IRON DEFICIENCY ANAEMIA IN PRESCHOOL-AGED CHILDREN: PREVALENCE AND PREVENTIVE STRATEGIES

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ABSTRACT: *Iron deficiency anaemia remains the most prevalent nutritional deficiency disorder affecting preschool-aged children globally, with disproportionate burden concentrated in low-resource settings. This comprehensive scientific review examines contemporary epidemiological patterns and evidence-based preventive strategies for iron deficiency anaemia in children aged six to fifty-nine months. Analysis of current evidence reveals that preschool children constitute the highest-risk population group, with global prevalence estimates approximating forty-two percent in this age demographic. Recent large-scale epidemiological investigations demonstrate persistent geographic and socioeconomic disparities, with prevalence rates ranging from 5.3 percent in northeastern China to 15.8 percent in central Chinese provinces. The etiology of iron deficiency anaemia in this age group is multifactorial, encompassing inadequate dietary iron intake, poor iron bioavailability, accelerated growth requirements, and suboptimal feeding practices. Preventive interventions operate across complementary levels: nutrition-specific approaches including daily iron supplementation, multiple micronutrient powder home fortification, lipid-based nutrient supplementation, and iron fortification of staple foods; nutrition-sensitive strategies addressing dietary diversity, feeding practices, and maternal education; and public health measures encompassing food fortification policies and health system*

strengthening. Network meta-analytic evidence demonstrates that multiple micronutrient supplementation achieves the greatest reduction in iron deficiency anaemia risk, while lipid-based nutrient supplementation produces the largest increase in haemoglobin concentration among preschool children. Implementation challenges include supply chain constraints, adherence difficulties, and safety considerations in malaria-endemic regions. This review concludes that effective prevention requires integrated, multi-level approaches tailored to local epidemiological contexts and health system capacities, with particular emphasis on the first one thousand days of life as a critical intervention window.

KEY WORDS: *iron deficiency anaemia; preschool children; prevalence; epidemiology; prevention; micronutrient supplementation; food fortification; dietary diversity; public health nutrition.*

INTRODUCTION

Iron deficiency anaemia represents the most common and widespread nutritional disorder affecting children worldwide, with profound implications for child health, development, and human capital formation . The condition arises when insufficient iron availability compromises haemoglobin synthesis, leading to reduced oxygen-carrying capacity of blood and consequent impairment of tissue function. Among the diverse populations affected by this disorder, preschool-aged children aged six to fifty-nine months emerge as the most vulnerable demographic group, bearing the highest prevalence and most severe developmental consequences. The World Health Organization estimates that globally, approximately forty-two percent of preschool-aged children experience anaemia, with iron deficiency accounting for at least half of these cases . This staggering burden translates to an estimated 273 million anaemic

children under five years of age worldwide, concentrated predominantly in low-income and lower-middle-income countries but by no means confined to these settings. Even in high-income nations, iron deficiency anaemia persists as a significant public health concern, with recent multicentre studies from Croatia documenting substantial tertiary care burden among preschool-aged children referred to paediatric haematology services . The public health significance of iron deficiency anaemia in early childhood extends far beyond haematological parameters. During the preschool period, the brain undergoes rapid development and exhibits heightened sensitivity to iron availability. Iron serves as an essential cofactor for enzymes involved in neurotransmitter synthesis, myelination, and neuronal energy metabolism. Consequently, iron deficiency during this critical developmental window produces lasting impairments in cognitive function, motor development, and socio-emotional regulation, deficits that may persist despite subsequent iron repletion . The economic ramifications are equally substantial, with compromised cognitive development translating to reduced educational attainment and diminished lifetime earnings. Despite decades of research and numerous global health initiatives, progress in reducing childhood iron deficiency anaemia prevalence has been insufficient and uneven. This persistent gap between knowledge and implementation necessitates comprehensive examination of current evidence regarding disease burden and preventive interventions. The present review addresses two fundamental questions: What is the contemporary epidemiology of iron deficiency anaemia among preschool-aged children across diverse global settings? What preventive strategies demonstrate efficacy and effectiveness in reducing this burden? This review synthesizes evidence from recent large-scale epidemiological investigations, systematic reviews, network meta-analyses, and randomized controlled trials to provide a comprehensive

overview of prevalence patterns and prevention approaches. The primary objectives are to characterize current prevalence estimates with attention to geographic, socioeconomic, and demographic variations; to analyze the efficacy and comparative effectiveness of diverse preventive interventions; to examine implementation considerations and contextual factors influencing intervention success; and to identify knowledge gaps and future research priorities. By integrating epidemiological and interventional evidence, this review aims to inform evidence-based policy and practice for the prevention of iron deficiency anaemia in this vulnerable population.

LITERATURE REVIEW

Definition and Diagnostic Criteria - Iron deficiency anaemia represents the advanced stage of iron deficiency, wherein insufficient iron stores lead to impaired haemoglobin synthesis and consequent reduction in blood haemoglobin concentration below age-specific and sex-specific thresholds. The condition exists along a continuum beginning with iron depletion, characterized by reduced serum ferritin concentration indicating exhausted iron stores; progressing to iron-deficient erythropoiesis, wherein iron supply becomes insufficient to support normal erythroblast haemoglobin synthesis; and culminating in iron deficiency anaemia, defined by haemoglobin concentration falling below the fifth percentile of the reference population distribution .

For preschool-aged children, the World Health Organization defines anaemia as haemoglobin concentration below 110 grams per litre for children aged six to fifty-nine months, with adjustment for altitude and smoking status. Iron deficiency is typically defined by serum ferritin concentration below 12 micrograms per litre in the absence of inflammation, or below 30 micrograms per litre when inflammation is present. Iron deficiency anaemia is diagnosed

when both haemoglobin and ferritin criteria are simultaneously satisfied. The diagnostic landscape is complicated by the acute phase response, wherein inflammation elevates serum ferritin independently of iron stores, potentially masking concomitant iron deficiency. This phenomenon is particularly relevant in regions with high infectious disease burden, necessitating concurrent measurement of inflammatory markers such as C-reactive protein or alpha-1-acid glycoprotein for accurate iron status assessment.

Global Epidemiology and Burden - Preschool-aged children bear the highest prevalence of anaemia of any demographic group globally. Comprehensive estimates from the World Health Organization indicate that 47.4 percent of preschool-aged children are affected by anaemia, with the highest regional burdens concentrated in South Asia and sub-Saharan Africa . Iron deficiency constitutes the predominant etiology, responsible for approximately fifty percent of anaemia cases in this age group, though contributions from other nutritional deficiencies, haemoglobinopathies, malaria, and helminth infections vary substantially across geographic contexts.

Recent large-scale epidemiological investigations provide contemporary prevalence estimates with enhanced precision. A cross-sectional study conducted across ten Chinese provinces from 2022 to 2023 examined 21,460 preschool children aged six months to seven years, reporting overall anaemia prevalence of 10.4 percent, iron deficiency prevalence of 28.3 percent, and iron deficiency anaemia prevalence of 3.9 percent . This represents substantial improvement compared with earlier Chinese national surveys, which documented iron deficiency anaemia prevalence of 20.5 percent among infants in 2000-2001, yet demonstrates persistent burden requiring continued public health attention. Marked geographic and socioeconomic disparities characterized the epidemiological pattern. Anaemia prevalence varied fourfold

across regions, from 5.3 percent in northeastern China to 15.8 percent in central provinces. Iron deficiency demonstrated even more dramatic geographic variation, ranging from 21.7 percent in eastern regions to 48.9 percent in northeastern areas. Rural children experienced significantly higher anaemia prevalence than urban children (11.8 percent versus 8.3 percent), while iron deficiency anaemia prevalence was similarly elevated in rural versus urban settings (4.6 percent versus 2.9 percent). These disparities reflect underlying inequalities in dietary quality, health service access, and socioeconomic conditions. Age emerged as a critical determinant, with infants aged six to twelve months demonstrating the highest prevalence of anaemia (18.0 percent) and iron deficiency (33.8 percent), followed by toddlers aged one to three years (anaemia 10.6 percent, iron deficiency 32.2 percent), with declining prevalence among older preschoolers . This age gradient reflects the convergence of multiple risk factors during infancy and toddlerhood: rapid growth velocity imposing high iron requirements, limited dietary iron content during complementary feeding transition, and marginal iron stores at birth that become depleted by four to six months of age. Evidence from high-income countries demonstrates that childhood iron deficiency anaemia is by no means a problem confined to low-resource settings. A multicentre retrospective analysis from Croatia examining 864 children referred to tertiary paediatric haematology services over five years found that preschool-aged children predominated among referrals, with inadequate nutrition identified as the prevailing underlying etiology . Notably, while primary care paediatricians generally performed appropriate basic diagnostic evaluation, half of affected children did not receive initiated oral iron therapy, highlighting gaps between evidence and practice even in well-resourced health systems.

Pathophysiology and Etiology

The pathogenesis of iron deficiency anaemia in preschool children involves a complex interplay of nutritional, physiological, and environmental factors operating at multiple levels. The fundamental mechanisms include inadequate dietary iron intake, poor dietary iron bioavailability, increased physiological requirements during periods of rapid growth, and excessive iron losses.

Dietary iron intake constitutes the primary modifiable determinant. Preschool children require approximately seven to ten milligrams of iron daily to support growth and maintenance, yet typical weaning diets frequently fail to meet this requirement . Exclusive breastfeeding beyond six months without appropriate complementary foods represents a well-established risk factor, as human milk provides insufficient iron (approximately 0.3 milligrams per litre) to sustain adequate iron stores beyond the first half of infancy.

Iron bioavailability critically influences the adequacy of dietary iron intake. Dietary iron exists in two forms: haem iron, derived from haemoglobin and myoglobin in animal-source foods, which is absorbed at 20-30 percent efficiency and is minimally influenced by other dietary components; and non-haem iron, present in plant-based foods and iron fortificants, which is absorbed at only 1-5 percent efficiency and is highly susceptible to dietary enhancers and inhibitors . Vitamin C, certain amino acids, and the unidentified meat factor enhance non-haem iron absorption, while phytates in grains and legumes, polyphenols in tea and coffee, calcium, and egg phosphoproteins inhibit absorption.

Excessive **cow milk consumption** represents a particularly important etiological factor in preschool children, especially in high-income settings. Cow milk has very low iron content (approximately 0.5 milligrams per litre), its calcium and casein content inhibit iron absorption, and it may displace iron-

rich complementary foods from the diet. Furthermore, cow milk protein can induce microscopic intestinal blood loss in some infants, compounding negative iron balance .

Physiological iron requirements peak during infancy and early childhood due to the dual demands of haemoglobin mass expansion and tissue growth. The full-term infant is born with approximately 75 milligrams of iron per kilogram body weight, primarily in haemoglobin and storage compartments. This endowment supports iron needs for the first four to six months, after which exogenous iron becomes essential. Preterm and low birth weight infants have substantially reduced iron stores at birth and consequently develop iron deficiency earlier and more severely.

Socioeconomic determinants operate through multiple pathways including dietary quality, health care access, maternal education, and food security. Low household income constrains access to iron-rich animal-source foods, while maternal educational attainment influences infant feeding practices, timely introduction of complementary foods, and health-seeking behaviour.

Preventive Intervention Classification Framework

Preventive interventions for childhood iron deficiency anaemia can be conceptually organized according to established public health frameworks distinguishing nutrition-specific interventions, which address immediate determinants of nutritional status; nutrition-sensitive interventions, which address underlying determinants; and health system strengthening, which addresses basic determinants.

Nutrition-specific interventions directly target iron intake and status through supplementation, fortification, and dietary diversification. Supplementation involves provision of iron in pharmacologic formulations,

typically as ferrous sulphate drops or syrups, administered at preventive or therapeutic doses. Fortification encompasses universal fortification of staple foods with iron, targeted fortification of complementary foods, and point-of-use home fortification with multiple micronutrient powders. Dietary diversification strategies aim to increase consumption of iron-rich foods and enhance iron bioavailability through meal planning and food preparation modifications.

Nutrition-sensitive interventions address root causes of inadequate dietary iron intake by improving food systems, social protection, maternal empowerment, and early childhood development. These include agricultural interventions to increase household production and consumption of iron-rich foods, cash transfer programmes to improve household food purchasing capacity, maternal education and counselling on optimal infant and young child feeding practices, and interventions to delay cord clamping at delivery to enhance neonatal iron endowment.

Public health and health system interventions encompass food fortification policies and regulations, malaria prevention and control in endemic areas, helminth control through periodic deworming, and health system strengthening to deliver preventive nutrition services through routine child health contacts including immunization visits and growth monitoring. This multi-level framework guides the organization of subsequent evidence synthesis and recognizes that sustainable anaemia reduction requires coordinated implementation across complementary intervention levels.

DISCUSSION

Comparative Effectiveness of Nutrition-Specific Interventions - The evidence base regarding efficacy of nutrition-specific interventions for preventing iron deficiency anaemia in preschool children has expanded

substantially in recent years, with multiple systematic reviews and network meta-analyses providing comparative effectiveness estimates across diverse intervention types. A comprehensive network meta-analysis published in 2025 synthesized evidence from sixty-one randomized controlled trials examining nutrition interventions for anaemia prevention and control in infants, children, and adolescents . The analysis stratified populations by age group, enabling specific conclusions regarding infants and preschool-aged children aged six to fifty-nine months. The investigators evaluated three intervention categories: micronutrient supplementation, macronutrient supplementation, and nutrition education. Network meta-analysis methodology permitted simultaneous comparison of multiple interventions and estimation of relative treatment effects even in the absence of head-to-head trials.

Among infants and preschool-aged children, micronutrient supplementation, macronutrient supplementation, and nutrition education all demonstrated significant effects on haemoglobin concentrations. However, the magnitude of effect varied substantially across intervention types. Lipid-based nutrient supplementation produced the highest increase in haemoglobin concentration, reflecting the combined benefits of iron provision and complementary macro- and micronutrients that support erythropoiesis and overall nutritional status . Conversely, multiple micronutrient supplementation resulted in the largest reduction in risk of anaemia and iron deficiency anaemia, likely due to the synergistic effects of iron combined with other micronutrients including vitamin A, zinc, and B vitamins that support iron metabolism and erythropoiesis.The Cochrane systematic review and overview of systematic reviews published in 2021 similarly synthesized evidence from seventy-five systematic reviews examining nutrition-specific interventions for anaemia prevention throughout the life cycle . For infants aged six to twenty-three

months, the review identified consistent evidence that iron supplementation increases haemoglobin concentration and reduces anaemia and iron deficiency anaemia risk compared with placebo, no intervention, or other interventions. Six systematic reviews demonstrated that iron fortification of milk or cereals, multiple micronutrient powder home fortification, and supplementary feeding increase haemoglobin levels and reduce anaemia risk.

For preschool-aged children aged two to ten years, the Cochrane overview identified two systematic reviews demonstrating that daily or intermittent iron supplementation increases haemoglobin concentration and reduces anaemia and iron deficiency risk . Direct comparison of daily versus intermittent iron supplementation revealed no significant difference in haemoglobin outcomes, but intermittent regimens were associated with increased anaemia and iron deficiency risk, suggesting that daily supplementation provides superior protection where implementation is feasible. Evidence regarding multiple micronutrient-fortified beverages demonstrated significant benefits, with eight trials including 3,835 children showing mean haemoglobin increase of 2.76 grams per litre and anaemia risk reduction of 37 percent . Multiple micronutrient powder point-of-use fortification similarly demonstrated significant benefits, with eleven trials including 2,746 children showing haemoglobin increase of 3.37 grams per litre and anaemia risk reduction of 34 percent . The evidence quality was graded as moderate for these outcomes, supporting confidence in effect estimates.

Lipid-based nutrient supplements represent a relatively recent intervention approach combining micronutrients with energy, protein, and essential fatty acids in a peanut-based paste formulation. The network meta-analysis identified lipid-based nutrient supplementation as producing the highest haemoglobin increase among evaluated interventions, though

confidence in this ranking requires tempering given the limited number of available trials . The mechanism likely involves both direct iron provision and improved overall nutritional status supporting haematopoietic function.

Zinc supplementation alone demonstrates no benefit for anaemia or iron status. A systematic review including twenty-six trials with 6,024 children found no evidence of haemoglobin improvement with zinc supplementation alone, and zinc supplementation was associated with significantly increased vomiting episodes . However, zinc plus iron supplementation demonstrated superior outcomes compared with zinc alone, with eight trials including 1,341 children showing significant haemoglobin benefit and reduced anaemia and iron deficiency prevalence. These findings underscore the importance of combined micronutrient supplementation approaches.

Nutrition Education and Behavioural Interventions

Nutrition education and counselling interventions aim to improve iron status indirectly by modifying dietary practices, complementary feeding behaviours, and food preparation methods. The network meta-analysis by Ren and colleagues identified that nutrition education significantly improves haemoglobin concentrations in infants and preschool-aged children, though effect magnitudes are smaller than those observed for supplementation or fortification interventions . Effective nutrition education interventions typically incorporate multiple behaviour change techniques, are delivered through multiple contacts over extended periods, and address both what to feed and how to feed. Key behavioural targets include timely introduction of iron-rich complementary foods, particularly animal-source foods; consumption of iron-rich foods in combination with vitamin C-containing foods to enhance non-haem iron absorption; avoidance of tea and coffee with meals due to polyphenol inhibition of iron absorption; and appropriate use of commercial iron-fortified

infant cereals. The Croatian multicentre study provides important insights regarding implementation gaps in nutrition counselling and iron therapy initiation. Despite preschool-aged children predominating among iron deficiency anaemia referrals and inadequate nutrition being identified as the prevailing etiology, half of referred children had not received initiated oral iron therapy from their primary care paediatrician . This evidence-practice gap persisted in a high-income country with universal health coverage and well-established primary care infrastructure, suggesting that additional education of primary health care providers and consistent implementation of national guidelines are urgently needed.

Dietary Strategies and Bioavailability Enhancement

Optimizing dietary iron intake through food-based approaches represents the most sustainable long-term strategy for anaemia prevention. The fundamental challenge in preschool child nutrition is not merely increasing iron intake but ensuring adequate intake of highly bioavailable iron forms while minimizing inhibitory factors. **Haem iron**, derived from haemoglobin and myoglobin in meat, poultry, and fish, is absorbed at 20-30 percent efficiency and is minimally affected by other dietary components. Red meat is particularly rich in haem iron, while poultry and fish provide moderate amounts. The American Academy of Pediatrics recommends introduction of iron-rich complementary foods including puréed meats by approximately six months of age . Despite this recommendation, meat introduction is frequently delayed, and many preschool children consume suboptimal amounts of animal-source foods.

Non-haem iron absorption can be substantially enhanced through strategic food combinations. Vitamin C is the most potent enhancer, reducing ferric to ferrous iron and forming soluble chelates that maintain iron in

absorbable form. Consuming iron-rich plant foods or iron fortificants with vitamin C-rich fruits and vegetables can increase non-haem iron absorption fourfold to sixfold. Conversely, dietary inhibitors including phytates in whole grains and legumes, polyphenols in tea and coffee, calcium in dairy products, and phosphoproteins in eggs markedly reduce non-haem iron absorption and should be consumed separately from iron-rich meals .

Food preparation modifications can reduce phytate content and enhance iron bioavailability. Traditional food processing techniques including fermentation, germination, and soaking reduce phytate concentrations in cereal-based complementary foods. The addition of ascorbic acid to iron-fortified infant cereals during manufacturing overcomes phytate inhibition and ensures adequate iron absorption. **Cow milk consumption** patterns require specific attention in anaemia prevention. Cow milk has low iron content, inhibits non-haem iron absorption, and may displace iron-rich complementary foods. Current recommendations limit cow milk intake to no more than 500 millilitres daily for children aged twelve months and older and emphasize that cow milk should not be introduced as the main milk drink before twelve months .

Implementation and Contextual Considerations - The translation of demonstrated intervention efficacy into population-level effectiveness requires careful attention to implementation context, delivery platforms, and behavioural determinants. Several implementation considerations critically influence the success of anaemia prevention programmes.

Supplementation adherence represents a persistent challenge. Daily oral iron supplementation requires sustained caregiver motivation and reliable product supply. Gastrointestinal side effects including constipation, nausea, and abdominal discomfort occur in some children and may precipitate

discontinuation. The Croatian multicentre study reported acceptable compliance rates ranging from 63.5 to 93.2 percent with dextriferron formulation, yet even the lower bound of this range indicates substantial incomplete adherence . Intermittent supplementation regimens reduce gastrointestinal side effects but, as previously noted, may be associated with increased anaemia risk compared with daily regimens.

Supply chain reliability determines whether efficacious products reach intended beneficiaries. Multiple micronutrient powders and lipid-based nutrient supplements must be procured, stored, distributed, and maintained in the home environment with appropriate storage conditions. Supply chain disruptions during the COVID-19 pandemic adversely affected micronutrient supplementation programmes globally, highlighting vulnerability of vertical delivery mechanisms.

Malaria-endemic areas present particular safety considerations for iron supplementation. Iron administration to iron-deficient children in malaria-endemic settings without access to effective malaria prevention and treatment services may increase risk of adverse outcomes. Current World Health Organization guidance recommends that in malaria-endemic areas, iron supplementation should be provided in conjunction with adequate measures to prevent, diagnose, and treat malaria . Multiple micronutrient powders and fortified foods may confer advantages in this context, as the lower iron dose per serving and provision with meals may reduce non-transferrin-bound iron and associated infection risk.

Health system integration enhances programme sustainability and reach. Integration of micronutrient supplementation with routine child health contacts including immunization visits, growth monitoring, and well-child checks creates multiple opportunities for intervention delivery and reduces

reliance on vertical programme infrastructure. The Expanded Programme on Immunization contact platform has been successfully leveraged for vitamin A supplementation and holds potential for micronutrient powder distribution.

Geographic and Socioeconomic Disparities

Contemporary epidemiological evidence reveals persistent and substantial disparities in iron deficiency anaemia burden that demand targeted intervention approaches. The ten-province Chinese study documented dramatic regional variation in iron deficiency, ranging from 21.7 percent in eastern coastal provinces to 48.9 percent in northeastern provinces . These disparities reflect underlying inequalities in dietary patterns, economic development, health service access, and perhaps food system characteristics. Rural-urban disparities similarly persist, with rural children experiencing significantly higher anaemia and iron deficiency anaemia prevalence than urban counterparts. These gradients are evident across both low-income and high-income country settings and reflect differential access to diverse, iron-rich foods; health service availability; maternal education levels; and socioeconomic resources. Age-specific vulnerability follows a consistent pattern globally, with infants and toddlers bearing disproportionate burden. The six-to-twenty-four-month window represents the period of highest risk, when iron requirements peak, complementary feeding transitions occur, and iron stores become depleted. This developmental window constitutes a critical opportunity for preventive intervention.

Knowledge Gaps and Research Priorities

Despite substantial advances in understanding iron deficiency anaemia epidemiology and prevention, important knowledge gaps persist. First, evidence regarding optimal iron dose and formulation for preventive supplementation in preschool children remains incomplete. Comparative

effectiveness trials directly evaluating different iron compounds, doses, and regimens would inform more precise recommendations. Second, the long-term developmental benefits of iron deficiency anaemia prevention programmes require rigorous quantification. While the adverse neurodevelopmental consequences of iron deficiency anaemia are well established, evidence linking specific preventive interventions to improved cognitive and educational outcomes is more limited and would strengthen the investment case for programme scale-up. Third, implementation science research examining strategies to optimize intervention delivery, adherence, and sustainability is urgently needed. Most existing trials evaluate efficacy under optimal conditions rather than effectiveness under routine programme conditions. Research identifying barriers and facilitators at caregiver, provider, health system, and policy levels would inform contextually appropriate implementation strategies. Fourth, evidence regarding optimal intervention combinations and sequencing is limited. Most trials evaluate single interventions in isolation, yet real-world programmes necessarily combine multiple approaches. Understanding synergistic effects and optimal sequencing would enhance programme design.

RESULTS

Synthesis of current evidence yields several definitive findings regarding iron deficiency anaemia prevalence and prevention in preschool-aged children.

First, preschool-aged children constitute the highest-prevalence population group for anaemia globally, with approximately 42 percent affected worldwide. Contemporary large-scale epidemiological studies demonstrate that while substantial progress has been achieved in some settings, prevalence remains unacceptably high with marked geographic and socioeconomic disparities. The 2022-2023 Chinese national survey documented overall anaemia prevalence of 10.4 percent, iron deficiency prevalence of 28.3 percent,

and iron deficiency anaemia prevalence of 3.9 percent, with fourfold geographic variation and significantly higher burden in rural compared with urban areas . Infants aged six to twelve months demonstrate the highest vulnerability, with anaemia prevalence of 18.0 percent and iron deficiency prevalence of 33.8 percent.

Second, multiple nutrition-specific interventions demonstrate proven efficacy for iron deficiency anaemia prevention in preschool children, with comparative effectiveness varying by intervention type and outcome measure. Network meta-analysis evidence demonstrates that multiple micronutrient supplementation achieves the largest reduction in anaemia and iron deficiency anaemia risk, while lipid-based nutrient supplementation produces the highest increase in haemoglobin concentration . Daily iron supplementation consistently increases haemoglobin concentration and reduces anaemia and iron deficiency anaemia risk, with high-quality evidence supporting these effects .

Third, intermittent iron supplementation regimens, while improving haemoglobin compared with placebo, are associated with increased anaemia and iron deficiency risk compared with daily supplementation. The Cochrane review found that while intermittent and daily supplementation produced comparable haemoglobin outcomes, intermittent regimens were associated with significantly higher anaemia prevalence (risk ratio 1.23) and iron deficiency prevalence (risk ratio 4.00) . This finding supports daily supplementation as the preferred preventive regimen where implementation is feasible.

Fourth, multiple micronutrient powder point-of-use fortification and multiple micronutrient-fortified beverages demonstrate consistent, moderate-quality evidence of benefit for preschool children. Multiple micronutrient

powders increase haemoglobin by 3.37 grams per litre and reduce anaemia risk by 34 percent; fortified beverages increase haemoglobin by 2.76 grams per litre and reduce anaemia risk by 37 percent . These delivery platforms offer advantages including lower iron doses administered with meals, acceptability to children and caregivers, and suitability for integration into existing child health programmes.

Fifth, zinc supplementation alone provides no benefit for anaemia or iron status and is associated with significantly increased vomiting. However, zinc-plus-iron combination supplementation demonstrates superior haemoglobin outcomes and reduced anaemia and iron deficiency prevalence compared with zinc alone, supporting combined micronutrient approaches .

Sixth, substantial evidence-practice gaps persist across diverse health system contexts. The Croatian multicentre study documented that half of preschool children referred to tertiary haematology services for iron deficiency anaemia had not received initiated oral iron therapy from primary care paediatricians, despite inadequate nutrition being identified as the prevailing etiology . This finding underscores the critical importance of health provider education and consistent implementation of evidence-based guidelines.

Seventh, food-based strategies emphasizing dietary diversification, iron bioavailability enhancement, and modification of feeding practices constitute essential long-term prevention approaches, though their effectiveness in controlled trials is less extensively documented than supplementation and fortification interventions. Key dietary recommendations include timely introduction of iron-rich complementary foods including puréed meats, consumption of vitamin C-rich foods with iron-containing meals, avoidance of tea and coffee with meals, limitation of cow milk intake, and use of iron-fortified infant cereals .

CONCLUSION

Iron deficiency anaemia in preschool-aged children represents a persistent global public health challenge with profound consequences for child development, health, and human capital formation. The evidence synthesized in this review demonstrates that while substantial epidemiological progress has been achieved in some populations, the burden remains unacceptably high, with marked and persistent disparities across geographic regions, urban-rural settings, and socioeconomic strata. Several overarching principles emerge from this comprehensive evidence review. First, the preschool period, particularly the window from six to twenty-four months, constitutes the critical opportunity for anaemia prevention. Interventions initiated during this developmental window address the convergence of peak iron requirements, complementary feeding transition, and depletion of neonatal iron stores. Delayed intervention beyond this period misses the opportunity to prevent iron deficiency before it compromises neurodevelopment and permits establishment of suboptimal dietary patterns that prove resistant to subsequent modification. Second, no single intervention suffices for anaemia prevention across all contexts. The comparative effectiveness evidence demonstrates that multiple micronutrient supplementation achieves greatest anaemia risk reduction, lipid-based nutrient supplementation produces highest haemoglobin increase, daily iron supplementation provides reliable individual-level protection, and dietary diversification offers the most sustainable long-term approach. Effective prevention programmes rationally combine these approaches based on local epidemiological context, health system capacity, and implementation feasibility. Third, supplementation and fortification interventions must be conceived not as competing alternatives but as complementary approaches serving different populations and purposes. Daily iron supplementation

provides targeted protection for high-risk individuals, including infants exiting the neonatal period, children with inadequate dietary iron intake, and those recovering from previous deficiency. Universal or targeted fortification approaches provide population-wide exposure at lower doses and may be more feasible for sustained implementation. Point-of-use fortification with multiple micronutrient powders occupies an intermediate niche, combining individual targeting with lower-dose, meal-time administration. Fourth, the persistent evidence-practice gaps documented across diverse health system contexts demand urgent attention. The finding that half of affected preschool children in a high-income country with universal health coverage did not receive initiated oral iron therapy despite confirmed iron deficiency anaemia diagnosis represents an unacceptable failure of evidence translation . Strategies to address such gaps include development and dissemination of clear, actionable clinical guidelines; pre-service and in-service education of primary health care providers; audit and feedback mechanisms; and integration of anaemia screening and prevention into routine child health contacts. Fifth, anaemia prevention cannot be achieved through nutrition-specific interventions alone. Sustainable progress requires concurrent nutrition-sensitive investments in food systems, social protection, maternal education, and women's empowerment, together with health system strengthening to ensure reliable supply chains, trained health workers, and functional service delivery platforms. The multi-sectoral nature of effective anaemia prevention demands corresponding multi-sectoral governance, financing, and accountability mechanisms. Critical knowledge gaps requiring urgent investigation include: determination of optimal iron doses and formulations for preventive supplementation across different age strata; rigorous quantification of long-term neurodevelopmental and economic benefits of preschool anaemia

prevention programmes; implementation science research identifying effective strategies to enhance intervention coverage, adherence, and sustainability; and evaluation of optimal intervention combinations and sequencing for maximum population-level impact.

The global commitment to anaemia reduction, articulated in the World Health Assembly Global Nutrition Target of 50 percent anaemia prevalence reduction in women of reproductive age by 2025 and subsequently extended to children, remains far from achievement. Yet the evidence synthesized in this review provides genuine grounds for optimism. Effective interventions exist across multiple delivery platforms. Their efficacy is established through rigorous randomized controlled trials and confirmed in diverse implementation contexts. Implementation barriers are increasingly well characterized and amenable to systematic address. The remaining gap is not primarily one of knowledge but of political commitment, resource allocation, health system strengthening, and accountable implementation. The millions of preschool children worldwide currently experiencing iron deficiency anaemia and its lifelong developmental consequences demand urgent translation of evidence into effective action.

REFERENCES

1. Ren T, Lu Y, Dai Z, Yang J, Wu Y, Chang F, Wang S, Wang L, Lu Y. Effects of nutrition-specific interventions to prevent and control nutrition-related anemia in infants, children, and adolescents: a systematic review and network meta-analysis of randomized controlled trials. Journal of the Academy of Nutrition and Dietetics. 2025;125(1):89-105.

2. Liu X. Iron deficiency anemia: high prevalence, significant harm, requires attention. JD Health Continuing Education. 2023; published online December 9.

3. World Health Organization Regional Office for the Eastern Mediterranean. Key family practices on child health care: micronutrients. Cairo: WHO Regional Office for the Eastern Mediterranean; 2018.

4. Wang L, Li Q, Chen J, Zhang Y, Liu H, Zhao X, Sun J, Zhou G, Huang X, Ma L, Jiang J. Epidemiological investigation of iron deficiency among preschool children in 10 provinces, autonomous regions, or municipalities in China. Zhonghua Er Ke Za Zhi. 2024;62(5):428-434.

5. Cochrane Public Health. Interventions throughout life for the prevention or treatment of anaemia. Cochrane Database of Systematic Reviews. 2021;(9):CD013092.

6. Ren T, Lu Y, Dai Z, Yang J, Wu Y, Chang F, Wang S, Wang L, Lu Y. Effects of nutrition-specific interventions to prevent and control nutrition-related anemia in infants, children, and adolescents: a systematic review and network meta-analysis of randomized controlled trials. Journal of the Academy of Nutrition and Dietetics. 2025;125(1):89-105.

7. EKF Diagnostics. Who has the highest risk of developing anemia? EKF Diagnostics News. 2017 May 9.

8. Cochrane. Interventions throughout life for the prevention or treatment of anaemia. Cochrane Library. 2021; CD013092.

9. Kranjčec I, Peroš-Golubičić T, Grgić S, Petković M, Šegulja S, Roganović J, Pavlović M, Končar M, Filipović-Grčić P, Janković S, Kuzmanić-Samija R, Čulić S, Lozančić D, Roglić M, Pušeljić S, Raguž M, Jakl R, Roganović J. Management of childhood iron deficiency anemia in a developed country: a multi-center experience from Croatia. Diagnostics. 2023;13(24):3607.

10. National Institutes of Health National Center for Biotechnology Information. Table 22: Results of included systematic reviews: preschool and

school-aged children (aged 2 to 10 years). In: Cochrane Database of Systematic Reviews. 2021; CD013092.

11. Berdiyevich, T. S., Aslanovich, A. G., Otabek ogli, N. F., Berdiyevich, T. S., Mirjanovna, M. M., & Otabekovich, N. F. (2025). INSON VA KOMPYUTER OZARO TA'SIRINI FAN VA TALIMDA QOLLASH. *Журнал научных исследований и их решений*, *4*(02), 63-71.

12. Boyir og, B. B., Istamovich, R. J., & Otabek ogli, N. F. (2025). O'RTA OSIYA HUDUDIDA NOINFEKSION KASALLIKLARDA O'ZIGA HOS TURMUSH TARZINING O'ZGARISHLARI VA ULAR KELTIRIB CHIQARADIGAN HAVFLI OQIBATLARI. *TANQIDIY NAZAR, TAHLILIY TAFAKKUR VA INNOVATSION G 'OYALAR*, *1*(1), 79-82.

13. Sayfullayev, A. K., & Abdullayeva, D. A. (2026). LABIAPLASTIKANING AYOLLARNING PSIXO-EMOSIONAL HOLATIGA TA'SIRI. *Zamonaviy ta'lim va rivojlanish* , *42* (1), 19-28.