



Anaemia during Pregnancy: From Conception to Childhood Consequences

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Abstract

Anaemia is a life-threatening global health issue, particularly affecting pregnant women, with severe implications for both maternal and foetal health. Its prevalence is alarmingly high in developing countries, including India, where nutritional deficiencies, infections, and socio-economic factors exacerbate the condition. Recent data suggests that approximately 37% (32 million) of pregnant women worldwide are projected to experience anaemia (WHO, 2021). Anaemia during pregnancy is associated with immediate outcomes such as preterm birth, low birth weight, and increased maternal mortality, as well as long-term developmental delays in children, including cognitive and motor impairments. Despite government interventions, the persistence of high anaemia rates reveals significant gaps in prevention strategies, highlighting the urgent need for enhanced awareness and comprehensive maternal care during pregnancy to mitigate these risks. Research gaps remain in understanding the multifactorial causes of anaemia and optimizing intervention approaches to reduce its prevalence globally. Addressing this issue is essential for achieving the sustainable development goals of the nation.

Keywords: Anaemia, Pregnancy, Determinants, Outcomes.

Introduction

Anaemia is an invisible enemy lurking within life from conception and silently undermining health and vitality, with its wide range of consequences reaching far beyond the mere depletion of red blood cells (WHO, 2020). In developing countries like India, the high prevalence of maternal anaemia is well-documented, with rates varying across regions due to inadequate nutrition, limited healthcare access, socioeconomic disparities, and cultural practices (Balarajan et al., 2011). Anaemia During pregnancy, poses significant threats not only to maternal well-being but also to the optimal growth and development of the unborn child that even leads to long-lasting effects such as developmental delays in cognitive, motor, and socio-emotional domains (Black et al., 2013; McLean et al., 2019). Despite the implementation of programs such as iron and folic acid

supplementation, antenatal care, and nutritional interventions, maternal anemia remains prevalent, especially in South Indian states, contributing to maternal morbidities and adverse pregnancy outcomes, including preterm birth, low birth weight, and intrauterine growth restriction (Singh et al., 2021; Kalaivani, 2009). More comprehensive early intervention and maternal healthcare strategies are vital in addressing the root causes of anaemia and mitigating its long-term impacts on child development (Ramakrishnan et al., 2016).

Anaemia during Pregnancy and it's prevalence

Anaemia during pregnancy is a multifaceted condition that can adversely affect both maternal and foetal health. According to the World Health Organization, anaemia is defined as a condition characterized by an inadequate number of red blood cells or insufficient oxygen-carrying capacity to meet physiological demands, which vary depending on factors such as age, sex, altitude, smoking habits, and pregnancy status, and in the case of pregnancy, anaemia is diagnosed when haemoglobin levels fall below 11 g/dL, with severity classified into mild (10.0–10.9 g/dL), moderate (7.0–9.9 g/dL), and severe forms (< 7.0 g/dL) (WHO,2023). Additionally, common forms of anaemia during pregnancy is categorized based on its underlying causes as iron-deficiency anaemia (IDA), folate-deficiency anaemia, and vitamin B12-deficiency anaemia (Ayoya et al., 2011). Bondevik et al. (2000) described anaemia as a condition in which pregnant women's blood lacks enough healthy red blood cells to carry sufficient oxygen to the body's tissues. Ahmad et al. (2010) further emphasized that anaemia results from increased iron demands due to the growing fetus and placenta, coupled with a physiological expansion of maternal blood volume, which dilutes haemoglobin levels. These definitions reinforce that anaemia during pregnancy is not only about reduced haemoglobin but also about the increased metabolic demands placed on the mother's body.

According to estimates by the World Health Organization (2023), anaemia affects approximately 36–37% of pregnant women worldwide. Prevalence rates ranged significantly across regions, from as low as 5.2% to as high as 65.7%, with the highest burdens observed in Sub-Saharan Africa and South Asia—regions that are not on track to meet the global anaemia reduction target by 2030 (WHO, 2021).

Studies have highlighted the severe impact of anaemia in less developed countries, where dietary iron deficiency is prevalent. Safiri et al. (2021) found that the highest anaemia prevalence rates are observed in countries like Zambia, Mali, and Burkina Faso, where poor nutrition and lack of access to iron-rich foods are key factors. A study conducted by Ozturk et al. (2017) in Ankara, Turkey, revealed that 20% of pregnant women were anaemic at the time of pregnancy detection, with most cases being mild. While the prevalence is lower compared to some less developed countries, the study highlights that anaemia still affects a significant portion of the pregnant population, emphasizing the need for early detection and management of maternal anaemia in both developed and developing countries.

India continues to face a major public health challenge with anaemia among pregnant women. In India, anaemia during pregnancy is particularly prevalent, affecting a significant proportion of women. National Family Health Survey-5 (NFHS-5) data (2019-21) revealed that overall pregnancy anaemia in India (15-49 years) as 52.2 %

(International Institute for Population Sciences (IIPS) and ICF, 2017) and Ladakh having the highest prevalence of anaemia in pregnancy (92.80%) followed by West Bengal (71.40%), Assam (65.90%), Gujarat (65%), and Odisha (64.30%). Toteja et al. (2006) reported a staggering 84.9% prevalence of anaemia among pregnant women in 16 Indian districts, with many cases classified as moderate or severe. Similarly, Agarwal et al. (2006) found anaemia prevalence exceeding 90% among pregnant and lactating women in certain Indian states, pointing to the long-term ineffectiveness of existing interventions to address the issue. These findings suggest that there is an urgent need for revisiting and strengthening anaemia prevention strategies in India. Anaemia prevalence is particularly high among tribal and socially disadvantaged groups in India. Kamath et al. (2013) reported a 55.9% prevalence of anaemia among tribal women of reproductive age in Karnataka. Nair et al. (2022) found a 40% prevalence of anaemia among antenatal women in Kozhikode, Kerala. Additionally, Sharif et al. (2023) revealed a higher prevalence of anaemia among socially disadvantaged women, with economic status being a significant determinant. These studies highlight the stark disparities in anaemia prevalence based on socioeconomic and regional factors, which call for targeted interventions to reduce the anaemia burden among the most vulnerable populations.

Determinants of Anaemia during Pregnancy

Anaemia during pregnancy is influenced by a variety of factors, with nutritional deficiencies, infections, and socioeconomic conditions being the most consistent contributors across different regions. For instance, Bondevik et al. (2000) found that in Nepal, low serum ferritin and vitamin A levels, along with infections such as hookworm, significantly increased the risk of severe anaemia. Similarly, Amengor et al. (2005) identified rural living, young age, low parity, and parasitic infections (malaria, hookworm) as key factors influencing anaemia in pregnant women in Ghana. Anorlu et al. (2006) further highlighted social and demographic influences, such as low socioeconomic status and short pregnancy intervals, as major contributors to anaemia in Nigeria.

Research from various regions also points to sociodemographic factors as significant determinants. Dim et al. (2007) and Ahmad et al. (2010) found that young maternal age, third-trimester pregnancy, HIV- positive status, and poor educational conditions were closely linked to anaemia prevalence in Nigeria and India, respectively. In Turkey, Karaoglu et al. (2010) identified iron, folate, and vitamin B12 deficiencies as major causes of anaemia, with specific risk factors like low income and high parity further compounding the issue. Ayoya et al. (2011) noted that in West and Central Africa, widespread nutritional deficiencies, poor healthcare services, and low literacy rates exacerbated the prevalence of maternal anaemia. Cultural and social barriers to iron and folic acid (IFA) supplementation also play a significant role in anaemia rates. Studies by Manortey et al. (2020) in Ghana and Williams et al. (2020) in India stressed the importance of addressing these barriers to improve supplement adherence. Zhang et al. (2021) and Singal et al. (2019) further emphasized the role of diet, physical activity, and socioeconomic status in preventing iron deficiency anaemia among pregnant women in China and rural India.

Lastly, recent studies by Rai et al. (2022) and Rahman et al. (2022) have highlighted the inadequacy of current

food fortification and supplementation programs in India and Malaysia, calling for more targeted interventions. Similarly, Mog et al. (2022) and Kuppusamy et al. (2023) stressed that rural living, low education, early pregnancies, and poor dietary intake remain significant predictors of anaemia in India. These findings underscore the importance of context-specific, multicomponent interventions that combine improved nutrition, healthcare access, and education to effectively reduce anaemia among pregnant women worldwide.

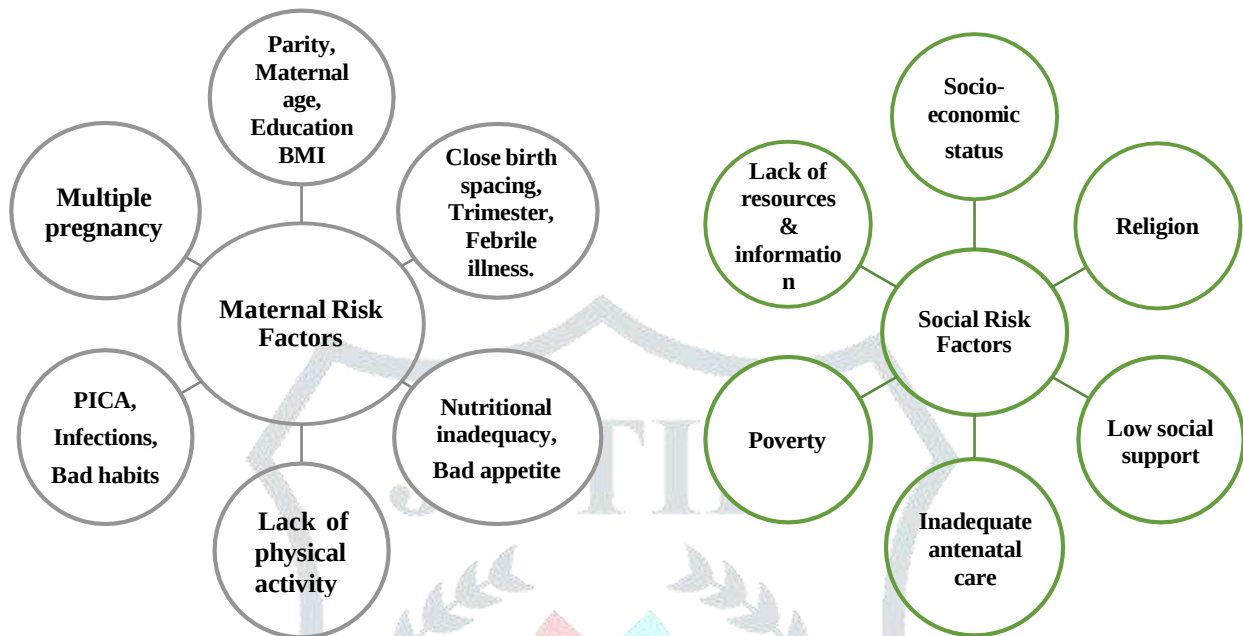


Fig. 1: Determinants of anaemia during pregnancy

Outcomes of Anaemia in Pregnancy

Pregnancy anaemia, prevalent in developing countries, significantly impacts maternal and fetal health, leading to adverse pregnancy outcomes. The Developmental Origins of Health and Disease (DOHaD) hypothesis highlights the vulnerability of the prenatal period to adverse conditions, including malnutrition, infections, and stress, which can permanently affect offspring health through developmental programming. Anaemia, particularly iron deficiency anaemia (IDA), during pregnancy has been linked to poor neurodevelopmental outcomes in children. Studies suggest that IDA during the first 1000 days of life can result in long-term deficits in socio-emotional, motor, cognitive, and physiological functioning. Gestational iron deficiency may program physiological mechanisms responsible for iron homeostasis in offspring, predisposing them to future iron deficiency regardless of adequate nutrition (Lacagnina et al., 2019). Despite interventions, infants born to iron-deficient mothers often exhibit persistently low iron levels, emphasizing the importance of early detection and treatment. Researchers, such as Tamura et al. (2001) and Cuco et al. (2005), underscored the association between foetal iron status and mental and psychomotor development, as well as the positive impact of maternal intake of vitamins B1, B6, and iron during pregnancy on neonatal behavior and neuromotor maturity.

The outcomes of anaemia during pregnancy underscore its profound impact on both maternal and neonatal health. The other research evidences regarding the outcomes of anaemia during pregnancy shows that low birth weight, preterm birth and perinatal mortality, caesarean delivery, neonatal mortality, miscarriage, preeclampsia (Rahman et al., 2020, Tiwari et al., 2021) as immediate outcomes and low general autonomous response, motor

performance & self regulation capabilities (Martinez et al., 2011), low school performances (Fararouei et al., 2010) as the long term outcomes.

Telatar et al. (2009) revealed significant differences in neonatal anthropometric measurements between infants born to anaemic and non-anaemic mothers, emphasizing the adverse effects of severe anaemia on height, weight, and head circumference. Furthermore, Rohilla et al. (2010) elucidated the heightened risks associated with severe maternal anaemia, including pre-term births, hypertensive disorders, fetal distress, and maternal mortality, underscoring the urgent need for preventive measures to safeguard maternal and perinatal health. Additionally, Fararouei et al. (2010) highlighted the long-term implications of maternal anaemia, showcasing the positive correlation between maternal haemoglobin levels during pregnancy and offspring's educational achievement later in life, suggesting that adequate iron prophylaxis during pregnancy may contribute to improved educational outcomes and overall well-being of the offspring.

Moreover, the intergenerational impact of maternal anaemia was emphasized by Singh et al. (2021) and Heesemann et al. (2021), who found that children born to anaemic mothers exhibited higher rates of anaemia, undernutrition, and anaemia persistence in rural India, highlighting the need for targeted interventions to break the cycle of anaemia. Additionally, Nakahara et al. (2022) revealed associations between maternal haemoglobin levels during pregnancy and adverse developmental outcomes in infants, such as sleep problems and abnormal motor skills in Japan, emphasizing the importance of addressing maternal anaemia to promote healthy infant development. Furthermore, Shah et al. (2022) and Dorsamy et al. (2022) demonstrated the increased risks of adverse birth outcomes among anaemic pregnant women in Pakistan and South Africa, respectively, including low birth weight, preterm birth, and hypertensive disorders of pregnancy. The complex ramifications of maternal anaemia extend beyond pregnancy, affecting both maternal and child health outcomes.

Development encompasses the transition from dependent infancy to independent adulthood, with psychomotor development comprising physical, cognitive, socio-emotional, and language domains. Developmental delay, categorized as mild, moderate, or severe, occurs when a child fails to meet age- appropriate milestones compared to peers (Mithyantha et al., 2017). Global developmental delay (GDD) refers to significant delays across two or more domains in children under five (Shevell et al., 2003). Iron deficiency anaemia during the first thousand days of life, particularly prenatal to 24 months, is linked to enduring deficits in socio-emotional, motor, cognitive, and physiological functioning, attributed to mechanisms such as altered dopamine metabolism, myelination, hippocampal structure, maternal depression, and unresponsive caregiving (De Pee et al., 2002; Georgieff et al., 2002; Emamghorashi and Heidari, 2004). Interventions targeting iron deficiency and promoting early child development, including ensuring adequate iron intake, nutritional status, and fostering responsive mother-child interactions and early learning opportunities, are crucial (Georgieff et al., 2002; Geltman et al., 2004). Gestational iron deficiency seems to program physiological mechanisms affecting iron homeostasis, increasing the likelihood of future iron deficiency in offspring, irrespective of adequate nutrition (Georgieff et al., 2002; Geltman et al., 2004).

Several studies conducted in the 1990s and beyond have highlighted the significant impact of maternal iron

deficiency anaemia (IDA) on fetal development and subsequent child outcomes. Tamura et al. (2001) found that poor iron status in utero was associated with diminished mental and psychomotor performance at age 5. Dellis (2009) observed behavioural and developmental disturbances in 9-month-old infants with a history of IDA in Tanzania. Similarly, Chang et al. (2011) noted less positive affect and more passive behavior in 4-year-old children with chronic IDA in infancy. Bhate et al. (2012) discovered lower mental and social developmental quotients in children of mothers deficient in vitamin B12. Tran et al. (2013) demonstrated adverse effects on infant cognitive development due to antenatal exposure to IDA and maternal common mental disorders. Mireku et al. (2015) revealed a complex relationship between maternal haemoglobin levels and infant cognitive and motor functions, suggesting an optimal range for maternal Hb concentration. Berglund et al. (2017) identified negative associations between maternal ID, pre-gestational overweight/obesity, and infant neurodevelopment at 18 months. Bajalan et al. (2018) found increased chances of developmental delay in infants associated with maternal gestational diabetes, anaemia, preeclampsia, and other medical disorders. Finally, Wieggersma et al. (2019) linked prenatal maternal anaemia particularly in early pregnancy, with an elevated risk of autism spectrum disorder (ASD), attention-deficit/hyperactivity disorder (ADHD), and intellectual disability (ID) in offspring, based on data from the Stockholm Youth Cohort.

Conclusion

Anaemia remains a critical global public health concern due to its extensive and long-lasting consequences on both mothers and their children. When anaemia occurs during pregnancy, its impact becomes particularly profound, as it compromises the health and development of two lives simultaneously. Although anaemia is largely preventable and treatable through timely screening, appropriate supplementation, and improved dietary intake, it continues to affect millions of women worldwide. This persistent burden contributes significantly to maternal morbidity, adverse birth outcomes, and developmental delays across cognitive, motor, and socio-emotional domains in children.

The reviewed evidence underscores the importance of early identification and management of maternal anaemia, especially during the first 1000 days of life—a critical window for growth and neurodevelopment. However, the literature also reveals several research gaps. The multifactorial determinants of anaemia—encompassing nutritional deficiencies, infections, socio-economic barriers, and cultural practices—are not fully understood in many contexts. Furthermore, the long-term effects of maternal anaemia on child development, educational performance, and adult health outcomes require more longitudinal and context-specific investigation.

Therefore, future research should focus on developing and evaluating integrated intervention strategies that combine nutritional supplementation, health education, antenatal care strengthening, and community-based behavioural change models. Enhancing maternal nutrition literacy, improving access to health services, and tailoring interventions to socio-cultural settings will be crucial in breaking the intergenerational cycle of anaemia. Addressing these challenges is vital not only for improving pregnancy outcomes, but also for

promoting lifelong health, development, and well-being among future generations.

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