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# Iron and Zinc Supplementation for Anemia and Learning Concentration: Narrative Review

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**ABSTRACT**

Anemia among adolescent girls remains a public health problem in Indonesia and is suspected to impair learning concentration. The national program relies on school-based iron-folic acid tablets, while the role of zinc, alone or together with iron, is unclear. This article reviews the evidence on the effects of iron and zinc supplementation on anemia status and learning concentration among female students and derives implications for future research designs. It is a narrative literature review of meta-analyses, randomized controlled trials and program documents published mainly in 2020–2026, supplemented by classic reference works. The findings indicate that (1) iron supplementation, including weekly school-based dosing, increases hemoglobin and reduces anemia; (2) zinc does not lower hemoglobin, but evidence that zinc alone corrects anemia is inconsistent, and zinc given simultaneously at high ratios can inhibit iron absorption; (3) effects on concentration are inconsistent, as an older meta-analysis reported improved attention and concentration whereas a more recent one found no significant effect on attention despite improvements in intelligence and short-term memory; and (4) evidence on combined iron and zinc for concentration outcomes in adolescent girls is almost absent, while the Indonesian zinc study identified appears to use a single-group design without a comparator. The article concludes that claims of large effects of combined iron and zinc on concentration cannot yet be sustained and proposes a three-arm cluster-randomised trial with haematological outcomes and validated concentration measures.

## INTRODUCTION

Anemia in adolescent girls is a multi-layered problem. It directly reduces the blood's oxygen-carrying capacity, leading to symptoms of fatigue, dizziness, and difficulty concentrating. In the long term, it becomes the starting point of an intergenerational cycle, as anemic adolescent girls are at risk of becoming anemic women of childbearing age and pregnant women (Ministry of Health, 2022). In Indonesia, the prevalence of anemia among the 15–24 age group was recorded at 32 percent in the 2018 Basic Health Research (Riskesdas) (Ministry of Health, 2022) and 15.5 percent in the 2023 Indonesian Health Survey (SKI) (Ministry of Health, 2026). These figures should



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be interpreted cautiously rather than as a directly comparable time trend. The cited reports do not establish identical sampling frames, age definitions, measurement procedures, or analytic methods across the two surveys. Therefore, the difference should not be attributed to a confirmed decline without a formal comparability assessment.

National policy addresses this issue primarily through iron tablets distributed through schools. However, the 2023 Indonesian Health Survey (SKI) showed that 54.8 percent of adolescent girls had never received iron tablets, that access to iron tablets was highly dependent on schools (88.9–90.3 percent), and that 51.4 percent of adolescent girls who did not use them admitted to being unaware of their benefits (Health Development Policy Agency, 2026). This means that the program's issues lie not only with the tablet's content but also with distribution, understanding, and compliance.

In school health discourse, anemia is often associated with decreased concentration in learning (Ministry of Health, 2022). This link is biologically plausible, but causal evidence from intervention trials is far more mixed than implied by health campaigns, as this article will demonstrate. Furthermore, there is growing interest in zinc as an additional or alternative supplement. A study in junior high schools reported that 20 mg of zinc per day for 30 days increased hemoglobin from 10.6 to 12.4 g/dL and Stroop test scores in 30 female students, with a very large effect size (Sahadewa et al., 2025). Such a substantial finding warrants careful scrutiny, especially since the abstract does not mention a comparison group.

This article answers three questions. First, what are the effects of iron, zinc, and their combination supplementation on the anemia status of female students? Second, what are their effects on learning concentration and related cognitive functions? Third, what factors moderate these effects, and what are the implications for designing further research. This article is a narrative literature review and does not contain primary data, so it does not claim new effects. Its contribution is to map what is known and unknown, highlight the limits of the available evidence, and propose a test design that can address these open-ended questions.

## METHODOLOGY

This article is a narrative literature review, not a formal systematic review, and does not contain new primary data or meta-analyses. The sources are grouped into four groups. First, meta-analyses and systematic reviews of iron, zinc, or multimicronutrient supplementation in children, adolescents, and young women with outcomes such as hemoglobin, anemia, attention, cognition, or school performance. Second, relevant randomized controlled trials and single-intervention trials, including studies from Indonesia. Third, official program documents and data on anemia in adolescent girls and iron-deficiency syndrome (IBS). Fourth, classic references on iron-zinc interactions and cognitive testing in adolescent girls, which were excluded from the publication year limit. The literature search was described as having been conducted in September 2026 using PubMed, PubMed Central, general web search engines, and Indonesian national journal portals. The reported English-language search phrases included “iron zinc supplementation in adolescent girls,” “iron supplementation cognition in adolescents meta-analysis,” and “iron supplementation tablets in adolescent girls,” alongside Indonesian equivalents. Sources were selected for relevance to female students or comparable adolescent populations; iron, zinc, or combined supplementation; and hematological or cognitive outcomes. Systematic reviews and randomized trials were prioritized for effect claims, while program documents provided contextual information

and uncontrolled studies were discussed as preliminary evidence. A complete database-specific query history, record counts, screening log, and list of excluded records were not retained; thus, this narrative review cannot claim comprehensive or reproducible systematic coverage.

The synthesis was conducted thematically according to three research questions, with an emphasis on concordance between populations, doses, and outcomes. The strength of evidence was assessed narratively, not using a validated risk-of-bias tool: meta-analyses and randomized trials were treated more strongly than uncontrolled pre-post designs. Limitations of the studies should be stated at the outset. The searches did not follow the PRISMA protocol and did not use a formal risk of bias assessment tool, so selection bias cannot be ruled out. Many meta-analyses combined different populations (children, adolescents, and adult women) and did not specifically focus on female students. Evidence regarding the combination of iron and zinc for concentration outcomes was very limited in the authors' search. Finally, some studies could only be assessed from abstracts, so details of their methods could not be verified.

## RESULTS AND DISCUSSION

### Results

#### Anemia burden and the context of the iron supplementation tablet program

National data indicates that anemia among adolescent girls is a persistent problem. The prevalence of 32 percent among 15–24-year-olds according to the 2018 Basic Health Research (Riskesdas) and 15.5 percent according to the 2023 Indonesian Health Survey (SKI) should not be treated as a demonstrated decline because differences in survey populations, definitions, measurement, or implementation may affect direct comparability (Ministry of Health, 2022, 2026). A more reliable policy message is that intervention coverage remains uneven. In 2022, it was reported that 8.3 million of 12.1 million adolescent girls were not taking iron-deficiency iron supplements (Ministry of Health, 2022), and the 2023 Indonesian Health Survey confirmed that more than half of adolescent girls had never received iron-deficiency iron supplements, with schools being the primary channel (Health Development Policy Agency, 2026).

The regimen used follows intermittent iron and folic acid supplementation. WHO guidelines recommend weekly supplementation for menstruating women in populations with a high prevalence of anemia (WHO, 2011), and the Indonesian program implemented this through schools with one tablet per week (Indonesian House of Representatives Expertise Agency, 2025). A review of the program's acceptability highlighted the need to educate adolescent girls and parents about the causes, side effects, and how to consume iron tablets (Helmyati et al., 2023). Against this backdrop, the question of zinc is not whether it replaces iron, but rather whether it adds value to existing programs.

#### Effect of iron supplementation on anemia status

Evidence that iron supplementation improves the hematological status of adolescents is strong and consistent. A meta-analysis of adolescent nutrition interventions reported that iron or iron-folic acid supplementation in schools, alone or with other micronutrients, reduced anemia (relative risk 0.67; 95% CI 0.60–0.74) and increased hemoglobin by an average of 1.94 g/dL (95% CI 1.48–2.41) (Salam et al., 2016). A synthesis of randomized trials in children and adolescents in sub-Saharan Africa showed that weekly iron-folic acid supplementation increased ferritin in adolescent girls (Hedges' g 0.53; 95% CI 0.28–

0.78) and hemoglobin in school-aged children (g 0.37; 95% CI 0.01–0.73), with high heterogeneity in hemoglobin results (Kedir et al., 2024). This heterogeneity suggests that the magnitude of the response depends on context, including baseline status, burden of infection, and adherence.

Evidence on formulation comparisons is more nuanced. In a double-blind randomized trial in Bangladesh of 324 anemic female students aged 11–17 years, once- or twice-weekly multimicronutrient supplementation compared with twice-weekly iron-folic acid supplementation (60 mg iron per dose) for 52 weeks showed no difference in hemoglobin between treatments in an intention-to-treat analysis. A greater increase in twice-weekly multimicronutrient supplementation was not observed until 26 weeks after excluding girls with hemoglobinopathies and adjusting for baseline hemoglobin ($p = 0.045$) (Ahmed et al., 2010). In other words, adding other micronutrients to iron tablets does not automatically improve hemoglobin response. In the Indonesian context, trials of weekly micronutrient supplementation in adolescent girls have been conducted since the late 1990s to build iron stores (Angeles-Agdeppa et al., 1997), but evaluations of current school iron supplementation programs have largely been quasi-experimental studies and surveys rather than randomized trials.

**Effect of zinc on anemia status**

A systematic review of 21 randomized trials in 3,869 healthy children aged 0–15 years concluded that zinc supplementation was not associated with decreased hemoglobin concentrations (Dekker & Villamor, 2010). This finding is reassuring from a safety perspective, but not proof that zinc improves anemia. The same review noted mixed results in malnourished or ill children, with potential benefits in children with severe anemia or zinc deficiency requiring further evaluation. In adolescents, a meta-analysis of nutritional interventions reported that zinc supplementation increased serum zinc concentrations (mean difference 0.96) (Salam et al., 2016). In the summary reviewed by the authors, the increase in hemoglobin was associated with iron, not zinc, supplementation.

In this context, a report from a junior high school that found a 1.8 g/dL increase in hemoglobin over 30 days with 20 mg of zinc per day in 30 anemic female students, with an effect size of $d = 3.86$ (Sahadewa et al., 2025), deserves critical reading. There are four reasons for this. First, the abstract does not mention a comparison group, so the effect of zinc cannot be separated from the effects of time, regression to the mean, repeated measurements, or other factors that change over the month, such as iron supplementation or diet. Second, the 1.8 g/dL increase in 30 days with zinc is equivalent to the mean increase reported by a meta-analysis for iron supplementation (1.94 g/dL; Salam et al., 2016), despite the lack of evidence for hemoglobin improvement by zinc alone. Third, the proposed mechanism for zinc, namely increased erythropoiesis, has not been supported by a synthesis of randomized trials in children. Fourth, the sample size of 30 without a comparison provides low precision. A safe conclusion is that the study generates a hypothesis that needs to be tested in controlled trials, not evidence of zinc's effect on anemia.

**Effects of supplementation on learning concentration and cognition**

The evidence on iron and concentration is mixed. A classic randomized trial in 81

iron-deficient high school girls in the United States without anemia, who were given either 650 mg of ferrous sulfate twice daily or placebo for eight weeks, used four tests of attention and memory as outcomes (Bruner et al., 1996), and reported improvements in verbal learning and memory tests in the iron-treated group. A meta-analysis of 14 randomized trials in children aged six years and older, adolescents, and women reported that iron improved attention and concentration regardless of baseline iron status (SMD 0.59; 95% CI 0.29–0.90), improved IQ by approximately 2.5 points in the anemic group, but had no effect on memory, psychomotor skills, or academic achievement (Falkingham et al., 2010).

More recent meta-analyses paint a more cautious picture. A synthesis of nine studies (1,196 participants aged 5–19 years in low- and middle-income countries) found that oral iron improved intelligence scores (SMD 0.47; 95% CI 0.10–0.83), with the effect increasing with dose, but found no significant effects on attention, short-term memory, long-term memory, or school performance (Chen et al., 2022). A 2025 meta-analysis of individuals without anemia, consisting mostly of menstruating adult women, reported that in randomized trials, iron supplementation improved anxiety, fatigue, physical well-being, intelligence, and short-term memory (d between 0.34 and 0.53), but not attention and depression (Fiani et al., 2025). A specific synthesis of weekly iron-folic acid supplementation in sub-Saharan Africa noted the scarcity of data on school performance and mental health (Kedir et al., 2024). Tests in young women point to a pattern supporting recovery of cognitive function after iron treatment (Murray-Kolb & Beard, 2007), but the population was not female students.

How to reconcile seemingly contradictory findings? Population and temporal differences appear to be important. Older reviews included adult women and a mix of anemia statuses and used broadly grouped attention outcomes (Falkingham et al., 2010). More recent reviews limited themselves to children and adolescents in low- and middle-income countries (Chen et al., 2022) or to individuals without anemia (Fiani et al., 2025), and found that attention plateaued. Another possibility is limited statistical power, as attention outcomes were assessed with different instruments and the study numbers were small. The finding that short-term memory and intelligence improved despite attention plateaus also suggests that so-called learning concentration in the field may not be the same construct as laboratory attention.

For zinc, a synthesis of evidence on cognition also showed no convincing effects. A meta-analysis of six randomized trials in children found no overall effect of zinc on intelligence (SMD less than 0.001), executive function (0.08), or motor skills (0.11), with design heterogeneity as the main limitation, although there were small indications of improvement in aspects of executive function and motor development that require high-quality testing (Warthon-Medina et al., 2015). Table 1 summarizes the key studies discussed.

**Table 1. Summary of Evidence on Iron and Zinc Supplementation**

| Source | Population and design | Intervention | Main findings |
|---|---|---|---|
| Bruner et al. (1996) | 81 high school girls (13–18 years) in the US with iron deficiency without anemia; double-blind, 8-week RCT | Ferrous sulfate 650 mg twice daily vs placebo | Four tests of attention and memory; reported improvements in verbal learning and memory tests in the iron group |
| Falkingham et al. (2010) | 14 RCTs in children ≥6 years, adolescents, and women | Oral iron | Attention and concentration improved regardless of baseline status (SMD 0.59); IQ increased by approximately 2.5 points in the anemia group; no effects on memory, psychomotor, and achievement (Indirect for female-student-specific combined supplementation.) |
| Chen et al. (2022) | 9 studies, 1,196 participants aged 5–19 years in low- and middle-income countries | Oral iron | Intelligence scores increased (SMD 0.47) and increased with dose; without significant effects on attention, memory, and school achievement. (Indirect for female-student-specific combined supplementation.) |
| Fiani et al. (2025) | 18 studies (12 RCTs), 1,408 participants without anemia; mostly menstruating adult women | Iron | RCT: anxiety, fatigue, physical well-being, intelligence, and short-term memory improved (d 0.34–0.53); attention and depression did not. (Indirect for female-student-specific combined supplementation.) |
| Salam et al. (2016) | Meta-analysis of adolescent nutrition interventions | Iron/iron-folic acid in schools, zinc, and more | Anemia decreased (RR 0.67); Hb increased 1.94 g/dL; zinc increased serum zinc (Indirect for female-student-specific combined supplementation.) |
| Kedir et al. (2024) | 10 RCTs in children and adolescents in sub-Saharan Africa | Weekly iron-folic acid | Ferritin in adolescent girls increased (g 0.53); Hb in school-age children increased (g 0.37; high heterogeneity); data on school performance and mental health were limited. (Indirect for female-student-specific combined supplementation.) |

| Source | Population and design | Intervention | Main findings |
|---|---|---|---|
| Dekker & Villamor (2010) | 21 RCTs, 3,869 healthy children aged 0–15 years | Zinc | Zinc is not associated with a decrease in Hb (Indirect for female-student-specific combined supplementation.) |
| Warthon-Medina et al. (2015) | 12 RCTs (11 in children); meta-analysis of 6 pediatric RCTs | Zinc | No overall effects on intelligence, executive function, and motor skills; design heterogeneity (Indirect for female-student-specific combined supplementation.) |
| Ahmed et al. (2010) | 324 anemic female students aged 11–17 years in Bangladesh; double-blind, 52-week RCT | Multimicronutrients 1 or 2 times/week vs iron-folic acid 2 times/week | ITT: no difference in Hb; MMN 2 times/week was higher at 26 weeks after adjustment ($p = 0.045$) (Multimicronutrient intervention, not an isolated iron–zinc comparison.) |
| Sahadewa et al. (2025) | 30 anemic junior high school students in Indonesia; appeared to be designed as one group (abstract does not mention comparison) | Zinc 20 mg/day, 30 days | Hb 10.6 → 12.4 g/dL; Stroop score increased; effect size was very large, without control (Uncontrolled evidence; causality cannot be inferred.) |

*Source: Narrative synthesis of the cited studies. The populations and outcomes differ across studies; results in children or adults and multimicronutrient trials provide indirect rather than direct evidence for combined iron–zinc supplementation and learning concentration in female students. SMD = standardized mean difference; RCT = randomized controlled trial; ITT = intention-to-treat; Hb = hemoglobin; MMN = multiple micronutrients.*

**Combinations of iron and zinc: the known and the unknown**

For the central question of this article, whether supplementing zinc with iron improves anemia and iron concentration in female students more than iron alone, direct evidence is very limited. The authors' search did not find any randomized trials in adolescent girls comparing iron plus zinc with iron alone on learning concentration outcomes. What is available are three sets of indirect evidence. First, mechanistic and absorption studies that warn of possible inhibition of iron absorption by zinc at high ratios (Fischer Walker et al., 2005; Olivares et al., 2007a, 2012). Second, multimicronutrient trials containing zinc among other components, such as the Bangladesh trial that found no consistent hemoglobin advantage over iron-folic acid (Ahmed et al., 2010). Third, uncontrolled pre-post reports on zinc (Sahadewa et al., 2025).

The practical consequences are threefold. First, adding zinc to the same iron tablet may reduce iron absorption, particularly when the zinc dose is high relative to the iron.

Second, if the combination is to be tested, the timing and ratio of administration should be part of the design, and a delay of several tens of minutes to an hour between zinc and iron is worth considering given the finding that acute inhibition is short-lived (Olivares et al., 2007b), although such a delay is difficult to implement in weekly school administration. Third, zinc should not replace iron in adolescent girls with iron-deficient anemia, as the evidence for hemoglobin improvement for iron is much stronger than for zinc (Salam et al., 2016; Dekker & Villamor, 2010).

**Moderating factors and measurement challenges**

Several factors explain why intervention outcomes differ across studies. Baseline status. Hemoglobin and cognitive responses differ between anemic, iron-deficient, and iron-sufficient adolescent girls. Studies with mixed populations tend to produce effects that are difficult to interpret. Zinc status is rarely measured at baseline, making the benefit of zinc in deficient subgroups impossible to assess. Dose and schedule. Meta-analyses in children and adolescents have shown a dose-response relationship between iron and intelligence scores (Chen et al., 2022), while weekly iron supplementation, the program's reference dose, may differ significantly from daily supplementation. Compliance. Compliance is a critical field factor. If more than half of the adolescent girls have not received or consumed iron tablets (Health Development Policy Agency, 2026), the observed effects in efficacy trials will outweigh the program's effectiveness.

Compliance itself is a social phenomenon, not simply an individual decision. Reasons reported by the 2023 SKI suggest that low consumption is related to ignorance of the benefits (Health Development Policy Agency, 2026). A cross-sectional study of 246 respondents in a high school in Makassar found that teacher attitudes and encouragement were significantly associated with compliance, while parental knowledge and encouragement were not (Factors Influencing the Level of Compliance with Iron Supplement Tablet Consumption in Adolescent Girls at SMA Negeri 10 Makassar City, 2024). For sociologists, findings like these demonstrate that schools are arenas of social regulation: teachers serve as enforcers of routines, and peer group norms can encourage or discourage consumption. Such single studies should not be generalized, but they are sufficient to warn that supplement effectiveness trials that ignore the mechanism of administration—who administers it, when, and under whose supervision—risk misinterpreting compliance failure as supplement failure.

Infection and inflammation. Inflammation alters ferritin and iron absorption, so interpreting iron status requires inflammatory markers. Measurement tools. Learning concentration is measured with standardized attention tests, working memory tests, or questionnaires, and each has weaknesses: the tests are susceptible to training effects, and questionnaires are susceptible to expectancy bias if participants are aware of the treatment. The Stroop test (Stroop, 1935) and the d2 attention test (Brickenkamp & Zillmer, 1998) are commonly used tools for selective attention and speed-accuracy, but both require parallel or control forms to rule out training effects. These latter two issues make the double-blind design and parallel forms of the test important. School context. Because the ITT is distributed across schools, a good test needs to account for cluster effects, where students within a school are more similar to each other than to students from other schools.

**Implications for further research design and school programs**

For research, the above findings suggest a three-arm cluster randomized trial in

schools with a standard iron supplement as the baseline for all arms. This design avoids the ethical dilemma of withholding iron from anemic adolescent girls while also examining unanswered questions: does zinc add value above iron supplementation and whether the timing of administration is important. As an example of a large-scale design, a cluster trial protocol in Burkina Faso and Tanzania compared weekly iron-folic acid supplementation with a daily multimicronutrient supplement and a control group in approximately 4,500 students from 84 schools, with hemoglobin as the primary outcome and school performance indicators as secondary outcomes (Cliffer et al., 2023). Table 2 presents elements of the proposed design.

**Table 2. Proposed Cluster-Randomized Trial to Evaluate Zinc Added to Standard Iron Supplementation**

| Element | Proposal |
|---|---|
| Design | Double-blind cluster randomized trial with schools as the unit of randomization; protocol registration prior to data collection |
| Population | Junior high and high school students aged 12–18 years; screening for hemoglobin, ferritin with CRP correction, and plasma zinc if possible; referral for severe anemia |
| Intervention arm | (A) Standard weekly iron supplement + zinc placebo; (B) Weekly iron supplement + zinc, taken simultaneously; (C) Weekly iron supplement + zinc, taken at scheduled intervals. The zinc dose is physiological and does not exceed the upper limit of intake. |
| Duration | Minimum 12 weeks with repeat measurements; follow-up to assess durability of effect |
| Primary output | Hemoglobin level (g/dL) and proportion of anemia |
| Secondary output | Plasma ferritin and zinc; attention with parallel standardized tests; working memory; self-reported fatigue; gastrointestinal side effects; compliance (teacher monitoring and tablet counting) |
| Sample size and analysis | Calculated by taking into account the intra-cluster correlation coefficient; intention-to-treat analysis with a mixed model, baseline adjustment, and correction for multiple outcomes |
| Ethics and safety | Parental consent and student consent; not withholding iron from anemic students; research ethics committee; monitoring for side effects |

*Source: author's formulation; structure refers to the school-based cluster testing protocol (Cliffer et al., 2023).*

For school programs, three implications appear more pressing than supplementing with zinc. First, improve iron supplement coverage and adherence, given that more than half of adolescent girls have not received it, and half of those who do not report being unaware of its benefits (Health Development Policy Agency, 2026). Second, strengthen education for adolescent girls and their parents (Helmyati et al., 2023). Third, convey claims of improved learning concentration with caution in promotional materials, as causal evidence for attention is inconsistent, while evidence for hemoglobin and iron stores is much stronger. The appropriate message should be that iron supplements reduce

anemia and fatigue, not that they necessarily improve grades or concentration.

## CONCLUSION

The review concludes four things. First, iron supplementation, including weekly school-based iron supplementation, improves hemoglobin and reduces anemia in adolescents. Second, zinc does not lower hemoglobin, but evidence that zinc alone corrects anemia is inconsistent, and zinc can inhibit iron absorption when given together at high ratios. Third, the effects of supplementation on learning concentration are mixed: evidence for intelligence and short-term memory is more consistent than for attention, and evidence for zinc on cognition does not show an overall effect. Fourth, direct evidence on the combination of iron and zinc on anemia and concentration in female students is almost nonexistent, and the Indonesian studies on zinc that the authors found appear to have been single-group without a control group, making the reported effect sizes unsuitable for policymaking.

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