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The Effects of Zinc and Iron Supplementation on Anemia Status and Academic Performance Among Female Students

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ABSTRACT

Anemia is common among adolescent and young adult women and is widely believed to impair concentration and school performance. Iron supplementation is the standard response, while zinc has been proposed as a complementary micronutrient. This article synthesizes recent evidence on how iron and zinc supplementation affect anemia status and cognitive or academic outcomes among female students. A structured narrative review was conducted. Thirty-two records exported from two reference-manager searches were de-duplicated to 22, and three further peer-reviewed articles published since 2021 were added, giving 25 sources for qualitative synthesis. Iron supplementation consistently raised hemoglobin and reduced anemia risk, and moderate to high doses, whether daily or weekly, performed similarly. Effects on cognition were more evident for intelligence-test scores and attention than for school grades, and most trials carried moderate or high risk of bias. Evidence for zinc was sparse: one small uncontrolled Indonesian study reported hemoglobin rising from 10.6 to 12.4 g/dL after 30 days, whereas a meta-analysis of 129 trials found that adding zinc to iron did not enhance, and may slightly attenuate, the anemia response. Adherence, diet quality, and nutrition education shaped outcomes. Iron remains the evidence-based core of school anemia programs; the added value of zinc is plausible but unproven.

INTRODUCTION

Anemia is among the most common nutritional problems of adolescence, and girls carry a disproportionate share of the burden. Rapid growth raises iron requirements, menstruation adds recurring blood loss, and diets in many settings supply little absorbable iron (Kedir et al., 2024; Mithra et al., 2021). Iron-deficiency anemia has been described as the leading cause of disability-adjusted life years lost among adolescents (Samson et al., 2022), and surveys of school populations in some settings report prevalence between 29.2% and 79.6% (Jeihooni et al., 2021). Beyond fatigue and reduced physical capacity, anemia is thought to impair attention, memory, and learning. For this reason, school-based supplementation is justified not only on health grounds but also on educational ones.

Schools are a core delivery platform for anemia control. The World Health Organization recommends delivering iron supplementation through school-based

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platforms, a strategy that depends on partnership with the education sector and is valued partly for its presumed benefits for learning (Samson et al., 2022). In Indonesia, weekly iron supplementation for adolescent girls is delivered through schools, yet its success depends on whether girls actually take the tablets, and low adherence, sometimes linked to gastrointestinal side effects, can undermine programs (Andersen et al., 2023; Silitonga et al., 2023; Taufiqurrahman et al., 2025). Recent reviews of supplementation and school-based support continue to find that supplementation works when it is delivered, while adherence, diet, and educational support determine how much of the potential benefit is realized (Amani & Sebayang, 2024; Silitonga et al., 2024; Yani et al., 2025).

The biological case for a link between iron status and learning is reasonable. Iron participates in oxygen transport, cellular energy metabolism, neurotransmission, and neurogenesis, so deficiency may plausibly alter cognitive development and behavior (Chen et al., 2022). Observational data from women point in the same direction: in a Turkish study, females with iron-deficiency anemia scored lower on the Montreal Cognitive Assessment than healthy volunteers (Aslan et al., 2021). Among Indonesian female students, food intake, anemia status, and learning achievement have been examined together to test whether poor diets and anemia translate into weaker academic outcomes (Nirwana et al., 2021). Associations of this kind, however, cannot show that correcting anemia improves learning.

It helps to separate three constructs that are often blurred. Hemoglobin and ferritin describe hematological status. Attention, memory, and intelligence-test scores describe cognition, measured under controlled conditions. Academic performance refers to grades, test results, or school progression, which depend on teaching quality, motivation, attendance, and home circumstances as well as nutrition. A supplement may move the first construct without visibly moving the third, so an honest appraisal has to ask which of the three a given study actually measured. This distinction matters for policy, because programs that promise better grades on the strength of improved hemoglobin may set expectations that biology alone cannot meet.

When supplementation itself is tested, the picture becomes more mixed. A systematic review of 50 studies in adolescents found that iron status and anemia were associated with academic performance in some contexts, yet nearly all supplementation trials had moderate or high risk of bias, and iron did not improve memory, recall, or intelligence (Samson et al., 2022). A meta-analysis of randomized trials in children aged 6 to 12 years found benefits for some cognitive domains but no effect on school achievement (Gutema et al., 2023), whereas a meta-analysis in low- and middle-income countries reported a positive effect on intelligence-test scores that increased with dose (Chen et al., 2022). A review of weekly iron-folic acid supplementation in sub-Saharan Africa concluded that there were too few studies to judge school performance (Kedir et al., 2024). Long-term follow-up of iron-fortified school lunches in India found higher hemoglobin and lower anemia, but no significant differences in education or cognition outcomes (Von Grafenstein et al., 2023). By contrast, a trial of iron-fortified lentils among Bangladeshi adolescent girls reported better performance on cognitive tasks, particularly among girls whose iron status improved (Barnett et al., 2023), and a longitudinal study in India linked iron-folic acid supplementation and dietary diversity to better nutritional and learning outcomes (Shinde et al., 2021). Hemoglobin can therefore be corrected without a guaranteed change in grades, and the relationship between the two deserves cautious reading.

Zinc enters this discussion from a different direction. Zinc is a cofactor in many enzymes, and zinc deficiency often coexists with iron-deficiency anemia, although zinc deficiency alone does not seem sufficient to cause anemia; excessive zinc, in turn, can induce copper deficiency and anemia (Jeng & Chen, 2022). In women with iron-deficiency anemia, cognitive scores correlated strongly with zinc level (Aslan et al., 2021). Interventional evidence is thin. A small Indonesian study of 30 junior high school girls with hemoglobin below 12 g/dL gave 20 mg of zinc daily for 30 days and reported a rise in hemoglobin together with better concentration on the Stroop test (Sahadewa et al., 2025). Against this, a meta-analysis of 129 randomized trials found that iron gave similar benefits alone or with zinc, with an attenuated effect on overall anemia when zinc was co-supplemented (Andersen et al., 2023). Safety also matters: in young children, higher zinc intakes had adverse effects on ferritin, copper, soluble transferrin receptor, and hemoglobin in some subgroups, although the clinical importance was unclear (Ceballos-Rasgado et al., 2022).

Supplements are not the only route. Nutrition education based on the PRECEDE model improved preventive behaviors and raised ferritin among Iranian female students (Jeihooni et al., 2021), and education programs have been evaluated for knowledge, attitude, and practice regarding iron-deficiency anemia in Jordan and for knowledge in rural India (Abu-Baker et al., 2021; Salam et al., 2023). In East Java, 20 weeks of school-based education on optimized food-based recommendations improved nutrient intakes and memory performance in adolescent girls (Suciyanti et al., 2025). Community communication, information, and education have also been paired with iron supplementation to support hemoglobin improvement (Indrayoni & Megayanti, 2022). Overviews of systematic reviews support supplementation and fortification with iron and micronutrients as effective ways to reduce anemia and raise hemoglobin in children and adolescents (Mithra et al., 2021).

Several gaps follow from this literature. First, most syntheses address iron alone, in children of mixed sex, and say little about female students specifically, even though they carry the highest risk. Second, zinc is usually studied in isolation or as a co-nutrient in young children, so evidence about zinc in adolescent girls is scattered across small studies. Third, hemoglobin, cognition, and academic achievement are often treated as interchangeable endpoints, although the evidence differs sharply between them. Fourth, adherence and diet are rarely analyzed alongside efficacy, even though the Indonesian school setting depends on both.

The novelty of this article lies in four features. It places iron and zinc evidence side by side for a single target group, female students, rather than for children in general. It separates three outcome tiers, namely hematological status, cognition and attention, and academic achievement, and rates the strength of evidence for each rather than reporting a single verdict. It treats co-supplementation as a question about interaction, weighing the Indonesian zinc report against the pooled trial evidence on attenuation and safety. Finally, it links efficacy to delivery by incorporating adherence, dietary, and educational evidence into a practical decision framework for school programs. Because the evidence base is small and uneven, the article states plainly where a claim rests on a single small study and where it rests on pooled randomized trials, so that readers can weigh each conclusion appropriately.

Accordingly, this article addresses three questions. What is the effect of iron supplementation on anemia status among female students? What is the effect of iron and zinc supplementation on cognition, concentration, and academic performance? What does

the current evidence imply about adding zinc to school-based iron programs, and what research is needed to settle the question?

METHODOLOGY

A. Study design

This study is a structured narrative review of recent evidence, organized with the flow logic of the PRISMA 2020 statement. It was not prospectively registered. A quantitative meta-analysis was not attempted because the included studies differ widely in population, dose, duration, and outcome instruments, a limitation that earlier syntheses in this field have also reported (Samson et al., 2022). No primary data were collected from participants, so no ethical approval was required.

B. Information sources and search

Two bibliographic exports in RIS format, generated on 29 October 2026 from an AI-assisted academic search platform, formed the core corpus. One export was based on the English title of this article and the other on its Indonesian equivalent. Together they contained 32 records. To fill gaps that the exports did not cover, namely zinc safety, compliance with iron supplementation, and overviews of anemia interventions, three further articles were identified through manual searches of Google Scholar and publisher websites. Each additional article was checked for peer-reviewed status, publication in 2021 or later, and a DOI that resolves to the article page.

C. Eligibility criteria

Sources were eligible if they were peer-reviewed, published between 2021 and 2026, and reported on iron or zinc supplementation, fortification, or closely related nutrition education and delivery strategies, with at least one outcome concerning hemoglobin, anemia, ferritin, cognition, concentration, or academic performance. The target population was female students, adolescent girls, or young women. Because few trials enroll girls only, reviews and trials of children and adolescents of both sexes were retained as indirect evidence, and this indirectness is flagged wherever it affects interpretation. Studies of pregnant women, hospital patients with chronic disease, and animal experiments were excluded.

D. Selection process

Ten records appeared in both exports and were removed, leaving 22 unique records. All 22 met the eligibility criteria on title and abstract screening. Three additional articles from manual searching were added, giving 25 sources in the final synthesis (Figure 1). The synthesis comprises 12 reviews (10 systematic reviews or meta-analyses and 2 narrative reviews) and 13 primary studies.

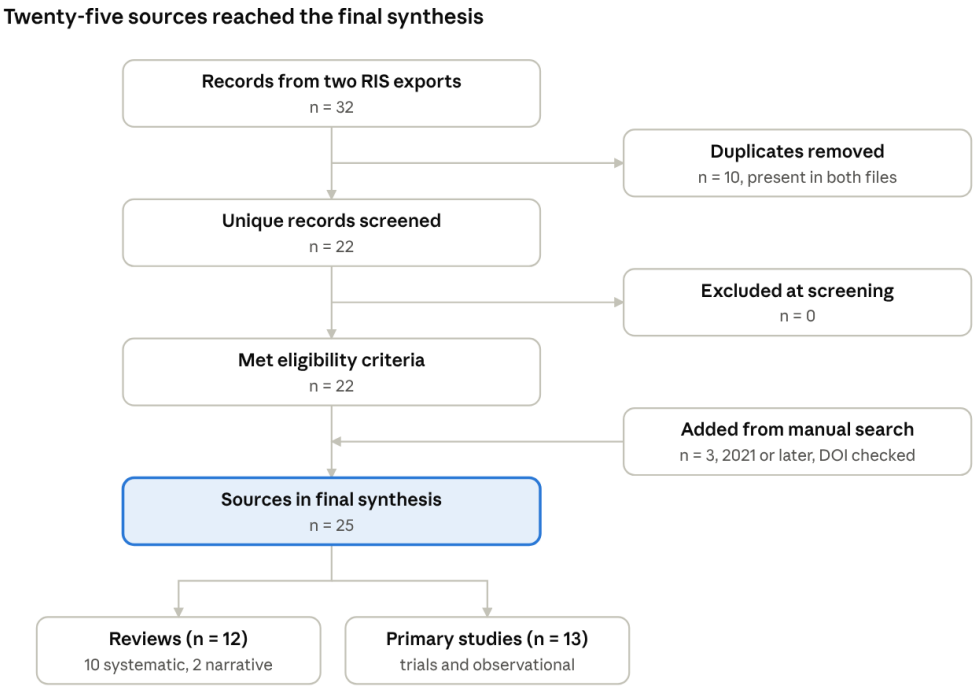


Figure 1: PRISMA-style flow diagram of source identification, screening, and inclusion

E. Data extraction and appraisal

For each source, the design, population, intervention, comparator, duration, and main findings on anemia status, cognition, and academic outcomes were extracted into a structured matrix. Formal risk-of-bias scoring was not repeated for sources that had already been appraised by their own authors; instead, the risk-of-bias judgments reported by the source reviews were carried forward. For the overall strength of evidence, a transparent three-level judgment (higher, moderate, or lower) was assigned by outcome, based on design hierarchy, consistency across sources, directness to female students, and precision. This is a reviewer judgment and not a formal GRADE assessment.

F. Synthesis

Findings were synthesized narratively under three outcome domains: anemia status, cognition and attention, and academic performance. Effect sizes are reported exactly as published and were not re-pooled. Zinc evidence was treated separately from iron evidence and then combined in a discussion of co-supplementation. Some primary studies were characterized from abstract-level information, which limits the detail that can be reported for them.

RESULTS AND DISCUSSION

A. Overview of the evidence base

The 25 sources span 2021 to 2025 and cover settings in Indonesia, India, Bangladesh, Ethiopia, sub-Saharan Africa, Iran, Jordan, and Turkey (Table 1). Reviews dominate: 12 of 25 sources are syntheses, whereas only two primary studies tested iron or zinc in tablet form against a control with hemoglobin as an outcome in female

adolescents (Handiso et al., 2021; Sahadewa et al., 2025), and only the first of these had a randomized control group. Evidence on zinc is by far the thinnest.

Table 1
Design distribution of the 25 included sources

Category	n	Sources
Systematic reviews and meta-analyses	10	Amani & Sebayang (2024); Andersen et al. (2023); Ceballos-Rasgado et al. (2022); Chen et al. (2022); Gutema et al. (2023); Kedir et al. (2024); Mithra et al. (2021); Samson et al. (2022); Silitonga et al. (2023); Silitonga et al. (2024)
Narrative reviews	2	Jeng & Chen (2022); Yani et al. (2025)
Randomized or controlled intervention studies	6	Barnett et al. (2023); Handiso et al. (2021); Jeihooni et al. (2021); Suciyanti et al. (2025); Von Grafenstein et al. (2023); Sahadewa et al. (2025; single group, 30 girls)
Education and community programs	3	Abu-Baker et al. (2021); Indrayoni & Megayanti (2022); Salam et al. (2023)
Observational studies	4	Aslan et al. (2021); Nirwana et al. (2021); Shinde et al. (2021); Taufiqurrahman et al. (2025)

Note. Design labels for studies read at abstract level are approximate.

B. Iron supplementation and anemia status

Across designs, iron supplementation reliably improved hematological status (Table 2). In the only randomized community trial among adolescent girls in this corpus, three months of weekly iron-folic acid in southern Ethiopia raised hemoglobin by 1.2 g/dL, serum ferritin by 39.1 μg/L, and serum folate relative to controls (Handiso et al., 2021). The pooled evidence agrees. A meta-analysis of 129 trials involving 34,564 children and adolescents found that moderate and high doses improved hemoglobin, ferritin, and iron-deficiency anemia more than low doses, and that frequent and intermittent schedules were similarly effective (Andersen et al., 2023). A review restricted to weekly iron-folic acid in sub-Saharan Africa reported a standardized mean difference of 0.53 for ferritin in adolescent girls and a 20% lower risk of anemia (Kedir et al., 2024). An overview of 31 systematic reviews likewise concluded that supplementation and fortification with iron and micronutrients reduce anemia risk and raise hemoglobin (Mithra et al., 2021).

Table 2
Selected evidence on iron and hematological status

Source	Design and population	Intervention	Main hematological finding
Handiso et al. (2021)	RCT, 226 girls aged 10–19 y, Ethiopia	Weekly iron-folic acid, 3 months	Hb +1.2 g/dL, ferritin +39.1 μg/L vs. control
Andersen et al. (2023)	Meta-analysis, 129 RCTs, 34,564 participants	Oral iron, varied schedules	Moderate/high doses better than low; daily and weekly similar
Kedir et al. (2024)	Meta-analysis, 10 articles, sub-Saharan Africa	Weekly iron-folic acid	Ferritin SMD 0.53 (girls); anemia risk RR 0.80
Barnett et al. (2023)	Cluster RCT, 359 girls aged 10–17 y, Bangladesh	Iron-fortified lentils, 4 months	Better iron status than controls at endline
Von Grafenstein et al. (2023)	Trial follow-up, India	Iron-fortified school lunch, 4 years	Higher Hb, lower anemia

Source	Design and population	Intervention	Main hematological finding
Mithra et al. (2021)	Overview of 31 systematic reviews	Supplementation, fortification	Lower anemia risk, higher Hb

Note. Hb = hemoglobin; RR = risk ratio; SMD = standardized mean difference.

Two qualifications apply. First, most pooled estimates come from mixed-sex or younger populations, so their application to female students is indirect. Second, duration matters differently for different markers: shorter and longer regimens produced similar benefits except for ferritin, which rose more with longer supplementation (Andersen et al., 2023). For school programs that run for a term or a year, this suggests that hemoglobin will respond early but iron stores need sustained delivery.

C. Iron, cognition, and academic performance

The evidence for cognition is more qualified than the evidence for hemoglobin (Table 3). The most comprehensive adolescent review concluded that iron status and anemia may be associated with academic performance in some contexts and that supplementation may improve school performance, attention, and concentration, yet it also found no evidence that iron status influenced attention, intelligence, or memory, and nearly all supplementation trials carried moderate or high risk of bias (Samson et al., 2022). These statements are not contradictory: they reflect inconsistency between studies and between outcome measures. The pooled estimate for intelligence-test scores in low- and middle-income countries was positive (SMD = 0.47, 95% CI 0.10 to 0.83) and rose with dose (Chen et al., 2022), while in school-age children benefits were seen for some cognitive domains but not for school achievement (SMD = 0.06, 95% CI −0.15 to 0.26; Gutema et al., 2023).

Table 3
Selected evidence on cognition and academic outcomes

Source	Population and design	Cognitive finding	Academic finding
Samson et al. (2022)	50 studies in adolescents	Mixed; no clear association with memory or intelligence	Possible benefit in some contexts; high risk of bias
Chen et al. (2022)	9 RCTs, 1,196 participants	Intelligence SMD 0.47, dose-responsive	Not the primary outcome
Gutema et al. (2023)	RCT meta-analysis, ages 6–12	Benefit in some domains	No effect (SMD 0.06)
Barnett et al. (2023)	359 girls, Bangladesh	Better performance in fortified-lentil group	Not assessed
Von Grafenstein et al. (2023)	Trial follow-up, India	No significant difference	No significant difference
Kedir et al. (2024)	Meta-analysis, Africa	Too few studies	Too few studies
Shinde et al. (2021)	12,035 adolescents, India	Not assessed	Dietary diversity linked to math proficiency and lower dropout

Source: Author's synthesis of the reviewed literature

A consistent pattern emerges. Studies using laboratory-style cognitive tasks tend to detect effects, whereas studies using real-world school outcomes tend not to. The trial in Bangladeshi adolescent girls illustrates the first pattern: cognitive performance was better in the fortified-lentil group and improved most in girls whose iron status improved

(Barnett et al., 2023). The long-term Indian school-lunch evaluation illustrates the second: hemoglobin was higher but education and cognition outcomes did not differ (Von Grafenstein et al., 2023). One plausible reading is that cognitive tasks capture attention and processing speed, which respond quickly to correcting anemia, whereas grades integrate many influences that a supplement cannot change. A second reading is statistical: most school trials are underpowered for academic endpoints.

Dose and duration may also explain part of the inconsistency. Trials in the adolescent review lasted from one to 14 months and used different iron forms and doses (Samson et al., 2022), and in the meta-analysis of intelligence outcomes, test scores improved as the supplemental dose rose (Chen et al., 2022). Baseline status matters as well. Benefits are most plausible in girls who are actually deficient, and a regimen given to a mixed population dilutes the average effect. For female students, whose menstrual losses keep iron stores under pressure, this argues for screening hemoglobin and targeting the greatest effort at anemic girls rather than assuming a uniform benefit.

D. Zinc: hematological and cognitive evidence

Direct evidence for zinc in female students is limited to a single small study (Table 4). In 30 junior high school girls with hemoglobin below 12 g/dL, 20 mg of zinc daily for 30 days was followed by a rise in mean hemoglobin from 10.6 ± 0.5 to 12.4 ± 0.4 g/dL (Δ = 1.8 g/dL, $p < 0.001$) and by improved Stroop performance, which the authors interpreted as better concentration (Sahadewa et al., 2025). The result is striking but must be read cautiously. No comparison group is described in the abstract, the sample is small, a 1.8 g/dL gain in one month is larger than the 1.2 g/dL gain that a randomized three-month iron trial achieved (Handiso et al., 2021), and the reported effect size (Cohen's d = 3.86) is unusually large for a nutrition intervention. Regression to the mean, concurrent dietary changes, and coexisting iron deficiency may all have contributed.

Table 4
Evidence on zinc

Source	Design	Finding	Interpretation
Sahadewa et al. (2025)	30 girls, 20 mg/day, 30 days	Hb 10.6 → 12.4 g/dL; improved Stroop	Promising, uncontrolled, imprecise
Aslan et al. (2021)	41 females with IDA vs. 40 controls	MoCA 24.63 vs. 27.43; MoCA correlated with zinc (r = 0.803) in IDA	Association, adults, not causal
Jeng & Chen (2022)	Narrative review	Zinc deficiency often coexists with IDA; alone unlikely to cause anemia; excess causes copper deficiency	Mechanistic context
Andersen et al. (2023)	Meta-analysis of iron with/without zinc	Similar benefit; attenuated anemia effect with zinc (p = 0.048)	Co-supplementation is not clearly additive
Ceballos-Rasgado et al. (2022)	Meta-analysis, ages 0–3 y	Possible adverse effects on ferritin, copper, sTfR, Hb in subgroups	Indirect; certainty very low to moderate

Note. IDA = iron-deficiency anemia; MoCA = Montreal Cognitive Assessment; sTfR = soluble transferrin receptor.

The mechanistic literature offers a reconciling explanation. Zinc deficiency commonly coexists with iron deficiency, but it appears insufficient alone to cause anemia (Jeng & Chen, 2022). Girls in the Indonesian study may therefore have had concurrent

micronutrient deficits that a zinc-containing regimen partly addressed, or the gain may reflect factors the design could not separate. The strong correlation between zinc level and cognitive score among women with iron-deficiency anemia (Aslan et al., 2021) supports the idea that zinc status tracks cognitive vulnerability, but a correlation in adults cannot show that supplementation would help.

E. Co-supplementation, interaction, and safety

The pooled trial evidence does not support the assumption that zinc adds to iron. Iron produced similar benefits alone or with zinc, and the effect on overall anemia was attenuated when zinc was co-supplemented (Andersen et al., 2023). Safety signals are also relevant. Excess zinc can interfere with copper uptake and lead to anemia (Jeng & Chen, 2022), and in children aged 0 to 3 years higher zinc intakes had adverse effects on several iron and copper indices in some subgroups, although it is unclear whether these were clinically important (Ceballos-Rasgado et al., 2022). The age group differs from female students, so these findings do not prove harm at 20 mg per day in adolescents, but they argue for measured doses and for monitoring if zinc is ever added to school programs.

Integrating these observations, the most defensible reading is that zinc may help where zinc deficiency is present and diet is poor, but current data cannot identify those girls, quantify the benefit, or exclude interference with iron. In the Indonesian context, where school programs already struggle with adherence, a second tablet would also add a second compliance problem. Food-based routes to zinc, such as animal-source foods, might avoid this trade-off, and the East Java trial shows that school education can change diets and cognitive test performance within a single term (Suciyanti et al., 2025).

F. Delivery: adherence, diet, and education

Efficacy in trials does not guarantee effect in schools (Table 5). A systematic review of compliance identified adherence as a determinant of program success among adolescent girls (Silitonga et al., 2023), and an Indonesian study of adolescent girls in Madiun examined adherence, dietary intake, and anemia risk together (Taufiqurrahman et al., 2025). Narrative and systematic reviews of school-based approaches converge on a combined model in which supplements are supported by education and food (Amani & Sebayang, 2024; Silitonga et al., 2024; Yani et al., 2025). Individual studies fit this model. Nutrition education raised ferritin and preventive behaviors in Iranian students (Jeihooni et al., 2021); a 20-week food-based education program in East Java improved intakes of protein, fat, and iron and memory performance in adolescent girls, and its authors recommended integrating it with weekly iron supplementation (Suciyanti et al., 2025); and education programs improved knowledge and practice in Jordan and India (Abu-Baker et al., 2021; Salam et al., 2023). Community communication and education alongside supplementation has also been reported in Bali (Indrayoni & Megayanti, 2022), and diet quality was linked with anemia and learning among female students in Gowa (Nirwana et al., 2021).

Table 5
Summary of evidence and strength of judgment by outcome

Outcome	Iron	Zinc	Strength of evidence (reviewer judgment)
Hemoglobin, anemia risk	Consistent improvement	One small uncontrolled study; not clearly additive to iron	Iron: higher; zinc: lower

Outcome	Iron	Zinc	Strength of evidence (reviewer judgment)
Ferritin, iron stores	Improves, more with longer duration	Possible adverse effect at high intake	Iron: higher; zinc: lower
Cognition, attention	Positive for intelligence scores and some domains; inconsistent	Association and one small study	Iron: moderate; zinc: lower
School grades, achievement	No clear effect in pooled analyses	No data	Iron: lower; zinc: lower
Adherence and delivery	Education and diet improve outcomes	Not studied	Moderate

Source: Author's synthesis of the reviewed literature

G. Implications and limitations

Three implications follow. First, school programs should continue to justify iron supplementation by its robust effect on anemia, while describing cognitive benefits as plausible and modest rather than promised. Second, zinc should be treated as a research priority and not as a routine addition: adequately powered randomized trials in female students should compare iron alone, zinc alone, and both, measure serum zinc and ferritin at baseline, and include attention tasks and academic indicators. Third, adherence, dietary support, and education should be built into every program, because they determine whether trial-level efficacy translates into school-level effect.

A practical framework for school programs follows in four steps. Screen hemoglobin to find anemic girls; supply iron on an evidence-based schedule, weekly or daily at moderate to high dose; support adherence through education, reminders, and diet; and reassess hemoglobin after a defined period. Zinc should enter this sequence only within a trial or where zinc deficiency has been documented. Outcome monitoring should include attention measures that schools can administer cheaply, because these appear more responsive than grades and can show benefit before an academic year ends.

This review has limitations. It is a narrative synthesis, so effect sizes were not re-pooled. The corpus derives mainly from two database exports plus three targeted additions, so relevant studies may be missing. Many sources are reviews of mixed-sex or younger populations, so findings are indirect for female students, and a few primary studies were characterized from abstract-level information. The strength-of-evidence labels are judgments, not formal GRADE ratings. Even so, the direction of the evidence is clear enough to guide practice and to shape the next generation of trials.

CONCLUSION

The evidence reviewed here supports a clear hierarchy. Iron supplementation reliably improves hemoglobin, ferritin, and anemia status in adolescent girls and children, with moderate to high doses and either weekly or daily schedules performing well. Its effects on cognition and attention are plausible and sometimes demonstrable, but its effects on school grades are not established, and most trials carry moderate or high risk of bias. Zinc has a biologically coherent role and one encouraging small study in female students, yet no controlled evidence shows that it improves anemia or academic performance beyond iron, and pooled trials suggest it may slightly attenuate the anemia response when combined with iron. School programs should therefore keep iron as the core intervention, couple it with adherence support, dietary improvement, and education, and avoid promising academic gains. Zinc should be added only within well-designed

randomized trials that measure baseline zinc and iron status, attention, and academic outcomes in female students.

REFERENCES

Abu-Baker, N. N., Eyadat, A. M., & Khamaiseh, A. M. (2021). The impact of nutrition education on knowledge, attitude, and practice regarding iron deficiency anemia among female adolescent students in Jordan. *Heliyon, 7*(2), Article e06348. https://doi.org/10.1016/j.heliyon.2021.e06348

Amani, Z., & Sebayang, S. (2024). The effect of iron supplementation and other school-based support on anemia status in adolescents: A systematic literature review. *Indonesian Midwifery and Health Sciences Journal, 8*(3), 312–325. https://doi.org/10.20473/imhsj.v8i3.2024.312-325

Andersen, C. T., Marsden, D. M., Duggan, C. P., Liu, E., Mozaffarian, D., & Fawzi, W. W. (2023). Oral iron supplementation and anaemia in children according to schedule, duration, dose and cosupplementation: A systematic review and meta-analysis of 129 randomised trials. *BMJ Global Health, 8*(2), Article e010745. https://doi.org/10.1136/bmjgh-2022-010745

Aslan, N. A., Kelkitli, E., & Ozturk, N. (2021). Effect of zinc deficiency on cognitive function in females with iron deficiency anemia. *Journal of Experimental & Clinical Medicine, 38*(2), 111–114. https://doi.org/10.52142/omujecm.38.2.10

Barnett, A. L., Wenger, M. J., Yunus, F. M., Jalal, C., & DellaValle, D. M. (2023). The effect of iron-fortified lentils on blood and cognitive status among adolescent girls in Bangladesh. *Nutrients, 15*(23), Article 5001. https://doi.org/10.3390/nu15235001

Ceballos-Rasgado, M., Lowe, N. M., Mallard, S., Clegg, A., Moran, V. H., Harris, C., Montez, J., & Xipsiti, M. (2022). Adverse effects of excessive zinc intake in infants and children aged 0–3 years: A systematic review and meta-analysis. *Advances in Nutrition, 13*(6), 2488–2519. https://doi.org/10.1093/advances/nmac088

Chen, Z., Yang, H., Wang, D., Sudfeld, C. R., Zhao, A., Xin, Y., Chen, J. C., Fawzi, W. W., Xing, Y., & Li, Z. (2022). Effect of oral iron supplementation on cognitive function among children and adolescents in low- and middle-income countries: A systematic review and meta-analysis. *Nutrients, 14*(24), Article 5332. https://doi.org/10.3390/nu14245332

Gutema, B. T., Sorrie, M. B., Megersa, N. D., Yesera, G. E., Yeshitila, Y. G., Pauwels, N. S., De Henauw, S., & Abbeddou, S. (2023). Effects of iron supplementation on cognitive development in school-age children: Systematic review and meta-analysis. *PLOS ONE, 18*(6), Article e0287703. https://doi.org/10.1371/journal.pone.0287703

Handiso, Y. H., Belachew, T., Abuye, C., Workicho, A., & Baye, K. (2021). A community-based randomized controlled trial providing weekly iron-folic acid supplementation increased serum-ferritin, -folate and hemoglobin concentration of adolescent girls in southern Ethiopia. *Scientific Reports, 11*(1). https://doi.org/10.1038/s41598-021-89115-5

Indrayoni, P., & Megayanti, S. (2022). Communication, information and education iron supplementation and hemoglobin. *Jurnal Abdimas ITEKES Bali, 1*(1). https://doi.org/10.37294/jai.v1i1.400

Jeihooni, A. K., Hoshyar, S., Harsini, P. A., & Rakhshani, T. (2021). The effect of nutrition education based on PRECEDE model on iron deficiency anemia among female students. *BMC Women's Health, 21*(1). https://doi.org/10.1186/s12905-021-01394-2

Jeng, S.-S., & Chen, Y.-H. (2022). Association of zinc with anemia. *Nutrients, 14*(22), Article 4918. https://doi.org/10.3390/nu14224918

Kedir, S., Abate, K. H., Mohammed, B., & Ademe, B. W. (2024). Weekly iron-folic acid supplementation and its impact on children and adolescents iron status, mental health and school performance: A systematic review and meta-analysis in sub-Saharan Africa. *BMJ Open, 14*(6), Article e084033. https://doi.org/10.1136/bmjopen-2024-084033

Mithra, P., Khatib, M. N., Sinha, A. P., Kumar, N., Holla, R., Unnikrishnan, B., Vijayamma, R., Nair, N. S., Gaidhane, A., & Quazi Zahiruddin, S. (2021). Interventions for addressing anemia among children and adolescents: An overview of systematic reviews. *Frontiers in Pediatrics, 8*, Article 549549. https://doi.org/10.3389/fped.2020.549549

Nirwana, N., Ibrahim, I., & Syahrir, S. (2021). Food intake, anemia status, and learning achievement at female students in Gowa Regency, Indonesia. *Diversity: Disease Preventive of Research Integrity, 2*(1). https://doi.org/10.24252/diversity.v2i1.23178

Sahadewa, S., Durry, F. D., Khamidah, N., & Windayani, N. R. (2025). The influence of zinc supplementation on improving learning concentration and hemoglobin levels in anemic adolescent girls at junior high school. *Prisma Sains: Jurnal Pengkajian Ilmu dan Pembelajaran Matematika dan IPA IKIP Mataram, 13*(3), 796–809. https://doi.org/10.33394/j-ps.v13i3.16399

Salam, S., Ramadurg, U., Charantimath, U., Katageri, G., Gillespie, B., Mhetri, J., Patil, S., Mallapur, A., Karadiguddi, C., Vastrad, P., Dandappanavar, A., Roy, S., Peerapur, B., Goudar, S., & Anumba, D. (2023). Impact of a school-based nutrition educational intervention on knowledge related to iron deficiency anaemia in rural Karnataka, India: A mixed methods pre–post interventional study. *BJOG: An International Journal of Obstetrics & Gynaecology, 130*, 113–123. https://doi.org/10.1111/1471-0528.17619

Samson, K. L. I., Fischer, J. A. J., & Roche, M. L. (2022). Iron status, anemia, and iron interventions and their associations with cognitive and academic performance in adolescents: A systematic review. *Nutrients, 14*(1), Article 224. https://doi.org/10.3390/nu14010224

Shinde, S., Madzorera, I., & Fawzi, W. W. (2021). Association of iron supplementation and dietary diversity with nutritional status and learning outcomes among adolescents: Results from a longitudinal study in Uttar Pradesh and Bihar, India. *Journal of Global Health, 11*, Article 04037. https://doi.org/10.7189/jogh.11.04037

Silitonga, H. T. H., Salim, L. A., & Nurmala, I. (2024). A systematic review of iron supplementation's effects on adolescent girls. *Jurnal Gizi Indonesia (The Indonesian Journal of Nutrition), 12*(2), 60–69. https://doi.org/10.14710/jgi.12.2.60-69

Silitonga, H. T. H., Salim, L. A., Nurmala, I., & Wartiningsih, M. (2023). Compliance of iron supplementation and determinants among adolescent girls: A systematic review. *Iranian Journal of Public Health, 52*(1), 37–48. https://doi.org/10.18502/ijph.v52i1.11664

Suciyanti, D., Kolopaking, R., Mustafa, A., Iwan, S., Witjaksono, F., & Fahmida, U. (2025). Effect of optimized food-based recommendations on nutrient intakes, hemoglobin levels, and memory performance of adolescent girls in East Java, Indonesia. *Nutrition Journal, 24*, Article 13. https://doi.org/10.1186/s12937-024-01061-w

Taufiqurrahman, T., Hafid, F., Mujayanto, M., Nuswantari, A., Ratno, R., Rahayuningtyas, R., Prasetyawan, A., & Rahayu, Y. S. (2025). Iron supplement adherence, dietary intake, and anemia risk among adolescent girls in Madiun Regency, Indonesia. *Journal of Health and Nutrition Research, 4*(3). https://doi.org/10.56303/jhnresearch.v4i3.723

Von Grafenstein, L., Kumar, A., Kumar, S., & Vollmer, S. (2023). Medium-run impacts of iron-fortified school lunch on anaemia, cognition, and learning outcomes in India. *Oxford Bulletin of Economics and Statistics, 85*(6), 1262–1294. https://doi.org/10.1111/obes.12559

Yani, A., Lestari, A., & Amin, N. (2025). Iron supplementation and anemia prevention among adolescent girls: A narrative review of school based. *Journal of FoodSecure Indonesia, 1*(1). https://doi.org/10.61978/foodsecure.v1i1.618