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Iron Deficiency Anaemia Among Vulnerable Populations: An Analytical Review of Intervention Approaches and Outcomes

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Abstract

Iron deficiency anaemia (IDA) is the most common form of anaemia worldwide, predominantly affecting women of reproductive age, infants, and children. It is highly prevalent in both rural and urban populations, particularly in tropical and developing regions. Iron deficiency accounts for approximately one-third of anaemia cases globally. When insufficient iron is available for haemoglobin synthesis, red blood cells become pale and small, resulting in hypochromic and microcytic anaemia. Despite the implementation of multiple intervention strategies, the prevalence of IDA remains high in many developing countries. This review analyses various intervention studies aimed at preventing and controlling iron deficiency anaemia among children and women. Electronic databases including Scopus, Web of Science, and Google Scholar were searched for articles published between 2013 and 2025. Studies evaluating supplementation, food fortification, dietary diversification, nutrition education, ferritin-guided strategies, and integrated approaches were included. Data were narratively synthesized based on intervention type, target population, sample size, duration, and outcomes. Findings indicate that iron supplementation and food fortification significantly improve haemoglobin levels, though effectiveness varies depending on adherence, baseline iron status, and contextual factors. Integrated approaches combining supplementation with education and infection control demonstrate greater sustainability. Continued efforts are required to enhance coverage, compliance, and long-term impact.

Keywords: Iron deficiency anaemia, intervention strategies, oral iron supplementation, biofortification, nutrition education, systematic review

Introduction

Iron deficiency anaemia continues to be a major global public health concern. It is one of the most widespread micronutrient deficiencies, particularly among children and women of reproductive age. According to the World Health Organization (2021), anaemia affects nearly one-third of the world's population, with iron deficiency accounting for approximately 50% of cases worldwide. The high prevalence reflects persistent nutritional inadequacies, socioeconomic disparities, and limited access to effective health and nutrition services.

Anaemia is defined as a condition in which haemoglobin concentration falls below established cut-off levels, reducing the blood's oxygen-carrying capacity (World Health Organization, 2011). Iron deficiency arises due to inadequate dietary intake, poor absorption, increased physiological requirements during growth and pregnancy, chronic blood loss, parasitic infections, and inflammatory conditions (Stoltzfus, 2011).

In children, IDA adversely affects physical growth, cognitive development, psychomotor performance, immune function, and academic achievement (Lozoff et al., 2006). Among women, especially adolescents and pregnant women, IDA contributes to fatigue, reduced productivity, impaired immunity, and increased maternal morbidity and mortality. During pregnancy, anaemia is associated with preterm delivery, low birth weight, and increased perinatal mortality (Allen, 2000).

In India, IDA remains highly prevalent despite longstanding national nutrition programs. Data from the National Family Health Survey (NFHS-5, 2019–21) indicate that more than half of children aged 6–59 months and women aged 15–49 years are anaemic. Contributing factors include poverty, low dietary diversity, predominantly plant-based diets with poor iron bioavailability, frequent infections, and limited nutrition awareness.

To combat IDA, multiple intervention strategies have been implemented. These include iron and folic acid supplementation, food fortification, dietary diversification, nutrition education, deworming, and behaviour change communication (Bhutta et al., 2013). In India, national initiatives such as Anaemia Mukt Bharat under the National Health Mission emphasize a life-cycle approach to anaemia control. Similarly, POSHAN Abhiyaan focuses on improving maternal and child nutrition outcomes through integrated community-based strategies.

Although these interventions have demonstrated effectiveness in controlled settings, real-world implementation faces challenges related to coverage, adherence, acceptability, and sustainability (Ruel & Alderman, 2013). Therefore, evaluating the combined impact of intervention strategies is essential to inform evidence-based policy and program strengthening.

Objectives

1. To systematically review and analyse various intervention studies aimed at preventing and controlling iron deficiency anaemia among children and women.
2. To assess the types of interventions employed and their impact on anaemia-related outcomes.

Method

Study Design

A systematic review of intervention-based studies was conducted.

Search Strategy

Relevant articles published between 2015 and 2025 were identified through electronic databases including Scopus, Web of Science, and Google Scholar.

Inclusion Criteria

- Peer-reviewed research articles published in English (2015–2025)
- Intervention-based studies (randomized controlled trials, quasi-experimental studies, community-based interventions)
- Studies conducted among children (2 months–18 years) and women of reproductive age (15–45 years)
- Studies evaluating at least one intervention related to iron deficiency anaemia

Exclusion Criteria

- Case reports, dissertations, editorials, conference abstracts, commentaries
- Observational studies without intervention components
- Studies addressing anaemia due to non-iron causes (e.g., haemoglobinopathies, protein deficiency)
- Animal studies

Data Extraction and Synthesis

Data were extracted and narratively synthesized based on:

- Type of intervention
- Target population
- Sample size
- Duration
- Key outcomes

Results

The present systematic review examined intervention-based studies published between 2015 and 2025 focusing on the prevention and control of iron deficiency anaemia (IDA) among children and women of reproductive age. The findings were categorized into six major intervention approaches: oral iron supplementation, home and industrial fortification, biofortification, ferritin/hepcidin-guided strategies, nutrition education, and integrated multi-component interventions.

Oral Iron Supplementation

Oral iron supplementation remains the most widely implemented strategy for IDA control. Evidence consistently demonstrates that daily iron supplementation significantly increases haemoglobin levels and reduces anaemia prevalence among infants, children, adolescents, and women (DaSilva Lopez et al., 2021; World Health Organization, 2023).

Meta-analytic findings indicate that daily supplementation is more effective in increasing haemoglobin levels compared to weekly or intermittent regimens (Ablewi et al., 2024). However, alternate-day dosing has been shown to improve fractional iron absorption and reduce gastrointestinal side effects, thereby enhancing tolerability and adherence (Stoffel et al., 2020; Dhanvijay et al., 2025).

These findings suggest that while daily supplementation may produce faster haematological improvement, alternate-day regimens may offer comparable long-term benefits with improved compliance.

Home and Industrial Fortification

Home fortification with multiple micronutrient powders (MNPs) significantly reduced anaemia and iron deficiency among children younger than two years in low- and middle-income countries (Suchdev et al., 2020). Similarly, industrial fortification of complementary foods, cereals, and milk products improved haemoglobin levels and overall micronutrient status, particularly when multi-micronutrient fortification was used rather than single iron fortification (Collé et al., 2022).

The effectiveness of fortification strategies was found to depend on coverage, regular consumption, and baseline prevalence of anaemia.

Biofortification

Biofortified staple crops, such as iron- and zinc-enriched pearl millet, demonstrated modest improvements in haemoglobin levels, particularly among children who were iron deficient at baseline (Mehta et al., 2022). However, the overall impact on iron status and growth indicators was limited, suggesting that biofortification may be more beneficial when combined with complementary nutrition strategies.

Ferritin/Hepcidin-Guided Strategies

Targeted supplementation based on biomarkers such as hepcidin and ferritin did not show superior outcomes compared to standard WHO-recommended universal supplementation regimens (Bah et al., 2019; Wegmuller, 2023). While theoretically promising for individualized treatment, such approaches may be limited by feasibility, cost, and implementation challenges in resource-constrained settings.

Nutrition Education Interventions

School-based and theory-driven educational interventions significantly improved knowledge, attitudes, and dietary practices related to iron intake (Salam et al., 2023; Rakhshani et al., 2025). Digital game-based and structured educational programs also demonstrated improvements in haemoglobin levels in some adolescent populations (Ghadam et al., 2022). However, education alone did not consistently reduce iron deficiency anaemia unless combined with supplementation or dietary improvement strategies.

Integrated Multi-Component Approaches

Integrated interventions combining iron supplementation, deworming, malaria control, dietary counselling, and behavioural change communication demonstrated greater effectiveness compared to single interventions (Pasricha et al., 2020). The net health benefits were highest in regions with high anaemia prevalence and lower infection burdens, emphasizing the importance of contextual adaptation.

Table 1
Summary of Intervention Studies on Iron Deficiency Anaemia (2013–2025)

Author(s), Year &Country	Intervention Strategy	Sample Size & Duration	Key Findings
Pasricha et al., 2013, Australia	Daily iron and folic acid supplementation	35 eligible RCTs (from 9,533 citations); children 4–23 months	Daily iron supplementation reduced anaemia; further research needed on non-haematological outcomes.
Bah et al., 2019, The Gambia (UK collaboration)	Hepcidin-guided screen-and-treat strategy	19 rural pregnant women (14–22 weeks gestation)	No significant advantage over WHO-recommended regimen in adherence or safety.
Suchdev et al., 2020, USA	Home fortification with multiple micronutrient powders (MNPs)	29 studies; 33,147 children; 2–44 months	Effective in reducing anaemia and iron deficiency in children under two years.
Pasricha et al., 2020, Multi-country (78 countries)	Universal distribution of iron-containing MNPs	78 countries; 6-month intervention	Highest benefit in areas with high anaemia and low infection burden; impact reduced with poor coverage.
Stoffel et al., 2020, Switzerland	Daily vs. alternate-day oral iron supplementation	19 non-pregnant women; crossover study	Alternate-day dosing improved fractional iron absorption and tolerability.
DaSilva Lopez et al., 2021, Japan	Nutrition-specific interventions (systematic review)	75 systematic reviews	Daily iron supplementation increased haemoglobin and reduced IDA risk across life stages.
Collé et al., 2022, Hungary	Industrial food fortification	16 studies; 6,423 participants	Multi-micronutrient fortification more effective than single iron fortification.
Mehta et al., 2022, India (Mumbai)	Biofortified pearl millet complementary feeding	223 children (12–18 months)	Improved haemoglobin in iron-deficient subgroups; limited overall impact.

Scholomovsky et al., 2022, Poland	Dietary intervention in pregnant women	7 RCTs (from 7,825 screened)	Increased nutrient intake and counselling were effective in preventing/treating IDA.
Ghadam et al., 2022, Iran	Digital game-based nutrition education	176 adolescent girls; 14 weeks	Improved knowledge, attitude, and haemoglobin levels; limited impact on IDA prevalence.
World Health Organization, 2023, Global	Daily iron supplementation guidelines	Infants 6–23 months	Recommended in settings with $\geq 40\%$ anaemia prevalence.
Wegmuller, 2023, The Gambia	Hepcidin-guided supplementation (RCT)	407 enrolled children	Less efficacious than standard iron supplementation.
Salam et al., 2023, India (Karnataka)	School-based nutrition education	455 students; 7 weeks	Improved awareness, dietary behaviour, and demand for supplements.
Ablewi et al., 2024, Saudi Arabia	Daily vs. intermittent iron supplementation (meta-analysis)	Studies from 2012–2023; children 2 months–18 years	Daily supplementation increased haemoglobin more than weekly regimens.
Pantopoulos, 2024, Canada	Oral iron supplementation review	Narrative review	Formulation choice should be individualized based on tolerance and iron status.
Dhanvijay et al., 2025, India	Daily vs. alternate-day oral iron (meta-analysis)	1,014 participants	Comparable effectiveness; alternate-day dosing showed better tolerability.
Rakhshani et al., 2025, Iran	Education based on Theory of Planned Behaviour	160 girls (14–19 years); 4 months	Significant improvement in preventive nutritional behaviours.

Discussion

The findings of this review highlight that iron supplementation remains the cornerstone of IDA management. Consistent with global recommendations from the World Health Organization (2023), daily iron supplementation significantly reduces anaemia prevalence, particularly in high-burden settings. However, emerging evidence supports alternate-day dosing as a viable alternative for improving adherence and minimizing side effects (Stoffel et al., 2020; Dhanvijay et al., 2025).

Fortification strategies, particularly multi-micronutrient fortification, offer sustainable population-level solutions, especially in communities where dietary diversity is limited (Collé et al., 2022; Suchdev et al., 2020). Unlike supplementation programs that rely heavily on compliance, fortification can improve iron intake without requiring active behavioural changes.

Biofortification and targeted biomarker-guided strategies represent innovative approaches but require further large-scale trials to confirm long-term effectiveness and cost-efficiency (Bah et al., 2019; Mehta et al., 2022).

Educational interventions significantly enhance knowledge and preventive behaviours; however, behavioural change alone may not sufficiently correct biological iron deficiency.

Therefore, education should complement, rather than replace, supplementation and fortification programs (Salam et al., 2023).

Integrated approaches appear to yield the most sustainable outcomes, as they address both biological and socio-environmental determinants of anaemia (Pasricha et al., 2020). These findings align with multi-sectoral frameworks emphasizing nutrition-sensitive and nutrition-specific interventions (Bhutta et al., 2013).

In the Indian context, national initiatives such as Anaemia Mukh Bharat and POSHAN Abhiyaan provide strong policy frameworks. However, persistent high prevalence rates indicate challenges related to coverage gaps, supply chain issues, compliance barriers, and socio-cultural factors influencing dietary practices.

Implications

Public Health Implications

- Daily or alternate-day iron supplementation should be implemented based on population needs and tolerability.
- Multi-micronutrient fortification programs should be expanded in high-burden areas.
- Integrated, multi-sectoral approaches combining supplementation, infection control, and education are more effective than single interventions.

Policy Implications

- Strengthening monitoring and evaluation mechanisms within national programmes is essential.
- Behaviour change communication should be incorporated into all supplementation initiatives to improve adherence.
- Targeted strategies should consider baseline anaemia prevalence, infection burden, and dietary patterns.

Research Implications

- Large-scale, high-quality randomized controlled trials are needed to evaluate long-term outcomes of biofortification and biomarker-guided interventions.
- More implementation research is required to assess real-world effectiveness and sustainability.
- Studies examining cost-effectiveness across diverse settings would support evidence-based policy decisions.

Limitations

Several limitations must be acknowledged.

1. The review relied on studies published in English, potentially introducing language bias.
2. Considerable heterogeneity existed in study designs, populations, intervention duration, and outcome measures, limiting direct comparability.
3. Many included studies were conducted in controlled settings, which may not reflect real-world implementation challenges.
4. Publication bias may have influenced findings, as studies reporting positive outcomes are more likely to be published.
5. Some interventions had short follow-up durations, preventing assessment of long-term sustainability.

Despite these limitations, the review provides comprehensive evidence on current intervention strategies and highlights the importance of integrated, context-specific approaches for reducing iron deficiency anaemia among vulnerable populations.

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