GLOBAL NUTRITION & PUBLIC HEALTH | NARRATIVE REVIEW

Iron Deficiency Anemia in Preschool Children of Central Asia: Epidemiology, Etiology, Health Impacts, and Intervention Effectiveness — A Narrative Review (2020–2025)

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Background: Iron deficiency anemia (IDA) is one of the leading nutritional disorders affecting preschool-aged children (6–59 months) across the five former Soviet Republics of Central Asia — Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan — despite measurable improvements over the past two decades.

Objective: To identify gaps in policy and implementation, this review summarizes available literature from 2020–2025 describing the epidemiology, etiology, health impacts, and intervention effectiveness of childhood IDA in Central Asia.

Methods: A structured narrative review guided by PRISMA-ScR principles was conducted using PubMed/MEDLINE, Scopus, WHO databases, UNICEF publications, and the GBD 2021 study. Peer-reviewed and credible grey literature published between January 2020 and March 2025 pertaining to children aged 0–18 years in the five Central Asian countries were included.

Results: Anemia prevalence among preschool children ranges from 22% in Kazakhstan to over 50% in Tajikistan, with iron deficiency identified as the leading contributor in all five countries. Key determinants include low dietary diversity, cereal-dominant diets, poverty, poor breastfeeding practices, low fortification coverage, and limited health system capacity. Primary long-term consequences include impaired neurodevelopment, growth faltering, and reduced educational attainment. Evidence supports the effectiveness of flour fortification, point-of-use micronutrient powders, and behaviour change communication; however, coverage remains inconsistent.

Conclusions: Significantly reducing IDA prevalence in Central Asian children requires improved national surveillance, expanded fortification programmes, updated iron supplementation protocols, and integrated nutrition-sensitive policies. Sustainable progress demands coordinated, multi-sectoral action aligned with the Sustainable Development Goals and the 2030 WHA nutrition targets.

Keywords: iron deficiency anemia, childhood anemia, Central Asia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Uzbekistan, micronutrient deficiency, food fortification, iron supplementation, pediatric nutrition, preschool children

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1. INTRODUCTION

The World Health Organization (WHO) designates IDA as the most common nutritional deficiency globally, with an estimated 1.2 billion cases worldwide, particularly among preschool children and women of childbearing age. The 2021 Global Burden of Disease (GBD) study found a modest 11.9% reduction in overall anemia prevalence from 1990 to 2021, with considerable geographic disparities persisting, especially in South Asia and Sub-Saharan Africa.

Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan constitute the five former Soviet Republics of Central Asia. Since independence in 1991, these countries have undergone significant social and economic transformation, creating diverse nutritional profiles both inter- and intra-nationally. Regardless of varying per capita incomes, all five countries report preschool (6–59 months) anemia rates at or above the WHO moderate-to-severe public

health problem threshold (≥20%).

Childhood IDA's consequences extend far beyond anemia. Iron deficiency during critical developmental windows impairs myelination, inhibits neurotransmitter synthesis, and damages the hippocampus — resulting in decreased cognitive capacity, impaired language acquisition, poor psychomotor development, and inferior academic performance. A 2024 landmark review by Knowles et al. in *Current Developments in Nutrition* found no nationally representative, peer-reviewed publications on childhood anemia in several ECA countries and identified little homogeneity in prevention or treatment policies across the region.

The objectives of this review are to: (1) provide an epidemiological overview of childhood anemia in Central Asia based on reports from 2019–2025; (2) examine the primary causes of childhood IDA at individual, household, and systemic levels; (3) describe the health and developmental impacts of childhood IDA; (4) evaluate the evidence for existing and emerging interventions; and (5) provide evidence-based policy recommendations for regional stakeholders.

2. METHODS

2.1 Study Design

This paper employs a structured narrative review methodology guided by PRISMA-ScR (Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews) checklist principles. A narrative approach was adopted given the heterogeneity of study designs, outcomes assessed, and population groups represented in the existing literature.

2.2 Data Sources and Search Strategy

Systematic searches were conducted across PubMed/MEDLINE, Scopus, Web of Science, and WHO Global Health Observatory from January 2020 through March 2025. Grey literature searches encompassed UNICEF country reports, WHO nutrition databases, World Bank Open Data, the GBD 2021 (IHME), and National Nutrition Survey Reports. Search terms included combinations of: "iron deficiency anaemia", "childhood anaemia", "central Asia", individual country names, "micronutrient deficiency", "food fortification", "iron supplementation", and "pediatric nutrition".

2.3 Inclusion and Exclusion Criteria

Studies were included if they: (1) documented childhood IDA or iron deficiency; (2) were conducted in at least one of the five Central Asian countries; (3) were published or available between January 2020 and March 2025 (foundational studies permitted where no equivalent recent publication existed); and (4) were published in English.

2.4 Data Extraction and Quality Evaluation

Data were extracted on study design, country, sample population, anemia/iron deficiency prevalence, hemoglobin and ferritin cut-off values used, determinants measured, intervention type and outcomes, and data source. Study quality was assessed using the Newcastle-Ottawa Scale for observational studies and GRADE criteria where applicable.

3. EPIDEMIOLOGY OF IRON DEFICIENCY ANEMIA IN YOUNG CHILDREN IN CENTRAL ASIA

3.1 Regional Overview

Current pooled data from WHO, the GBD 2021 study, and UNICEF Multiple Indicator Cluster Surveys (MICS) indicate a 12–20% relative reduction in childhood anemia between 2000 and 2019; however, the burden among children under 6 years in Central Asia remains high (35–50%), with iron deficiency as the leading etiology. Stevens et al. (2022) demonstrated in a pooled analysis in *Lancet Global Health* that Uzbekistan and Kazakhstan recorded among the largest declines in child anemia rates between 2000 and 2019, yet both still qualify as countries with moderate public health significance.

3.2 Country-Level Data

3.2.1 Kyrgyz Republic

The Kyrgyz Republic has the most comprehensive nutrition documentation in the region, anchored by the National Integrated Micronutrient and Anthropometric Survey (NIMAS 2021), conducted in partnership with UNICEF, FAO, WFP, WHO, Mercy Corps, and USAID. Covering 3,062 households across all seven regions, the survey — the first nationally representative nutrition survey in Kyrgyzstan — found severe anemia (Hb <110 g/L) in children aged 6–23 months, with approximately 60% or more iron deficient by venous blood analysis. Significant rural-urban disparities exist, with southern Kyrgyzstan bearing a substantially higher burden than Bishkek. Kyrgyzstan's high-altitude geography additionally complicates anemia assessment, as physiological erythropoiesis at elevations >2,000 metres above sea level elevates baseline hemoglobin concentrations, potentially underestimating true anemia prevalence with standard WHO cut-offs.

3.2.2 Tajikistan

Tajikistan carries the highest estimated childhood anemia burden in the region, with prevalence among preschool-aged children reported at 50–56% in the latest Demographic and Health Survey (DHS). With a per capita GDP of approximately USD 1,100 — the lowest in Central Asia — Tajikistan faces compounding structural vulnerabilities: pervasive food insecurity, constrained health system capacity, and wheat flour fortification coverage below 10%, the lowest in the region.

3.2.3 Kazakhstan and Turkmenistan

Kazakhstan, the region's upper-middle-income economy, reports the lowest childhood anemia prevalence at approximately 22%, though with notable rural-urban variation. Turkmenistan presents an instructive paradox: it achieves approximately 90% wheat flour fortification coverage — the highest in the region — yet maintains an estimated childhood anemia prevalence of 37% among under-fives. This finding underscores that fortification alone is insufficient without dietary diversity and health service access.

3.2.4 Uzbekistan

Uzbekistan's MICS 2021–22 reports 36% of children as anemic, with iron deficiency attributable in 40–45% of cases. With intermediate flour fortification coverage (40–50% of wheat flour), Uzbekistan occupies a middle position relative to its neighbors. The highest IDA concentration in young children is found in densely populated rural and peri-urban areas of the Fergana Valley.

Table 1. Childhood Anemia Prevalence and Flour Fortification Coverage in Central Asian Countries

Country	Anemia Prevalence (Children <5 yrs)	Income Level (World Bank)	Flour Fortification Coverage	Primary Data Source
Kazakhstan	~22%	Upper-middle	40–50%	National surveys, Stevens et al. 2022
Kyrgyz Republic	~38–45%	Lower-middle	~25%	NIMAS 2021 (UNICEF/WHO)
Tajikistan	50–56%	Low	<10%	DHS (latest available)
Turkmenistan	~37%	Upper-middle	~90%	WHO/UNICEF estimates
Uzbekistan	~36%	Lower-middle	40–50%	MICS 2021–22

Sources: Stevens et al. (2022) *Lancet Global Health*; NIMAS 2021 (Kyrgyzstan); UNICEF MICS 2021–22 (Uzbekistan); Knowles et al. (2024) *Current Developments in Nutrition*; WHO/UNICEF country estimates.

4. ETIOLOGY AND RISK FACTORS

4.1 Dietary Iron Inadequacy

Cereal-based staples — wheat and rice products such as bread, noodles, and porridges — dominate dietary patterns across all five republics, while animal products, legumes, fruits, and ascorbic acid-rich vegetables that enhance non-heme iron absorption are minimally consumed. Chouraqui (2022, *Nutrients*) demonstrated that the bioavailability of iron in plant-based diets is as low as 1–8%, compared with 15–35% for heme iron from animal sources, making dietary iron adequacy structurally challenging in cereal-based food systems. Early introduction of cow's milk before 12 months of age — still prevalent in parts of Central Asia — increases IDA risk by approximately 39% per month of exposure, owing to

cow's milk's low iron content, iron absorption inhibition, and risk of occult gastrointestinal blood loss.

4.2 Socioeconomic and Structural Determinants

Poverty is the single most significant structural determinant of childhood IDA in the region. Gedfie et al. (2022) identified household income, maternal education level, and lack of access to safe water and sanitation as consistent contributors to childhood IDA globally — patterns directly applicable to rural Tajikistan, southern Kyrgyzstan, and remote Uzbekistan. Maternal anemia represents a critical intergenerational pathway: iron stores established in utero constitute the primary determinant of neonatal iron levels for the first 4–6 months of life, and anemic mothers deliver infants with depleted iron stores. Sunuwar et al. (2023) documented an odds ratio of 1.44–1.66 for childhood anemia in infants born to anemic mothers in South and Southeast Asia — a finding of high relevance given the comparably elevated maternal anemia rates in Central Asia.

4.3 Altitude and Geographic Factors

Kyrgyzstan's mountainous geography presents a unique epidemiological challenge: a substantial proportion of the population lives at elevations ≥2,000 metres above sea level, where physiological stimulation of erythropoiesis elevates baseline hemoglobin concentrations. Application of standard WHO hemoglobin cut-offs at high altitude may underestimate true anemia prevalence or misclassify physiological polycythemia as normal. The 2024 WHO Guideline on haemoglobin cut-offs recommends altitude-adjusted values — a correction with significant implications for survey design and targeting of interventions in Kyrgyzstan.

4.4 Infectious Disease and Inflammation

Recurrent infections — particularly intestinal helminthiases, respiratory infections, and diarrheal diseases — induce chronic inflammation that decreases iron absorption and complicates differentiation of IDA from anemia of chronic disease. The BRINDA project's methodological framework, employing C-reactive protein and alpha-1-acid glycoprotein as acute phase proteins to adjust serum iron marker values for inflammation, has not yet been widely applied in Central Asian national-level surveys.

4.5 Health System Access and Capacity

Antenatal iron supplementation, point-of-care childhood anemia testing, and growth monitoring services vary substantially across the region. Knowles et al. (2024) reported that only a minority of ECA countries had current information on the etiology of iron deficiency, and very few employed WHO-recommended population-level anemia prevention strategies. This service delivery gap results in large numbers of children with IDA going undetected until presentation at symptomatic or severe stages, by which point neurodevelopmental consequences may be irreversible.

5. IMPACTS OF CHILDHOOD IDA

5.1 Neurodevelopmental and Cognitive Impacts

Iron is essential for myelin production, dopamine and serotonin synthesis, hippocampal function, and cerebral energy metabolism. Deficiency during critical developmental windows — particularly the first 1,000 days — triggers time-sensitive processes that cannot be fully corrected by later iron repletion. Leung et al. (2024, *Current Pediatric Reviews*) documented that severe or prolonged early childhood IDA may produce neurodevelopmental deficits equivalent to 5–10 IQ points, measurable at school age as deficits in language, motor, and coordination skills. Gingoyon et al. (2022, *Pediatrics*) further confirmed the association between chronic iron deficiency and impaired cognition in infancy.

Gutema et al. (2023) conducted a systematic review and meta-analysis demonstrating that iron supplementation significantly improves intelligence, attention/concentration, memory, and academic performance in school-aged children — providing causal evidence supporting observational associations and indicating that partial cognitive reversal is achievable when iron status is corrected during the school-age period.

5.2 Physical Growth and Immune Function

IDA is associated with delayed physical growth, reduced work capacity, and impaired immune function. Iron is a critical co-factor for macrophage oxidative burst and lymphocyte proliferation — key components of innate immunity.

Iron-deficient children demonstrate attenuated vaccine responses and higher rates of respiratory and gastrointestinal infections, creating bidirectional reinforcement between infection-induced inflammation and iron deficiency. A 2024 systematic review in *Children (Basel)* identified a significant correlation between IDA and stunted linear growth in developing countries — a finding of particular relevance in Central Asia, where stunting rates remain elevated.

5.3 Educational Attainment and Economic Productivity

The economic consequences of childhood IDA are lifelong. Cognitive impairment reduces educational attainment, which in turn diminishes adult productivity and earning capacity. The WHO estimates productivity losses attributable to IDA of up to 30% in severely affected populations. Nguyen et al. (2022, *Nutrients*) systematically reviewed 50 publications and consistently demonstrated negative impacts of iron deficiency on attention, memory, and learning ability among adolescents, with school-based supplementation programs showing measurable improvements in academic performance.

6. INTERVENTIONS AND THEIR EFFECTIVENESS

6.1 Wheat Flour Fortification

Iron-fortified wheat flour is the primary preventive strategy currently deployed across Central Asia, supported by UNICEF technical assistance since approximately 2000. As documented by Knowles et al. (2024), implementation varies markedly: Turkmenistan achieves ~90% coverage; Kazakhstan and Uzbekistan report 40–50%; Kyrgyzstan approximately 25%; and Tajikistan below 10%. Key barriers to effective fortification include weak regulatory enforcement, variable iron compound bioavailability, inadequate monitoring infrastructure, and competition from non-fortified artisanal flour in rural areas. Chouraqui (2022) emphasizes that mass fortification is most effective when population coverage is high and the chosen iron compound has sufficient bioavailability — both considerations frequently overlooked in Central Asian programme implementation.

6.2 Point-of-Use Micronutrient Powder Supplementation

Micronutrient powders (MNPs, also known as Sprinkles), containing 12.5 mg elemental iron per sachet mixed into semi-solid complementary foods, target children aged 6–23 months — the highest-risk group for IDA. Multiple systematic reviews confirm MNP efficacy in reducing anemia prevalence in low- and middle-income country children under five. UNICEF supports MNP distribution in Kyrgyzstan and Tajikistan; however, suboptimal coverage and adherence remain ongoing challenges.

6.3 Therapeutic and Preventive Iron Supplementation

WHO recommends 3 mg/kg elemental iron daily for treatment of IDA in children under five, with lower preventive doses for at-risk groups. Gastrointestinal side effects — epigastric pain, nausea, constipation — frequently compromise compliance across the region. Intermittent supplementation regimens (two to three times weekly) have demonstrated comparable efficacy with improved tolerability in randomized controlled trials, yet most Central Asian clinical protocols have not yet adopted them. Antenatal iron supplementation, though recommended by WHO to prevent maternal anemia and optimize neonatal iron stores, is inconsistently delivered due to supply chain deficiencies and limited adherence tracking at antenatal care facilities.

6.4 Dietary Diversity and Behaviour Change Communication

Sustainable IDA reduction requires promoting iron-rich complementary foods, optimal breastfeeding practices, iron-enriched weaning foods, and reduction of iron absorption inhibitors (such as tea with meals). Mobile health technologies offer a promising platform for behaviour change communication (BCC) in urban Central Asia, where smartphone penetration among young women is high.

6.5 Integration into Health System Screening

The American Academy of Pediatrics and WHO recommend universal hemoglobin screening at 9–12 months to enable early detection and timely treatment. Implementation requires functional health information systems, trained community health workers, and reliable diagnostic and therapeutic supply chains — all of which require targeted investment throughout the region.

Table 2. Summary of Key Interventions for Childhood IDA in Central Asia

Intervention	Target Group	Evidence Level	Regional Coverage	Key Barriers
Wheat flour fortification	General population	Strong	10–90% by country	Enforcement gaps; artisanal flour competition
Micronutrient powders (MNPs)	Children 6–23 months	Strong (RCT)	Limited (KG, TJ only)	Adherence; logistics
Iron supplementation (therapeutic)	Diagnosed IDA cases	Strong	Inconsistent	GI side effects; protocol gaps
Antenatal iron supplementation	Pregnant women	Strong	Inconsistent	Supply chain; monitoring
Behaviour change comm.	Caregivers, women	Moderate	Limited	Scale; reach in rural areas
Universal Hb screening	Infants 9–12 months	Strong (guideline)	Very limited	Infrastructure; trained staff

GI = gastrointestinal; Hb = hemoglobin; KG = Kyrgyzstan; TJ = Tajikistan; MNP = micronutrient powder; RCT = randomized controlled trial.

7. POLICY FRAMEWORKS AND GAPS

7.1 National Policies

All five Central Asian republics have developed some form of national anemia prevention and control policy, typically embedded within broader nutrition and health frameworks and combining oral supplementation for high-risk groups, wheat flour fortification, and education — frequently with UNICEF and WHO technical support. However, Knowles et al. (2024) found no specific UN, EU, or regional-level policies or guidelines addressing the distinct needs of the Eastern and Central Asia region. National programs therefore operate with limited guidance from regional-level policy architecture — a serious gap given the transnational dimensions of the anemia burden through cross-border labor migration, shared food systems, and common environmental exposures.

7.2 Surveillance and Data Gaps

A primary challenge across all five countries is the absence of recent (within 5–10 years), nationally representative, methodologically rigorous data on anemia prevalence, IDA etiology, and intervention coverage. The Kyrgyz NIMAS 2021 exemplifies the surveillance quality achievable through multi-partner investment, but remains an exception. Tajikistan — which carries the highest estimated anemia burden — has not conducted a DHS or equivalent survey in over four years. Without current data, effective intervention targeting, resource allocation, and SDG progress monitoring are not feasible.

7.3 Alignment with SDGs and 2030 WHO Nutrition Targets

Reducing childhood anemia is directly aligned with SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-Being). The WHO 2030 Global Nutrition Target calls for a 50% reduction in anemia prevalence among women of reproductive age from the 2012 baseline — a target closely correlated with reducing childhood anemia. Kazakhstan and Uzbekistan are on moderate trajectories toward this target; Tajikistan and Kyrgyzstan face systemic challenges requiring significantly accelerated action.

8. DISCUSSION

This review confirms a complex and heterogeneous burden of childhood IDA across Central Asia, with particularly severe challenges in Tajikistan and Kyrgyzstan. While the overall regional burden has declined substantially from its 1990s peak

following the post-Soviet economic collapse and subsequent reconstruction of food security and health infrastructure, all five countries remain above the WHO public health significance threshold.

The primary drivers — dietary iron inadequacy in cereal-dominant food systems, poverty, insufficient child dietary diversity, suboptimal infant feeding practices, maternal anemia, and limited healthcare access — are interrelated and mutually reinforcing. Kyrgyzstan's high-altitude context necessitates methodological adaptation in survey design and clinical practice, as recently formalized in the 2024 WHO hemoglobin cut-off guidelines.

The neurodevelopmental consequences of childhood IDA represent an insidious but profound public health emergency with intergenerational consequences. Countries pursuing knowledge-based economies — exemplified by Kazakhstan's national development strategies — must recognize that childhood IDA directly undermines human capital formation through its impact on cognitive capacity and educational performance.

The 1,000-day window — from conception through 24 months — represents the critical period during which iron status exerts its greatest influence on brain development. Interventions implemented beyond this window cannot replicate the developmental benefits of adequate iron during this phase, reinforcing the imperative of early, targeted action.

This review's principal strength lies in its integration of the most recent available evidence, including NIMAS Kyrgyzstan 2021, the 2024 UNICEF ECA review, and GBD 2021 data. A significant limitation is the differential distribution of evidence across the five countries: Kazakhstan and Kyrgyzstan are comparatively well-studied, limiting the generalizability of conclusions to Tajikistan, Turkmenistan, and Uzbekistan.

Future research priorities should include: (1) nationally representative nutrition surveys in Tajikistan, Turkmenistan, and Uzbekistan using standardized methods and inflammation-adjusted biomarkers; (2) implementation research on fortification monitoring methods; (3) evaluation of MNP delivery through community health worker systems; (4) longitudinal studies linking childhood IDA to education and economic outcomes; and (5) integration of altitude-adjustment protocols into national survey and clinical practice guidelines.

9. CONCLUSIONS

Childhood iron deficiency anemia in Central Asia is a persistent, multidimensional public health problem with consequences far exceeding hemoglobin deficits. Iron deficiency during critical developmental windows may permanently impair cognitive development for an entire generation. The evidence supports a multi-pronged regional strategy encompassing:

- Universal wheat flour fortification at mass-market scale using highly bioavailable iron compounds, backed by robust government enforcement mechanisms;
- Community-based MNP supplementation programmes for children aged 6–24 months;
- Supervised antenatal iron supplementation to reduce maternal anemia and its intergenerational effects;
- Behaviour change communication to promote dietary diversity and optimal infant and young child feeding practices;
- Universal hemoglobin screening of all infants between 9 and 12 months at each health service contact;
- Establishment and funding of national nutrition surveillance systems in all five countries.

Achieving these goals requires coordinated, multi-sectoral action spanning ministries of health, agriculture, finance, and education, alongside NGOs and international partners including WHO, UNICEF, WFP, and FAO. The 2030 SDG framework and WHO Global Nutrition Targets provide the policy architecture. The convergence of biological opportunity — the 1,000-day window — and ongoing regional health reforms creates a moment that must not be wasted.

Conflicts of Interest: The authors declare no conflicts of interest relevant to this manuscript.

Author Contributions: A. Siddiqui and S. Siddiqui conceptualized and designed the review. A. Siddiqui and M. Sarfaraz conducted the literature search and data extraction. S. Siddiqui led epidemiological data synthesis. All authors contributed to writing and revision. A. Siddiqui acts as guarantor of the review.

Data Availability: All data used in this review are available in published sources cited herein. WHO nutrition databases are publicly available at https://www.who.int/nutrition.

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