



ADOLESCENT ANEMIA: A SYSTEMATIC REVIEW OF PREVALENCE, DETERMINANTS, AND HEALTH IMPACTS

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ABSTRACT

Adolescent anemia remains a major global public health concern with significant implications for physical, cognitive, and developmental outcomes. This systematic review aims to synthesize current international evidence on the prevalence, determinants, and health impacts of anemia among adolescents, with a particular focus on adolescent girls who experience heightened vulnerability due to increased physiological iron requirements and menstrual blood loss. Using a systematic approach, fifteen peer-reviewed studies published between 2020 and 2025 were analyzed, encompassing diverse regions including Africa, South Asia, Southeast Asia, East Asia, the Middle East, and Europe. Data extraction included study design, sample characteristics, anemia prevalence, associated factors, and reported health consequences. The findings reveal considerable prevalence variability across countries, ranging from moderate to severe public health significance. Nutritional deficiencies—particularly low intake of iron, protein, and vitamin C—emerged as the strongest determinants, alongside socioeconomic disparities, menstrual characteristics, infectious diseases, and environmental conditions. Anemia was consistently associated with reduced physical stamina, increased susceptibility to illness, impaired cognitive function, lower academic achievement, psychosocial difficulties, and long-term reproductive and intergenerational risks. The review highlights the need for multisectoral, gender-responsive interventions that integrate dietary improvement, menstrual health management, WASH enhancements, and school-based health programs. These findings reinforce the urgency of prioritizing adolescent anemia within global and national health agendas.

Keywords: Adolescent anemia; Iron deficiency; Dietary determinants, Menstrual health; Public health interventions

1. INTRODUCTION

Anemia remains one of the most significant public health concerns affecting adolescents worldwide, with profound implications for growth, cognitive development, academic performance, and long-term health outcomes. Adolescence is a critical developmental period characterized by rapid physical growth, increased nutritional demands, hormonal changes, and evolving lifestyle behaviors. These biological and behavioral shifts elevate the risk of nutrient

deficiencies, particularly iron, folate, and vitamin B12, making anemia a prevalent condition within this age group (Sari et al., 2022; Chaber et al., 2024).

Although anemia in adolescents is a global problem, it disproportionately affects populations in low- and middle-income countries (LMICs), where nutritional inadequacies, socioeconomic disparities, and limited access to healthcare services remain persistent challenges (Kebede et al., 2025; Mbou et al., 2025).

The global burden of adolescent anemia is driven by multifactorial determinants, including inadequate dietary intake, chronic infections, parasitic infestations, menstrual blood loss, and underlying genetic disorders such as sickle cell disease. For example, case evidence shows that adolescents with sickle cell anemia may experience severe complications such as acute soft head syndrome, highlighting the medical vulnerability of this population (Magitta et al., 2023). Nutritional deficiencies, particularly in iron, are the leading contributor to anemia worldwide. Studies across different geographical settings consistently report that low intake of iron-rich foods, inadequate dietary diversity, and poor consumption of vitamin C—which enhances iron absorption—are strongly associated with anemia among adolescent girls (Yanti et al., 2024; Nanda et al., 2025). This is particularly pronounced in regions where plant-based diets predominate, and intake of animal-source foods is limited due to cultural or economic constraints (Puspitasari et al., 2025).

Emerging evidence also highlights that dietary patterns alone do not fully explain the prevalence of anemia. Socioeconomic status, parental education, household food security, and access to health information significantly mediate adolescents' nutritional behaviors and anemia risk (Nahid & Firoz, 2025; Agarwal et al., 2024). In many LMIC contexts, adolescent girls are further disadvantaged due to gender norms that deprioritize their nutritional intake, exacerbating risks related to menstrual blood loss (Li et al., 2022). Moreover, environmental and community-level factors—including sanitation, prevalence of infectious diseases, and availability of adolescent-friendly health services—contribute to disparities in anemia prevalence between rural and urban populations. For instance, Kebede et al. (2025) found substantially higher rates of anemia among rural adolescent girls in Ethiopia, driven by both nutritional inadequacies and limited health service accessibility.

Anemia has far-reaching consequences for adolescent well-being. Physiological impairments such as fatigue, reduced immunity, and impaired physical endurance can undermine daily functioning. More importantly, anemia is strongly linked to poor cognitive performance, decreased concentration, and reduced academic achievement. Taqwin et al. (2025) demonstrated that students with anemia exhibited significantly lower learning outcomes compared to their non-anemic peers, emphasizing the condition's detrimental impact on educational attainment. In addition, anemia during adolescence may predispose girls to complications later in life, including adverse pregnancy outcomes, intergenerational malnutrition, and heightened risk of perinatal morbidity and mortality (Sari et al., 2022; Chaber et al., 2024).

Despite the magnitude of the problem, interventions and preventive strategies targeting adolescent anemia remain insufficient and inconsistently implemented across countries. Evidence from India shows that iron-fortification programs, weekly iron-folic acid supplementation, and school-based nutrition interventions can substantially reduce the burden of iron-deficiency anemia when delivered consistently and monitored effectively (Felix et al., 2025). However, the effectiveness of such interventions varies widely, often depending on adherence, cultural acceptance, and the availability of supportive health

infrastructure. In some contexts, early screening and appropriate diagnosis are insufficiently prioritized, even though clinical guidelines emphasize the importance of routine assessment of iron status during adolescence (Chaber et al., 2024).

Therefore, this systematic review aims to synthesize current international evidence on adolescent anemia by examining its prevalence, key determinants, and health impacts across different contexts. By integrating findings from recent high-quality studies, this review seeks to provide a holistic understanding of the factors driving adolescent anemia and highlight implications for public health policies, school-based interventions, and future research directions.

2. METHODS

This study employed a systematic review design to synthesize existing evidence on the prevalence, determinants, and health impacts of anemia among adolescents. A systematic review was chosen because it allows for a structured, transparent, and reproducible approach to identifying, appraising, and synthesizing relevant empirical evidence from diverse geographical settings and methodological orientations. This design is consistent with prior anemia research syntheses such as interventions meta-analysis by Felix et al. (2025) and epidemiological assessments in multiple regions (Kebede et al., 2025; Agarwal et al., 2024). The review procedure adhered to the core principles of systematic evidence synthesis: comprehensive literature search, explicit inclusion and exclusion criteria, quality assessment of included articles, and structured extraction of findings.

A comprehensive literature search was conducted across major scientific databases, including PubMed, Scopus, Web of Science, and Google Scholar, to ensure broad coverage of high-quality peer-reviewed articles. The search was performed between January and February 2025 and included studies published from 2020 to 2025 to capture the most recent evidence, in line with the publication periods of studies such as Magitta et al. (2023), Puspitasari et al. (2025), and Mbou et al. (2025).

A combination of Medical Subject Headings (MeSH) terms and free-text keywords was used:

- "anemia", "anaemia", "iron deficiency anemia"
- "adolescent", "teenager", "youth", "school-going adolescents"
- "prevalence", "determinants", "risk factors", "dietary factors"
- "learning outcomes", "health impact", "interventions"

Boolean operators such as AND, OR, and NOT were applied to refine the search. Reference lists of selected studies were additionally screened to identify relevant articles not captured through database searches, following approaches used in previous cross-sectional and clinical anemia studies (Nahid & Firoz, 2025; Yanti et al., 2024).

Studies were eligible if they:

1. Examined adolescent populations (ages 10–19), consistent with the WHO definition.
2. Reported data on prevalence, determinants, and/or health impacts of anemia.
3. Employed quantitative, qualitative, or mixed-methods designs.
4. Were peer-reviewed journal articles.

5. Provided sufficient methodological detail, including sample characteristics and diagnostic criteria for anemia (e.g., hemoglobin cut-offs per WHO guidelines).
6. Were published between 2020 and 2025, aligning with recency of the included literature.

Studies such as cross-sectional analyses (e.g., Agarwal et al., 2024; Kebede et al., 2025; Mbou et al., 2025), nutritional determinants analyses (Yanti et al., 2024; Nanda et al., 2025), and learning- outcome investigations (Taqwin et al., 2025) met these criteria.

Exclusion criteria

Studies were excluded if they focused on adults or children outside the 10–19 age range.

1. Did not directly measure anemia or its determinants.
2. Were reviews, commentaries, dissertations, or non-peer-reviewed documents.
3. Lacked accessible full text or insufficient methodological descriptions.
4. Reported highly specific medical cases not generalizable to population-level anemia (with the exception of Magitta et al. (2023), which was included to illustrate clinical manifestations relevant to adolescent anemia).

All retrieved records were imported into a database for systematic screening. Titles and abstracts were reviewed independently to identify potentially relevant studies. Full texts of selected articles were then assessed according to the inclusion and exclusion criteria. Conflicts arising during the screening process were resolved through discussion and consensus.

After full-text evaluation, 15 studies were included, covering diverse geographical regions such as India, Ethiopia, Indonesia, China, Cameroon, and Europe. These studies encompassed cross- sectional surveys (e.g., Nahid & Firoz, 2025; Puspitasari et al., 2025), community-based studies (Kebede et al., 2025), nutritional assessments (Yanti et al., 2024), clinical case reports (Magitta et al., 2023), and national surveillance datasets (Li et al., 2022).

A structured data extraction matrix was developed to ensure consistency across studies. Extracted information included:

- Author(s), year, and country
- Study design and sampling method
- Sample size and demographic characteristics
- Anemia definitions and diagnostic criteria
- Prevalence rates
- Determinants or associated factors
- Outcomes and health impacts
- Intervention effects, if applicable

This extraction approach is consistent with the methodology applied in intervention-focused systematic reviews such as Felix et al. (2025) and surveillance-based studies (Li et al., 2022). Special attention was given to variations in hemoglobin thresholds, laboratory techniques, and operational definitions, particularly since some papers used WHO standards while others employed local clinical guidelines (Chaber et al., 2024).

Quality appraisal of included articles was conducted using a modified version of the Joanna Briggs Institute (JBI) Critical Appraisal Checklist, which is suitable for cross-sectional, case-control, and clinical studies. Each study was assessed on:

- Clarity of objectives
- Appropriateness of study design
- Adequacy of sampling procedures
- Validity and reliability of anemia measurements
- Control for confounding factors
- Statistical analysis robustness

Cross-sectional studies (e.g., Mbou et al., 2025; Nahid & Firoz, 2025; Agarwal et al., 2024) were evaluated for sampling adequacy and analytical rigor. Clinical case studies (Magitta et al., 2023) were appraised for diagnostic accuracy and reporting clarity. Studies reporting dietary associations (Yanti et al., 2024; Nanda et al., 2025) were evaluated for diet assessment reliability. Disagreements in quality scoring were reviewed collaboratively, and no study was excluded based on quality alone, consistent with practices in anemia-related syntheses.

Given the heterogeneity of study designs, populations, and outcome measures, a narrative synthesis approach was applied. Data were grouped into three principal domains aligned with the study objectives:

1. Prevalence of adolescent anemia
2. Determinants and risk factors, including dietary, socioeconomic, clinical, and environmental elements
3. Health impacts, including learning outcomes, physical performance, and clinical complications

Where numerical data were comparable (e.g., prevalence percentages, hemoglobin levels), descriptive comparison tables were constructed. Intervention effects were analyzed qualitatively based on direction and strength of findings, referencing meta-analytic insights from Felix et al. (2025). Case reports such as Magitta et al. (2023) were synthesized separately to provide clinical context. Studies linking anemia to cognitive outcomes (Taqwin et al., 2025) and quality of life (Sari et al., 2022) were grouped under health impacts.

As this study is a systematic review of existing literature, it did not involve the collection of primary data from human subjects. Therefore, ethical approval was not required. However, all included studies reported adherence to ethical principles such as informed consent, institutional review board approval, and confidentiality protections, as documented in cross-sectional surveys (Mbou et al., 2025; Puspitasari et al., 2025) and clinical studies (Magitta et al., 2023).

3. RESULTS AND DISCUSSION

Evidence from African settings demonstrates that adolescent anemia remains a persistent and widespread public health issue, with prevalence rates often exceeding global averages. In Cameroon, Mbou et al. (2025) reported that 38.4% of school-going adolescents in Douala were anemic, indicating a moderate-to-severe public health problem based on WHO classifications. The study found that anemia was particularly common among females, with prevalence

significantly higher than in males, reflecting biological and hormonal factors associated with menstruation. Similarly, Kebede et al. (2025) documented a 42.7% anemia prevalence among rural adolescent girls in West Badewacho, Ethiopia. Their findings showed a pronounced rural–urban disparity, where limited dietary diversity, food insecurity, and poor access to health services contributed substantially to the high anemia burden. Both African studies highlight overlapping patterns: adolescents in low-resource settings face nutritional deficiencies, socio-cultural constraints, and environmental challenges that collectively increase susceptibility to anemia. Furthermore, the age distribution indicates that late adolescents (15–19 years) exhibit higher anemia prevalence due to intensified menstrual blood loss and higher iron requirements compared to early adolescents — a pattern observed consistently across the continent (Mbou et al., 2025; Kebede et al., 2025).

Asian countries similarly experience high prevalence levels of adolescent anemia, with marked variability across regions. In India, Agarwal et al. (2024) examined school-going adolescents in Vadodara District and found a prevalence rate of 29.6%, with girls experiencing disproportionately higher rates. The prevalence aligns with national Indian estimates, publicly recognized as among the highest globally. Likewise, a study in Bangladesh by Nahid and Firoz (2025) recorded a 47.1% anemia prevalence among adolescents, with nutritional inadequacies and infectious diseases serving as key contributors. The high prevalence underscores the complex interplay between socioeconomic constraints, dietary patterns, and cultural norms surrounding adolescent nutrition.

In Indonesia, evidence from multiple regions shows a similar burden. Sari et al. (2022) identified anemia prevalence among adolescent girls in West Java at 32.8%, while Maryatun et al. (2024) assessed early adolescents in elementary schools and found particularly high vulnerability where more than one-third were anemic. Puspitasari et al. (2025), studying adolescent girls in Nawangsasi Health Center, documented anemia prevalence at 28.9%, confirming that anemia remains a persistent challenge throughout various Indonesian provinces.

China, although more nutritionally advantaged, still reports considerable anemia prevalence among adolescent girls. Li et al. (2022), drawing from China Nutrition and Health Surveillance (2015–2017), showed that 16.7% of Chinese adolescent girls were anemic. While lower than most South Asian regions, the rate remains epidemiologically significant, especially given China's improved economic standing.

Although high-income countries generally report lower anemia rates, iron-deficiency anemia (IDA) remains a considerable concern, especially among adolescent girls. Clinical guidelines from Poland emphasize that IDA remains “highly prevalent and underdiagnosed” in pediatric and adolescent populations due to subclinical manifestations and insufficient routine screenings (Chaber et al., 2024). While precise prevalence estimates vary across European nations, the guideline reports indicate that up to 20% of adolescent girls may experience iron deficiency, with a fraction progressing to clinically significant anemia.

These findings reaffirm that anemia is not merely a problem of low-income countries but rather a multifactorial condition affecting adolescents globally.

An emerging concern is the increasing prevalence of anemia among overweight or obese adolescents — a paradox well documented by Al-Attar et al. (2020). Their study revealed that 19.7% of overweight and obese adolescents were anemic, challenging the assumption that anemia is limited to undernourished populations. Obesity-induced inflammation may impair iron metabolism, reducing hepcidin activity and disrupting iron absorption, thereby increasing anemia susceptibility.

Additionally, Magitta et al. (2023) provided a clinical case illustration in Tanzania, showing that adolescents with sickle cell anemia are at heightened risk of severe complications, including acute soft head syndrome. Although a single case study, it demonstrates the clinical gravity of hematologic conditions in this age group.

Across nearly all studies reviewed, female adolescents consistently show higher anemia prevalence than males, attributed to menstrual blood loss, inadequate dietary intake during puberty, and cultural patterns that deprioritize girls' nutrition (Nahid & Firoz, 2025; Yanti et al., 2024; Nanda et al., 2025). Age-specific analysis shows that older adolescents (15–19 years) exhibit higher prevalence compared to younger adolescents (10–14 years), consistent with increased iron needs during late puberty.

Educational level also appears associated with lower prevalence among adolescents in higher grades who tend to have better health literacy and dietary knowledge (Puspitasari et al., 2025). Across the 15 studies in this review:

Region	Lowest Prevalence	Highest Prevalence
Africa	38.4% (Cameroon)	42.7% (Ethiopia)
South Asia	29.6% (India – Vadodara)	47.1% (Bangladesh)
Southeast Asia	28.9% (Indonesia – Nawangsasi)	>35% (Indonesia – Elementary Schools)
East Asia	16.7% (China)	—
High- income/Europe	~10–20%	—
Special populations	19.7% (Obese adolescents)	—

These trends confirm that adolescent anemia is a global health concern, disproportionately affecting low- and middle-income regions but still significant across developed nations.

Determinants of adolescent anemia identified across the reviewed studies indicate that anemia is a multifactorial condition shaped by biological, socioeconomic, environmental, dietary, and behavioral contributors. While iron deficiency remains the most common etiology, the complexity of adolescent physiology and living conditions makes anemia a condition arising from interacting pathways rather than a single cause. The included studies consistently emphasize that the risk profile for anemia is highest among adolescent girls due to menstrual blood loss, insufficient dietary intake, sociocultural norms, and higher physiological iron requirements. This section synthesizes key determinants across five major domains.

Nutrition-related factors emerged as the strongest and most consistent determinants of anemia across studies. Multiple investigations documented that low intake of iron, protein, folate, and vitamin C — essential nutrients for hemoglobin synthesis — directly increases anemia risk.

Yanti et al. (2024) demonstrated that insufficient intake of iron-rich foods (such as meat, fish, and eggs), inadequate dietary protein, and low vitamin C intake significantly predicted anemia among adolescent girls. The study reported that vitamin C intake was particularly important because it enhances non-heme iron absorption — a crucial factor in predominantly plant-based diets found in Indonesia, India, Ethiopia, and Bangladesh.

In Denpasar, Nanda et al. (2025) reported that adolescents with poor dietary patterns and low consumption of iron-rich food groups were significantly more likely to exhibit anemic

symptoms. Their findings further suggested that dietary behavior is not solely influenced by food availability but also by adolescents' understanding of iron's role in health, indicating a behavioral-educational component influencing nutritional choices.

Similarly, Puspitasari et al. (2025) found that 68.3% of the anemic adolescents in their study consumed inadequate levels of iron-rich foods, while 73% exhibited insufficient dietary diversity

— reinforcing the centrality of diet. Their research emphasized that adolescents in rural or low-income households were less likely to consume animal-source foods, often due to cost constraints.

In India, Agarwal et al. (2024) confirmed similar patterns: iron-deficiency anemia (IDA) was strongly associated with poor nutritional status, inadequate intake of fruits and vegetables, and low caloric intake among adolescents in Vadodara district. Meanwhile, Kebede et al. (2025) found that Ethiopian adolescent girls with low dietary diversity scores were twice as likely to be anemic.

The cross-regional consistency underscores the central conclusion that nutritional determinants are universal, regardless of socioeconomic or cultural context.

Socioeconomic Determinants

Socioeconomic factors also appeared prominently across studies. Lower household income, food insecurity, unemployment among parents, and low educational attainment were recurring predictors of anemia.

In Cameroon, Mbou et al. (2025) demonstrated that adolescents from low-income households had significantly higher anemia prevalence, largely due to reduced diet quality, limited access to healthcare, and greater vulnerability to infections. Income disparities directly affected dietary diversity and consumption frequency of iron-rich foods.

In Bangladesh, Nahid and Firoz (2025) identified parental education as a key determinant: adolescents whose parents had limited education were more likely to be anemic, likely due to poorer nutritional literacy and inadequate health-seeking behaviors. Their study found that maternal education, in particular, had a protective effect against adolescent anemia.

Similarly, in Indonesia, Puspitasari et al. (2025) found that adolescents from families with unstable economic conditions had a three-fold increased risk of anemia. Economic instability constrained dietary choices and reduced access to supplements and health services.

Global surveillance data from China also linked anemia prevalence with lower household socioeconomic status and limited access to dietary diversity, particularly for rural girls (Li et al., 2022). Overall, socioeconomic determinants consistently shape anemia risk by influencing diet, health access, and living conditions.

Menstrual and Reproductive Determinants

Menstruation-related factors are among the most potent biological determinants of anemia in adolescent girls. Heavy menstrual bleeding (menorrhagia), irregular cycles, and early menarche substantially increase iron loss.

Multiple studies, including Yanti et al. (2024), Nanda et al. (2025), and Sari et al. (2022), consistently reported that girls with heavier menstrual cycles had significantly lower hemoglobin levels. Adolescents with prolonged bleeding were up to three times more likely to be anemic.

Sari et al. (2022) found strong evidence that menstrual characteristics were the single most significant predictor of anemia among adolescents in West Java, besides diet. Their analysis indicated that girls with heavy menstrual flow had a 75% higher risk of anemia.

Moreover, early menarche (before age 12) was documented as an additional risk factor because it extended the duration during which adolescents experienced menstrual blood loss (Puspitasari et al., 2025). These biological mechanisms confirm that adolescent girls, especially older ones with heavier menstrual flow, require greater iron intake than boys — yet dietary insufficiency often fails to compensate for menstrual losses.

Disease-Related Determinants (Infectious & Genetic)

Infectious and genetic conditions also contribute significantly to anemia risk in adolescents. While iron deficiency is the most common cause, infections such as helminthiasis, malaria, and chronic illnesses remain important contributors in many low-income regions.

Mbou et al. (2025) and Kebede et al. (2025) noted that adolescents with recurrent infections had higher anemia prevalence, highlighting the interaction between infection, immune response, and iron metabolism. Parasitic infections can cause gastrointestinal blood loss and impair nutrient absorption, while chronic inflammation disrupts hepcidin regulation.

Genetic determinants, though less common, can significantly worsen anemia outcomes. Magitta et al. (2023) illustrated a severe case of acute soft head syndrome in a teenager with sickle cell anemia, demonstrating that hemoglobinopathies can produce life-threatening complications.

Al-Attar et al. (2020) showed that even overweight and obese adolescents were susceptible to anemia through inflammatory pathways: obesity-induced chronic inflammation disrupts iron homeostasis, leading to functional iron deficiency.

These findings indicate that anemia is not solely a nutritional condition but also influenced by underlying disease processes.

Environmental and Behavioral Determinants

Environmental and behavioral factors — including hygiene practices, dietary behaviors, physical activity, and access to health information — also contribute to anemia risk.

In Ethiopia, Kebede et al. (2025) found that adolescents with poor handwashing practices and inadequate sanitation facilities were more vulnerable to infections leading to anemia. Environmental conditions such as unsafe drinking water and lack of latrines indirectly influence anemia outcomes via infection pathways.

Behaviorally, inadequate eating frequency, picky eating, skipping meals, excessive dieting, and reliance on processed foods were associated with anemia in the studies by Nanda et al. (2025) and Yanti et al. (2024). Low nutrition literacy, limited awareness about anemia, and insufficient health education were identified as indirect but influential determinants in both Indonesian and African contexts (Mbou et al., 2025; Puspitasari et al., 2025).

These determinants highlight that adolescent anemia is closely tied to lifestyle and environmental factors.

Results: Health Impacts of Adolescent Anemia

The reviewed evidence shows that adolescent anemia is associated with a broad spectrum of health consequences that span physical, cognitive, psychosocial, academic, and long-term domains. While iron-deficiency anemia (IDA) is the most prevalent form, the health impacts

extend beyond iron metabolism and affect nearly every physiological system. This section synthesizes findings from the included studies, highlighting four main impact categories.

Physical Health Consequences

Physical consequences of anemia among adolescents were consistently reported across studies, with fatigue, reduced physical endurance, impaired immunity, and stunted growth emerging as key themes. Physiologically, anemia limits oxygen transport capacity, leading to systemic hypoxia and reduced organ performance. Adolescents, who are in a stage of rapid growth and increased metabolic demand, are particularly vulnerable.

Sari et al. (2022) reported that adolescent girls with anemia experienced significantly lower physical functioning scores, including reduced stamina, frequent dizziness, and decreased ability to participate in school activities. Similarly, Puspitasari et al. (2025) identified recurrent fatigue, shortness of breath, and low exercise tolerance as common presentations among anemic adolescents in Indonesia.

Evidence from Africa shows similar trends. Mbou et al. (2025) documented that Cameroonian adolescents with anemia were significantly more likely to experience generalized weakness, headaches, reduced appetite, and susceptibility to infections. Kebede et al. (2025) also reported that Ethiopian adolescents with moderate to severe anemia exhibited more frequent illness episodes, likely due to the compromised immune response associated with micronutrient deficiency.

A particularly severe physical manifestation is illustrated by Magitta et al. (2023), who reported acute soft head syndrome in a teenager with sickle cell anemia. Although this represents a specific hematological condition rather than nutritional anemia, it demonstrates the extreme physiological vulnerability experienced by adolescents with pre-existing hematologic disorders.

This case highlights the risk of acute neurological complications and underscores the clinical importance of early identification of anemia.

Taken together, the evidence clearly demonstrates that anemia compromises adolescent physical health by reducing oxygen delivery, limiting physical capacity, weakening immunity, and increasing susceptibility to both acute and chronic health conditions.

Cognitive and Academic Performance Impact

One of the most significant and well-documented consequences of anemia among adolescents is its negative effect on cognitive performance and academic achievement. Several studies in the review highlighted that the hypoxic effects of anemia impair brain function, leading to difficulties in concentration, memory, and executive functioning.

Taqwin et al. (2025), in a cross-sectional study in Indonesia, found a strong association between anemia and decreased student learning outcomes. Anemic students scored significantly lower on academic performance assessments compared to their non-anemic peers. The study concluded that anemia is an independent predictor of academic underachievement.

Sari et al. (2022) also demonstrated that adolescents with anemia had lower scores in cognitive functioning and school attendance. Disruptions in cognitive processes, such as working memory and attention, were among the key impacts documented. They noted that iron deficiency affects neurotransmitter synthesis and myelination, both essential for efficient brain functioning.

In African contexts, similar findings were reported. Mbou et al. (2025) noted that adolescents who were anemic performed significantly worse in school-related tasks. This deficit

was attributed to both physiological (hypoxia-induced cognitive impairment) and psychosocial factors (e.g., fatigue reducing study consistency). Studies in South Asia provide corroborating evidence. Nahid and Firoz (2025) reported that Bangladeshi adolescents with anemia were more likely to have poor concentration in class and lower examination scores. Agarwal et al. (2024) also observed that Indian adolescents with anemia frequently missed school due to fatigue and illness, contributing to poorer overall academic performance.

The cumulative evidence strongly supports the conclusion that anemia directly reduces educational achievement, posing long-term consequences for human capital development, particularly in low- and middle-income countries.

Psychosocial and Quality-of-Life Impacts

Beyond physical and cognitive effects, anemia substantially impacts psychosocial well-being. Adolescence is a vulnerable developmental phase, and the presence of chronic health conditions can profoundly disturb emotional, social, and behavioral functioning.

Sari et al. (2022) reported that adolescents with anemia had significantly poorer quality-of-life scores across emotional, social, and school functioning domains. Fatigue, irritability, and reduced self-esteem were common psychosocial outcomes. The authors conclude that anemia affects not only physiological functioning but also the emotional stability of adolescents, reducing their confidence and motivation.

Puspitasari et al. (2025) similarly noted that anemic adolescents often reported feeling socially withdrawn, lacking motivation, and experiencing mood fluctuations. Such psychosocial effects may be secondary to both physiological fatigue and the stigma associated with chronic illness.

In Ethiopia, Kebede et al. (2025) documented that adolescents with severe anemia expressed feelings of hopelessness, social isolation, and anxiety. Their findings indicate that the psychosocial burden of anemia may be magnified in communities where the condition is associated with weakness or perceived laziness.

The psychosocial consequences of anemia are therefore not incidental but integral to its clinical and public health significance. Poor emotional well-being can further exacerbate poor dietary habits, reduced engagement in health programs, and difficulty adhering to supplementation regimens.

Long-Term Consequences and Intergenerational Outcomes

The long-term impacts of anemia during adolescence extend into adulthood and have implications for intergenerational health. As adolescence is a period of reproductive maturation, inadequate iron stores during this period can predispose females to complications during pregnancy later in life.

Chaber et al. (2024) highlight that adolescent iron deficiency, if not addressed, increases the risk of maternal anemia in adulthood, which is associated with preterm birth, low birth weight, and increased maternal mortality. These findings emphasize that adolescent anemia has consequences that span far beyond the immediate developmental stage.

Li et al. (2022) emphasize that inadequate nutrition and anemia during adolescence impair peak bone mass development, potentially increasing the risk of osteoporosis in later life. They also highlight that the long-term productivity and socioeconomic prospects of adolescents are undermined when cognitive and physical development is compromised by early anemia.

Further, Felix et al. (2025) highlight through meta-analysis that untreated IDA in adolescence leads to persistent iron depletion, which cannot be easily replenished through diet alone. This prolonged deficiency undermines adult physical capacity, economic productivity, and overall quality of life. Thus, the long-term impacts of adolescent anemia are profound: impaired physical development, compromised cognitive function, reduced economic potential, and increased maternal health risks — all of which contribute to cyclical patterns of poor health in future generations.

Discussion: Integrated Cross-Study Interpretation, Emerging Patterns, and Public Health Implications

The collective synthesis of the fifteen studies included in this review demonstrates that adolescent anemia is a complex, multifactorial condition driven by the intersection of nutritional, socioeconomic, biological, environmental, and behavioral determinants. Despite regional variations in prevalence and contextual influences, the studies reveal several overarching patterns that converge across Africa, South Asia, Southeast Asia, East Asia, and Europe. This integrated discussion consolidates cross-study comparisons, emerging epidemiological and nutritional patterns, intervention insights, and connections to broader global evidence.

Cross-Study Convergences in Prevalence and Determinants

Across all regions, adolescent girls consistently emerge as the highest-risk group for anemia. This convergence reflects the combined effects of menstruation-related iron loss, increased iron requirements during puberty, and inadequate dietary compensation (Mbou et al., 2025; Kebede et al., 2025; Sari et al., 2022; Yanti et al., 2024). Studies from India, Bangladesh, Indonesia, Ethiopia, and Cameroon confirm that iron intake among adolescent girls is insufficient relative to physiological needs (Agarwal et al., 2024; Nahid & Firoz, 2025; Nanda et al., 2025; Puspitasari et al., 2025). Another strong convergence relates to nutritional determinants, particularly low dietary diversity. Studies consistently show that anemia risk is more strongly linked to micronutrient deficiencies than to total caloric intake (Yanti et al., 2024; Nanda et al., 2025). Adolescents consuming limited animal-source foods and insufficient vitamin C exhibited substantially higher anemia rates.

Socioeconomic determinants also converge across studies. Low parental education, household income instability, food insecurity, and limited healthcare access significantly elevate anemia risk (Mbou et al., 2025; Nahid & Firoz, 2025; Puspitasari et al., 2025). These pathways align with global evidence that socioeconomic inequalities influence anemia through both dietary and health- service-related mechanisms.

Environmental and behavioral determinants present additional layers of risk. Poor sanitation, inadequate hygiene, meal-skipping, and low nutrition literacy contribute to anemia through infection pathways and suboptimal dietary habits (Kebede et al., 2025; Nanda et al., 2025).

Divergences Across Regions and Populations

Despite strong thematic convergence, marked divergences exist in prevalence rates across countries. South Asia (Bangladesh, India) and Africa (Ethiopia, Cameroon) exhibit the highest prevalence (30–47%), whereas East Asia (China) reports significantly lower rates (Li et al., 2022). These differences reflect:

- Variations in dietary patterns (e.g., high-phytate diets in South Asia)
- Differences in infection burdens (higher in Sub-Saharan Africa)
- Socioeconomic disparities

- Differences in national nutrition programs and healthcare systems

The determinants also vary in relative importance. For example, menstrual disorders dominate anemia risk in Indonesia and India (Yanti et al., 2024; Agarwal et al., 2024), whereas environmental and infection-related pathways are more prominent in Ethiopia and Cameroon (Kebede et al., 2025; Mbou et al., 2025). Conversely, obesity-related inflammation emerges as a unique determinant in Middle Eastern contexts (Al-Attar et al., 2020), indicating a shift toward the double burden of malnutrition.

Integrated Interpretation of Health Impacts

Across all studies, the consequences of anemia consistently affect four major domains: physical, cognitive, psychosocial, and long-term health.

- **Physical impacts** include fatigue, reduced stamina, and increased infection susceptibility (Sari et al., 2022; Mbou et al., 2025). Severe outcomes occur among adolescents with hemoglobinopathies, such as the acute soft head syndrome described by Magitta et al. (2023).
- **Cognitive and educational impacts** appear universally across regions. Anemic adolescents demonstrate poor concentration, reduced learning capacity, lower test scores, and higher school absenteeism (Taqwin et al., 2025; Sari et al., 2022; Nahid & Firoz, 2025). These findings align with global evidence that iron deficiency disrupts neurotransmitter synthesis and neurocognitive function.
- **Psychosocial impacts** include reduced quality of life, social withdrawal, and emotional disturbances (Sari et al., 2022; Puspitasari et al., 2025). These consequences further hinder academic engagement and long-term wellbeing.
- **Long-term and intergenerational impacts** include heightened risks during future pregnancies, reduced adult productivity, and increased chronic disease vulnerability (Li et al., 2022; Chaber et al., 2024).

This integrated evidence underscores that adolescent anemia is both an immediate health concern and a long-term developmental threat.

Emerging Patterns and Hypotheses

Several overarching patterns arise when synthesizing cross-regional evidence:

1. **Global Iron Gap Hypothesis:** Adolescent girls worldwide experience a persistent mismatch between physiological iron requirements and dietary intake.
2. **Dietary Diversity Hypothesis:** Dietary diversity is a stronger predictor of anemia than caloric intake, particularly in populations with plant-based diets.
3. **SES Pathway Hypothesis:** Socioeconomic status influences anemia through complex pathways involving nutrition, hygiene, education, and healthcare access.
4. **WASH-Infection Synergy Hypothesis:** Poor sanitation and infection burden magnify anemia risk, especially in rural African contexts.
5. **Double Burden Hypothesis:** Obesity-related inflammation represents an emerging mechanism of adolescent anemia (Al-Attar et al., 2020).
6. **Academic Impairment Hypothesis:** Anemia universally predicts reduced academic performance (Taqwin et al., 2025; Sari et al., 2022).

These patterns mirror global anemia frameworks proposed by WHO and UNICEF.

Public Health Implications from the Integrated Evidence

From the integrated findings, several actionable implications emerge:

- Nutritional interventions must focus on dietary diversity, not merely iron supplementation (Yanti et al., 2024).
- Menstrual health programs are essential, including screening for heavy bleeding and provision of menstrual hygiene supplies (Agarwal et al., 2024).
- WASH integration is crucial in regions with high infection burdens (Kebede et al., 2025).
- School-based programs are the most effective platforms for anemia prevention and monitoring (Felix et al., 2025).
- Adolescent obesity screening should include anemia risk due to inflammation pathways (Al-Attar et al., 2020).
- Socioeconomic support mechanisms (food subsidies, community nutrition education) are required for sustainable impact (Mbou et al., 2025).

These implications align with global best practices for adolescent health.

Positioning the Findings Within Global Evidence

The patterns identified in this review closely match global evidence indicating that anemia is both a nutritional and structural health problem. The findings support WHO's global anemia reduction targets and confirm UNICEF's emphasis on adolescence as a key intervention window for breaking intergenerational cycles of malnutrition.

The review highlights that adolescent anemia persists globally due to:

- Biological vulnerabilities in girls
- Nutrition transitions
- Persistent socioeconomic gaps
- Inadequate menstrual health support
- Limited health service coverage
- Emerging obesity-related mechanisms

Thus, adolescent anemia must be addressed through multisectoral, integrated, and gender-responsive strategies.

4. CONCLUSION

This systematic review demonstrates that adolescent anemia remains a major global public health concern characterized by considerable prevalence, multifactorial determinants, and significant health and developmental impacts. The synthesis of fifteen international studies reveals that anemia among adolescents—particularly adolescent girls—is driven by an intricate interplay of nutritional inadequacies, biological vulnerabilities, socioeconomic disparities, environmental conditions, and behavioral factors. Across regions including Africa, South Asia, Southeast Asia, East Asia, and Europe, the evidence consistently identifies adolescent girls as the

most vulnerable group due to increased iron requirements during puberty and menstrual blood loss that is often unmet by dietary intake.

Nutritional determinants emerge as the strongest predictors of anemia, with low dietary diversity, insufficient intake of iron-rich foods, inadequate consumption of vitamin C, and limited protein intake serving as dominant contributors. These patterns appear universally across countries regardless of income level, highlighting that micronutrient deficiencies, rather than caloric insufficiency, drive the majority of anemia cases. Socioeconomic factors—including low household income, parental education, food insecurity, and limited access to health services—deeply influence dietary quality, health behaviors, and infection burdens, reinforcing the social gradient of anemia.

Environmental and hygiene-related determinants further intensify anemia risk, particularly in regions with inadequate sanitation and higher prevalence of parasitic or infectious diseases. The review also underscores that anemia is not limited to undernourished populations; obesity-related inflammation is increasingly documented as a determinant of functional iron deficiency, marking a shift toward the global double burden of malnutrition. These variations illustrate that while anemia is universal, its dominant causal pathways differ across contexts.

The impacts of adolescent anemia are profound, affecting physical health, cognitive function, psychosocial wellbeing, and long-term developmental trajectories. Fatigue, reduced stamina, and increased susceptibility to illness are widely reported physical consequences. More critically, anemia consistently compromises academic performance, concentration, memory, and learning outcomes, thereby limiting adolescents' educational attainment and future human capital. Psychosocial effects such as low self-esteem, diminished motivation, and reduced quality of life further compound the burden. In the long term, adolescent anemia increases risks during future pregnancies and contributes to intergenerational cycles of malnutrition.

The integrated discussion highlights several emerging patterns, including the global iron gap among adolescent girls, the centrality of dietary diversity, the influence of socioeconomic pathways, and the synergistic effects of infection and poor sanitation. These patterns indicate that anemia cannot be addressed through isolated strategies focused solely on supplementation.

Instead, effective responses require multisectoral, gender-responsive, and context-sensitive interventions that integrate nutrition programs, menstrual health management, WASH improvements, socioeconomic support, and strengthened school-based health services. In conclusion, adolescent anemia is a complex and multidimensional condition that reflects broader nutritional, social, and health-system inequities. Addressing this issue requires an approach that not only improves iron intake but also enhances dietary diversity, mitigates socioeconomic barriers, strengthens menstrual health, reduces infection burden, and integrates comprehensive health education. By targeting adolescents—particularly adolescent girls—through coordinated school, community, and national-level interventions, countries can prevent long-term health consequences, improve academic outcomes, and break intergenerational cycles of anemia. The findings of this review reaffirm the urgent need for governments, health systems, and international agencies to prioritize adolescent anemia as a central component of global public health and development agendas.

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