Iron Deficiency Anemia in Children: Causes, Symptoms, and Prevention: A Critical Review

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Abstract
Iron deficiency anemia (IDA) is one of the most common nutritional disorders affecting children worldwide and remains a significant public health concern due to its impact on growth, cognitive development, immune function, and overall well-being. This literature review examines the current evidence on the causes, clinical manifestations, prevention strategies, and policy implications of pediatric iron deficiency anemia. The review highlights that although iron deficiency is the primary cause of childhood anemia, its etiology is multifactorial and is influenced by other micronutrient deficiencies, infectious diseases, chronic inflammation, genetic disorders, poor dietary diversity, and socioeconomic factors. Clinical manifestations range from nonspecific symptoms such as pallor and fatigue to long-term complications including impaired cognitive development, delayed physical growth, and reduced academic performance. Evidence from the reviewed studies indicates that iron supplementation, food fortification, micronutrient powders, and nutrition education are effective strategies for reducing the burden of IDA, particularly when implemented alongside infection control measures and improvements in maternal and child health. The review also identifies ongoing debates regarding the proportion of anemia attributable to iron deficiency in different populations and the context-specific implementation of iron interventions, especially in malaria-endemic regions. Overall, the findings emphasize that sustainable prevention of pediatric IDA requires integrated, multisectoral approaches that combine nutritional interventions with healthcare services, infection prevention, food security, water, sanitation, and hygiene (WASH) initiatives, and caregiver education. Strengthening early screening and tailoring interventions to local epidemiological and socioeconomic conditions are essential for reducing the global burden of iron deficiency anemia in children.

Keywords
Iron deficiency anemia; Pediatrics; Children; Iron supplementation; Nutritional deficiency; Micronutrient deficiency; Childhood anemia; Prevention; Food fortification; Public health.

1. Introduction

Iron deficiency anemia (IDA) remains the most common form of anemia in children globally and is a leading contributor to morbidity, growth delay, and impaired cognitive development in early life (Khan, 2018; Onyeneho et al., 2019; Wang et al., 2015). The multifactorial nature of pediatric anemia requires an integrated understanding of nutritional, infectious, environmental, and socio-economic determinants to inform effective prevention strategies. Across diverse settings, iron deficiency is repeatedly identified as the predominant etiologic factor, though many contexts reveal substantial contributions from other micronutrient deficiencies, infections, and inflammation that modify iron metabolism and erythropoiesis (Al-Jawaldeh et al., 2021; Brabin et al., 2001; Crawley, 2004; Fançony et al., 2020; Hazavehei et al., 2006; J, 2015; Onyeneho et al., 2019). This review synthesizes evidence on the causes, clinical manifestations, and preventive interventions for IDA in children, with emphasis on modifiable risk factors and population-level prevention.

2. Causes and Etiopathogenesis

Iron deficiency is widely recognized as the leading nutritional cause of iron deficiency anemia (IDA) in children. However, evidence suggests that the causes of pediatric anemia are multifactorial, and the proportion of anemia attributable to iron deficiency varies across populations. Studies have shown that although iron deficiency remains the primary contributor, other nutritional deficiencies, infections, inflammatory conditions, and genetic factors also influence the development of anemia (Al-Jawaldeh et al., 2021; Brabin et al., 2001; Fançony et al., 2020; Onyeneho et al., 2019; Wang et al., 2015). For example, research conducted in Nepal found that iron deficiency was one of the most common biological causes of anemia among young children, but vitamin B12 deficiency and inadequate dietary intake also contributed significantly to anemia risk (Locks et al., 2023). Similarly, studies from India have demonstrated that maternal anemia and poor dietary practices increase the likelihood of childhood anemia, reflecting the influence of shared nutritional status and infant feeding practices within households (Onyeneho et al., 2019). These findings support the view that pediatric IDA should not be attributed solely to iron deficiency, as deficiencies in other micronutrients such as folate, vitamins A, B-complex, C, D, E, zinc, and copper may impair iron metabolism and contribute to anemia (Al-Jawaldeh et al., 2021; Crawley, 2004).

In addition to nutritional deficiencies, several non-nutritional factors play an important role in the development of pediatric anemia. Infectious diseases such as malaria, helminth infections, and HIV can contribute directly to anemia through blood loss, hemolysis, chronic inflammation, and impaired erythropoiesis. In malaria-endemic regions, malaria-related hemolysis and inflammatory responses substantially increase the burden of anemia beyond the effects of iron deficiency alone. Consequently, integrated interventions that combine malaria prevention, deworming, and nutritional support have been recommended to reduce childhood anemia (Akter, 2020; Crawley, 2004; Fançony et al., 2020). Genetic hemoglobin disorders and chronic inflammatory conditions also interfere with iron utilization and red blood cell production, further contributing to anemia. Moreover, maternal health has an important influence on childhood anemia, as maternal anemia has consistently been associated with a higher risk of anemia in offspring, highlighting the effects of intergenerational nutritional status and shared environmental factors (Hazavehei et al., 2006).

Diet quality is another important determinant of iron deficiency anemia in children. Poor dietary diversity and monotonous feeding patterns have been consistently associated with a greater risk of anemia, regardless of iron intake alone. Studies from China and Nepal reported that children consuming less diverse diets were more likely to develop anemia, particularly those aged 12–35 months, with iron and vitamin B12 deficiencies identified as major contributing factors (Locks et al., 2023; Wang et al., 2015). These findings emphasize the importance of adequate dietary diversity during early childhood to ensure sufficient intake of essential micronutrients required for normal growth, iron metabolism, and healthy red blood cell production.

3. Symptoms and Clinical Implications

Iron deficiency anemia (IDA) in children commonly presents with pallor, fatigue, weakness, irritability, and poor appetite. In many cases, particularly during the early stages, symptoms may be mild or nonspecific, making diagnosis based on clinical presentation alone difficult. As the condition progresses, children may also experience delayed growth, impaired cognitive development, reduced attention span, and behavioral changes. Because of these potential consequences, many pediatric guidelines recommend early screening, particularly for infants, toddlers, and children at increased risk, such as those who are exclusively

breastfed without appropriate iron supplementation or who consume non–iron-fortified formula (Khan, 2018; Onyeneho et al., 2019; Wang et al., 2015). Screening recommendations vary across countries according to national health policies, available resources, and access to healthcare, although routine screening during early childhood is generally encouraged for high-risk populations (Khan, 2018; Wang et al., 2015).

Untreated IDA can have significant long-term consequences that extend beyond hematologic abnormalities. Iron deficiency during critical periods of growth has been associated with impaired cognitive and motor development, delayed physical growth, weakened immune function, and poorer academic performance. Evidence also suggests that the effects of early iron deficiency may persist even after anemia has been corrected, potentially influencing educational achievement and future economic productivity. These findings highlight the importance of early detection, timely treatment, and preventive strategies to minimize the long-term impact of IDA on child development (Hazavehei et al., 2006; Khan, 2018; Onyeneho et al., 2019; Wang et al., 2015).

4. Prevention and Intervention Strategies

Iron supplementation and food fortification remain the cornerstone of preventing iron deficiency anemia in children. The World Health Organization (WHO) and many national health programs recommend iron supplementation for children at high risk of deficiency, particularly those aged 6–23 months. Numerous systematic reviews and clinical studies have shown that iron supplementation effectively reduces the prevalence of IDA and improves hemoglobin levels, although its effectiveness may differ according to age, nutritional status, and local disease burden (Al-Jawaldeh et al., 2021; Brabin et al., 2001; Crawley, 2004; Fançony et al., 2020; Onyeneho et al., 2019). Randomized controlled trials conducted in low- and middle-income countries have generally demonstrated improvements in hematologic outcomes following iron supplementation, while findings regarding cognitive benefits have been less consistent. These studies also emphasize the importance of monitoring safety, particularly in settings with a high burden of infectious diseases (Pasricha et al., 2021). Food fortification programs, including the addition of iron and other micronutrients to staple foods such as wheat and maize flour, have also contributed to reductions in anemia prevalence, although their effectiveness depends on program coverage, dietary habits, and overall nutritional status (Al-Jawaldeh et al., 2021; Fançony et al., 2020).

Micronutrient powders containing iron and other essential vitamins and minerals have emerged as another preventive strategy, particularly for young children in resource-limited settings. Evidence suggests that these home-based supplements improve iron status and reduce the prevalence of iron deficiency and anemia. However, improvements in cognitive development have been inconsistent, indicating that correcting iron deficiency alone may not fully address developmental outcomes. Consequently, several reviews recommend combining iron supplementation with other micronutrients, maternal nutrition programs, and measures to prevent and treat infections in order to achieve greater overall benefits (Al-Jawaldeh et al., 2021; Fançony et al., 2020; Pasricha et al., 2021).

Nutrition education also plays an important role in preventing pediatric IDA. Educational programs that increase caregivers' knowledge of iron-rich foods, appropriate complementary feeding practices, and dietary diversity have been shown to improve feeding behaviors and awareness of anemia prevention. Although improvements in knowledge do not always translate into immediate changes in hemoglobin levels, sustained educational interventions can support healthier dietary practices over time. Studies from Nigeria reported improved

caregiver knowledge following nutrition education, while interventions based on the PRECEDE model in Iran demonstrated positive changes in maternal behaviors and higher recovery rates among children with IDA (Hazavehei et al., 2006; Nwaba et al., 2022).

In selected cases where oral iron therapy is ineffective, poorly tolerated, or insufficient to correct severe iron deficiency, intravenous iron may be considered. Clinical studies have reported rapid improvements in hemoglobin concentrations following parenteral iron therapy, particularly among individuals with severe anemia or conditions that limit iron absorption. However, evidence supporting its routine use in children remains limited, and treatment decisions should consider safety, availability, cost, and clinical necessity (Sinha & Amit, 2020).

Given the complex causes of pediatric anemia, many researchers advocate integrated approaches that extend beyond iron supplementation alone. Effective prevention requires coordinated efforts that combine nutritional interventions with infection control, maternal health services, improved water, sanitation, and hygiene (WASH), food security initiatives, and poverty reduction programs. Community-based interventions implemented in countries such as Nepal and Mozambique have demonstrated that combining nutrition-specific and nutrition-sensitive strategies with strengthened healthcare services can substantially reduce the burden of childhood anemia. Overall, the literature consistently emphasizes that sustainable reductions in pediatric anemia require addressing both nutritional deficiencies and the broader social, environmental, and health-related factors that contribute to the condition (Akter, 2020; Al-Jawaldeh et al., 2021; Fançony et al., 2020; Locks et al., 2023).

5. Areas of Debate

Although iron deficiency is the leading cause of pediatric iron deficiency anemia (IDA), the proportion of anemia attributable to iron deficiency varies considerably across populations. Regional studies have shown that, in some settings, iron deficiency accounts for less than half of all anemia cases, indicating that other factors such as deficiencies in additional micronutrients, infectious diseases, chronic inflammation, and genetic disorders also play substantial roles. These findings suggest that strategies focusing solely on iron supplementation may be insufficient in areas where multiple causes of anemia coexist, highlighting the need for broader nutritional interventions and effective infection control measures (Al-Jawaldeh et al., 2021; Fançony et al., 2020; J, 2015).

The use of iron supplementation and food fortification also remains an area of ongoing discussion, particularly in malaria-endemic and high-infection settings. While iron interventions are effective in reducing iron deficiency and improving hemoglobin levels, concerns have been raised regarding their potential effects on infection risk in certain populations. Current evidence indicates that the benefits of iron supplementation generally outweigh the risks when programs are carefully targeted and implemented alongside malaria prevention, deworming, and other infection control measures. Consequently, many international guidelines recommend that iron interventions be adapted to local epidemiological conditions rather than applied uniformly across all settings (Crawley, 2004; Fançony et al., 2020; Pasricha et al., 2021).

Another area of debate concerns the effectiveness of caregiver education as a stand-alone intervention. Although educational programs consistently improve caregivers' knowledge of iron-rich foods, dietary diversity, and appropriate feeding practices, these improvements do not always translate into sustained behavioral change or measurable improvements in

children's hemoglobin levels. Socioeconomic constraints, food insecurity, limited access to nutritious foods, and cultural dietary practices often reduce the impact of education alone. Therefore, many studies recommend combining nutrition education with broader social and economic support to achieve more sustainable improvements in child nutrition and anemia outcomes (Hazavehei et al., 2006; Nwaba et al., 2022).

6. Implications for Policy and Practice

The available evidence highlights the importance of strengthening policies aimed at the early detection and prevention of iron deficiency anemia among children. Routine screening of infants, toddlers, and other high-risk groups should be incorporated into primary healthcare services whenever feasible, as early diagnosis and treatment can reduce the adverse effects of IDA on growth, cognitive development, and overall health (Khan, 2018; Onyeneho et al., 2019; Wang et al., 2015).

Iron supplementation and food fortification programs should be implemented according to local health priorities and disease patterns. In regions where malaria, helminth infections, or chronic inflammation are common, iron interventions should be integrated with infection prevention and control programs to maximize their effectiveness while minimizing potential risks (Al-Jawaldeh et al., 2021; Crawley, 2004; Fançony et al., 2020).

Addressing pediatric anemia also requires a multisectoral approach that extends beyond healthcare services. Nutrition-sensitive interventions, improved water, sanitation, and hygiene (WASH), food security initiatives, and strengthened maternal and child health programs are essential for tackling the underlying social and environmental determinants of anemia. Community-based programs that combine these strategies have shown greater potential to reduce regional disparities in anemia prevalence and improve child health outcomes (Akter, 2020; Fançony et al., 2020).

Finally, caregiver education should remain an important component of anemia prevention programs but should be supported by practical measures that improve access to iron-rich foods and promote healthy feeding practices. Regular monitoring of children's hematologic status can help evaluate the effectiveness of these interventions and guide future improvements in policy and clinical practice (Hazavehei et al., 2006; Nwaba et al., 2022).

7. Conclusion

The literature consistently identifies iron deficiency as the central nutritional driver of pediatric anemia, but acknowledges substantial contributions from other micronutrient deficiencies, infections, inflammation, and socio-economic determinants. Prevention strategies that combine iron supplementation/fortification with nutrition education and broad public health interventions addressing infectious disease burden, sanitation, and food security are most likely to reduce the prevalence and harms of IDA in children. National and regional policies should tailor interventions to local etiologic profiles, ensuring integration across health, education, and development sectors to achieve durable improvements in child health and development.

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