. 2023;13(1):20335. doi: 10.1038/s41598-023-46739-z.
41. Williams PA, Poehlman J, Moran K, Siddiqui M, Kataria I, Rego AM, Mehrotra P, Saldanha N. Strategies to address anaemia among pregnant and lactating women in India: a formative research study. Public Health Nutr. 2020;23(5):795-805. doi: 10.1017/S1368980019003938.
42. Kuma MN, Tamiru D, Belachew T. Hemoglobin Level and Associated Factors among Pregnant Women in Rural Southwest Ethiopia. Biomed Res Int. 2021; 2021:9922370. doi: 10.1155/2021/9922370.
43. Omotayo MO, Abioye AI, Kuyebi M, Eke AC. Prenatal anemia and postpartum hemorrhage risk: A systematic review and meta-analysis. J ObstetGynaecol Res. 2021;47(8):2565-2576. doi: 10.1111/jog.14834.
44. Tancred T, Mubangizi V, Dei EN, Natukunda S, Abankwah DNY, Ellis P, Bates I, Natukunda B, Asamoah Akuoko L. Prevention and management of anaemia in pregnancy: Community perceptions and facility readiness in Ghana and Uganda. PLOS Glob Public Health. 2024;4(8): e0003610. doi: 10.1371/journal.pgph.0003610.
45. Mildon A, Lopez de Romaña D, Jefferds MED, Rogers LM, Golan JM, Arabi M. Integrating and coordinating programs for the management of anemia across the life course. Ann N Y Acad Sci. 2023;1525(1):160-172. doi: 10.1111/nyas.15002.
46. Alwan NA, Hamamy H. Maternal Iron Status in Pregnancy and Long-Term Health Outcomes in the Offspring. J Pediatr Genet. 2015;4(2):111-23. doi: 10.1055/s-0035-1556742.
47. Zych-Krekora K, Sylwestrzak O, Krekora M. The Critical Role of Iron in Pregnancy, Puerperium, and Fetal Development. Journal of Clinical Medicine. 2025; 14(10):3482. https://doi.org/10.3390/jcm14103482
48. Chen Y, Zhong T, Song X, Zhang S, Sun M, Liu X, Wei J, Shu J, Liu Y, Qin J. Maternal anaemia during early pregnancy and the risk of neonatal outcomes: a prospective cohort study in Central China. BMJ Paediatr Open. 2024;8(1): e001931. doi: 10.1136/bmjpo-2023-001931.
49. Zavala E, Rhodes M, Christian P. Pregnancy Interventions to Improve Birth Outcomes: What Are the Effects on Maternal Outcomes? A Scoping Review. Int J Public Health. 2022; 67:1604620. doi: 10.3389/ijph.2022.1604620.
50. Lopez de Romaña D, Mildon A, Golan J, Jefferds MED, Rogers LM, Arabi M. Review of intervention products for use in the prevention and control of anemia. Ann N Y Acad Sci. 2023;1529(1):42-60. doi: 10.1111/nyas.15062.
51. Seidu H, Gaa PK, Mogre V. Adherence to Iron and Folic Acid Supplementation Among Pregnant Women from Northern Ghana. NutrMetab Insights. 2024:11786388231218664. doi: 10.1177/11786388231218664.
52. Engidaw MT, Lee P, Ahmed F. Iron and folic acid supplementation compliance during pregnancy and its effect on post-pregnancy anaemia among reproductive-age women in East Africa. Womens Health (Lond). 2025:17455057251317547. doi: 10.1177/17455057251317547.
53. Obeagu EI, Obeagu GU. Protecting maternal health: Strategies against HIV and malaria in pregnancy. Medicine (Baltimore). 2024;103(36): e39565. doi: 10.1097/MD.0000000000039565.
54. Saapiire F, Dogoli R, Mahama S. Adequacy of antenatal care services utilisation and its effect on anaemia in pregnancy. J Nutr Sci. 2022;11: e80. doi: 10.1017/jns.2022.80.
55. Rebouças P, Falcão IR, Barreto ML. Social inequalities and their impact on children's health: a current and global perspective. J Pediatr (Rio J). 2022;98 Suppl 1(Suppl 1): S55-S65. doi: 10.1016/j.jped.2021.11.004.

56. Totade M, Gaidhane A, Sahu P. Interventions in Maternal Anaemia to Reduce Maternal Mortality Rate Across India. Cureus. 2023;15(10): e46617. doi: 10.7759/cureus.46617.
57. Yoseph A, Mussie L, Belayineh M, Aguinaga-Ontoso I, Guillen-Grima F, Mutwiri G. The Determinants of Coexisting Anemia and Undernutrition Among Pregnant Women in Southern Ethiopia: A Multi-Level Analysis. Healthcare (Basel). 2025;13(13):1495. doi: 10.3390/healthcare13131495.

Access this Article in Online	
	Website: www.ijcrims.com
Quick Response Code	Subject: Haematology
DOI: 10.22192/ijcrms.2026.12.03.002	

How to cite this article:
Emmanuel Ifeanyi Obeagu and Angela Amarachi Obeagu. (2026). Hemoglobin Dynamics in Pregnancy: Implications for Maternal and Fetal Health in Global Public Health. Int. J. Curr. Res. Med. Sci. 12(3): 8-22.
DOI: http://dx.doi.org/10.22192/ijcrms.2026.12.03.002