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SCHOOL-BASED INTERVENTIONS TO IMPROVE IRON SUPPLEMENTATION ADHERENCE AND HEMOGLOBIN LEVELS IN ADOLESCENT GIRLS: A LITERATURE REVIEW WITH IMPLICATIONS FOR THE TRANSTHEORETICAL MODEL

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ABSTRACT

Iron deficiency anemia (IDA) remains a critical public health concern affecting a large proportion of adolescent girls globally, particularly in low- and middle-income countries. Poor adherence to iron supplementation programs and limited implementation of theory-based health education contribute to persistently high anemia rates in this population. This literature review aims to examine the effectiveness of school-based interventions in improving iron supplementation adherence and hemoglobin levels among adolescent girls, with a particular focus on the potential role of behavioral change models such as the Transtheoretical Model (TTM). A structured narrative review was conducted by analyzing 11 primary intervention studies identified through Scopus, PubMed, ScienceDirect, and Google Scholar. The synthesis shows that school-based iron supplementation programs consistently improve hemoglobin concentrations and reduce anemia prevalence. Interventions incorporating behavioral components, especially those grounded in the Theory of Planned Behavior demonstrate significant improvements in iron intake behaviors and adherence. However, no existing study has utilized the TTM in school-based anemia interventions, highlighting a critical gap in the literature. These findings underscore the importance of integrating behavioral theories into adolescent nutrition programs and suggest that TTM-based approaches hold promise for enhancing supplement adherence and anemia outcomes.

Keywords: Iron deficiency anemia; Adolescent girls, Iron supplementation adherence; School-based intervention; Transtheoretical model (TTM), Behavioral change theories

1. INTRODUCTION

Iron deficiency anemia remains one of the most prevalent nutritional problems among adolescent girls globally and continues to pose a major public health concern, particularly in low- and middle-income countries. Recent global reports emphasize that anemia among adolescent

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girls remains a major public health concern, particularly in low- and middle-income countries, and requires integrated school-based interventions (WHO, 2023; UNICEF, 2023).

According to recent global estimates, adolescent girls are highly vulnerable to anemia due to increased iron requirements during growth, menstrual blood loss, and inadequate dietary intake (World Health Organization [WHO], 2023; UNICEF, 2023). Anemia during adolescence has been associated with impaired cognitive performance, reduced academic achievement, decreased physical capacity, and increased risks during future pregnancies.

School-based iron supplementation programs have been widely implemented as a cost-effective strategy to address anemia among adolescent girls. Schools provide a structured environment that allows regular distribution of iron supplements, close supervision, and integration with health and nutrition education (Gosdin et al., 2021; Cliffer et al., 2023). Recent evidence indicates that weekly iron–folic acid supplementation delivered through schools can significantly improve hemoglobin levels and reduce anemia prevalence when adherence is adequately maintained.

However, despite the availability of supplementation programs, poor adherence remains a persistent challenge. Studies have shown that factors such as low perceived benefits, fear of side effects, lack of motivation, and insufficient behavioral support can reduce compliance with iron supplementation among adolescents (Righa et al., 2021; Alemayehu et al., 2020). These findings highlight the importance of incorporating behavioral change strategies into school-based interventions.

Behavioral theories have increasingly been applied to improve health-related behaviors, including nutrition and supplementation practices. The Theory of Planned Behavior has been widely used to explain and predict adherence to iron supplementation by addressing attitudes, subjective norms, and perceived behavioral control (Karimy et al., 2020; Aghamolaei et al., 2019). Educational interventions based on this theory have demonstrated improvements in knowledge, intention, and iron consumption behaviors among adolescent girls.

In addition to the Theory of Planned Behavior, the Transtheoretical Model conceptualizes behavior change as a staged process and emphasizes readiness to change as a key determinant of intervention effectiveness. Recent public health frameworks recommend stage-based approaches to design more tailored and sustainable nutrition interventions for adolescents (WHO, 2023; UNICEF, 2020). Nevertheless, the application of the Transtheoretical Model in school-based iron supplementation programs for adolescent girls remains limited.

Several intervention studies conducted in different countries, including India, Vietnam, Iran, Kenya, Ethiopia, and Indonesia, have reported positive effects of school-based iron supplementation and education on adherence and hemoglobin levels (Gosdin et al., 2021; Righa et al., 2021; Lestari et al., 2022). However, variations in program design, supervision, and behavioral components contribute to differences in outcomes across settings.

Therefore, this literature review aims to synthesize evidence from school-based intervention studies examining the effects of behaviorally informed approaches on adherence to iron supplementation and hemoglobin levels among high school female students. By focusing on intervention characteristics and behavioral determinants, this review seeks to identify gaps and

provide recommendations for future school-based anemia prevention programs, particularly the potential role of the Transtheoretical Model.

2. METHODS

This study utilized a structured narrative literature review methodology to synthesize empirical evidence on school-based interventions aimed at improving iron supplementation adherence and hemoglobin levels among adolescent girls. The methods were designed to ensure a transparent, systematic, and replicable process in identifying, selecting, and analyzing relevant research studies. The overall approach consisted of four primary stages: search strategy, screening and eligibility assessment, data extraction, and narrative synthesis.

A narrative literature review was selected as the methodological framework because it allows for a comprehensive and flexible synthesis of evidence from diverse intervention studies, including randomized controlled trials (RCTs), quasi-experimental research, community-based adolescent programs, and school-based nutrition interventions. Unlike systematic reviews, narrative reviews accommodate wide variability in study design, intervention characteristics, and outcome measures, making it appropriate for exploring behavioral-theory–based interventions on iron supplementation in adolescent populations. The review emphasized descriptive interpretation rather than meta-analytic quantification due to heterogeneity across studies in terms of sample size, study duration, intervention type, and measurement tools.

A comprehensive literature search was performed between January and March 2025 across four major academic databases: Scopus, PubMed, ScienceDirect, and Google Scholar. These databases were chosen because they index high-impact journals in nutrition, public health, behavioral science, and adolescent health. The search covered studies published from January 2000 to December 2024, aligning with the time period when global adolescent anemia interventions became widely studied.

A combination of Medical Subject Headings (MeSH) and free-text keywords was utilized. Boolean operators “AND” and “OR” were applied to refine the search. The search terms included:

1) “iron supplementation” OR “iron folic acid” OR “IFA tablets”
2) “adolescent girls” OR “female adolescents” OR “high school girls”
3) “school-based intervention” OR “school health program”
4) “iron deficiency anemia” OR “hemoglobin levels”
5) “behavior change” OR “nutrition education”
6) “Transtheoretical Model” OR “Theory of Planned Behavior”

Additionally, reference lists of the included studies were manually screened to identify any articles that may not have appeared through database searches.

1) Inclusion Criteria
    - Studies were included if they met all of the following conditions:

- Study Population: Female adolescents aged 10–19 years, with preference for those enrolled in middle or high school.
- Study Type: Primary research studies, including randomized controlled trials, quasi-experimental studies, cluster-randomized school interventions, or community-based educational programs targeting adolescent anemia.
- Intervention Characteristics, Studies that implemented: iron supplementation (IFA, weekly iron-folic acid, or therapeutic iron), nutrition education, behavioral interventions (e.g., TPB, social cognitive theory, peer counseling), school-based activities aimed at improving micronutrient intake or adherence.
- Outcome Measures, at least one of the following: hemoglobin concentration, anemia prevalence, adherence to iron supplementation, changes in dietary iron consumption or related behaviors
- Publication Standards: Articles must be published in peer-reviewed journals indexed in Scopus and written in English.

2) Exclusion Criteria

Studies were excluded if they: focused on pregnant women, lactating women, adult populations, or young children; were review papers, meta-analyses, editorials, or theoretical discussions; emphasized food fortification rather than supplementation; lacked quantifiable outcomes related to hemoglobin or adherence.

The initial database search yielded 178 records. After removing duplicates, 142 titles and abstracts were screened for relevance. Screening focused on population characteristics, intervention type, and outcome relevance. Of these, 34 articles were selected for full-text review. During full-text evaluation, articles were assessed against all inclusion and exclusion criteria. Reasons for exclusion included: non-adolescent populations (n = 9), absence of school- or behavior-based intervention (n = 7), inadequate outcome measures such as no Hb/adherence assessment (n = 5), and publication not indexed in Scopus (n = 2). Ultimately, 11 studies met all eligibility criteria and were included in the final synthesis. A PRISMA-style flow description was used to track the screening process, ensuring transparency and replicability.

A standardized data extraction sheet was developed to ensure consistency across studies. For each included study, the following information was extracted: authors and publication year, country and study setting, study design, sample size and participant characteristics, intervention type, duration, and theoretical framework, measurement tools for Hb, adherence, and behavior, key quantitative and qualitative findings. Data extraction was conducted independently and cross-verified to minimize errors and reduce bias.

Given the heterogeneity among studies, a narrative synthesis approach was used. Studies were grouped into thematic categories based on intervention characteristics: school-based iron supplementation programs, behavioral theory–based educational interventions, combined education and supplementation models, and community-supported adolescent anemia programs.

Within each theme, patterns in outcomes were identified, including improvements in hemoglobin, changes in supplementation adherence, and behavioral shifts. Comparisons were made to identify which intervention components were most effective. Special attention was given to whether studies incorporated behavioral models and how these models influenced outcomes. The review also analyzed existing evidence gaps related to the Transtheoretical Model.

As this study is a literature review based on previously published research, no ethical approval was required. However, all included studies were expected to have obtained ethical clearance from their respective institutions, as indicated by their publication in peer-reviewed journals.

3. RESULTS AND DISCUSSION

Characteristics of Included Studies

A total of 11 primary intervention studies met the inclusion criteria. These studies were conducted across diverse geographical settings including Iran, India, Ghana, Vietnam, Tanzania, Ethiopia, Kenya, and Indonesia. Most were carried out in lower- and middle-income countries, where the burden of iron deficiency anemia (IDA) among adolescent girls is highest.

1) Study Designs

Among the included studies:

- 4 were cluster randomized controlled trials (RCTs) (Cliffer et al., 2023; Casey et al., 2009; Gupta et al., 2014; Gosdin et al., 2021)
- 5 were quasi-experimental interventions (Aghamolaei et al., 2019; Karimy et al., 2020; Alemayehu et al., 2020; Lestari et al., 2022; Righa et al., 2021)
- 2 used prospective cohort or longitudinal school-based designs (Talsma et al., 2016)

Sample sizes ranged from 90 to 3,800 adolescent girls, with a median of 400 participants. Most studies focused specifically on female adolescents aged 12–18 years, consistent with the demographic exhibiting the highest prevalence of anemia due to menstruation and rapid physical growth (WHO, 2021).

2) Intervention Duration

Intervention durations varied widely:

Education-only programs: 4–12 weeks

IFA supplementation programs: 3–9 months

Combined education + supplementation: 3–12 months

Longer interventions tended to demonstrate stronger effects on both hemoglobin (Hb) and adherence.

3) Intervention Types

The interventions could be categorized as:

Behavioral theory–based education (TPB, empowerment models)

– e.g., TPB-based studies in Iran (Aghamolaei et al., 2019; Karimy et al., 2020)

School-based iron supplementation programs (IFA/WIFAS)

– e.g., Ghana, India, Vietnam, Tanzania (Casey et al., 2009)

Combined supplementation + education

– e.g., Kenya, Ethiopia (Alemayehu et al., 2020; Righa et al., 2021)

Community-based adolescent empowerment models

– e.g., Juminten Tabah in Indonesia (Lestari et al., 2022)

Notably, none of the 11 studies applied the Transtheoretical Model (TTM), confirming a clear evidence gap.

4) Outcome Measures

The studies assessed one or more of the following:

Hemoglobin concentration (Hb) (all studies except TPB-only studies)

Anemia prevalence (7 studies)

Adherence to iron supplementation (9 studies)

Knowledge, attitude, practice (KAP) scores

Behavioral constructs (intention, social norms, perceived control)

Instruments included hemoglobinometers, validated questionnaires, and behavior scales.

Effects of School-Based Iron Supplementation Interventions

1) Improvements in Hemoglobin Levels

Across the 11 studies, significant improvements in Hb levels were consistently reported in school-based supplementation programs. Cluster RCTs in Ghana and Vietnam demonstrated 0.5–1.2 g/dL increases in Hb following weekly iron–folic acid supplementation combined with school monitoring (Gosdin et al., 2021; Casey et al., 2009). Similarly, school-based interventions in India and Tanzania resulted in 30–50% reductions in anemia prevalence after 3–6 months (Talsma et al., 2016). These findings indicate that consistent IFA distribution in schools substantially improves hematologic outcomes.

2) Effects on Anemia Prevalence

Across all supplementation-focused studies:

Ghana: anemia reduced from 42% to 23%

Vietnam: from 37% to 18%

Tanzania: from 41% to 24%

India: from 51% to 28%

These reductions reflect both biochemical improvements and high adherence.

3) Adherence Patterns

Adherence rates increased significantly when: tablets were administered during class time, teachers were trained to supervise, side effect education was provided, peer support was incorporated. Gupta et al. (2014) observed that adherence improved from 52% to 81% with weekly school-based iron distribution compared to home-based supplementation.

Effects of Behavioral-Theory–Based Interventions

1) Studies Using the Theory of Planned Behavior (TPB)

Two key studies from Iran (Aghamolaei et al., 2019; Karimy et al., 2020) demonstrated that TPB-based educational modules improved: attitudes toward iron consumption, perceived behavioral control, subjective norms, intention to consume iron-rich foods or supplements. Although they did not directly measure Hb, both studies reported significant increases in self-reported Fe intake and iron supplement adherence.

2) Mechanisms of Change

TPB-driven changes were attributed to: correcting misconceptions about iron tablets, enhancing confidence in managing side effects, strengthening supportive norms through teachers and peers, increasing motivation by showing benefits (e.g., reduced fatigue, cognitive benefits).

3) Community Empowerment Model

The Juminten Tabah intervention in Indonesia improved: anemia knowledge (+27%), dietary iron practices (+19%), Hb levels (from 11.2 to 12.1 g/dL) (Lestari et al., 2022). Its success is linked to intensive peer counseling, reflective discussions, and culturally sensitive modules.

Combined Education + Supplementation Programs

Studies in Ethiopia and Kenya showed that combining IFA tablets with structured nutrition education yielded stronger outcomes.

1) Ethiopia: anemia decreased from 32% to 14% with combined intervention (Alemayehu et al., 2020).
2) Kenya: adherence improved from 48% to 87%, and Hb increased by +0.8 g/dL (Righa et al., 2021).

These studies confirm that knowledge + behavior change support enhances adherence significantly more than supplementation alone.

Identified Gaps in the Evidence

Across all studies, several consistent gaps emerged:

1) No interventions used the Transtheoretical Model (TTM)

   Despite strong evidence for TPB and empowerment models, none used stage-of-change tailoring.

2) Limited long-term follow-up

   Most studies lasted only 2–6 months.

3) Few studies measured ferritin or biochemical markers

   Hb alone may not reflect iron stores.

4) Minimal use of digital or mobile-based adherence tools

   An opportunity for modern intervention design.

5) Lack of individualized stage-based counselling

   Current programs treat all adolescent girls as if they are at the same readiness to change.

These gaps justify the need for a TTM-based school intervention, which tailors strategies across the five stages of change.

Interpretation of Overall Evidence

The evidence strongly supports the effectiveness of school-based iron supplementation combined with education. Across diverse settings, improvements in Hb, reductions in anemia, and increases in adherence were consistent. This affirms that schools are an optimal platform for micronutrient interventions, offering structure, routine, and social reinforcement.

In contrast, studies conducted in less densely populated or resource-limited settings demonstrated more modest improvements, suggesting that contextual factors such as supervision intensity and health system support influence outcomes (Alemayehu et al., 2020; Righa et al., 2021).

Comparison with Previous Literature

Globally, WHO (2021) recommends school-based weekly IFA supplementation as the most cost-effective approach for preventing IDA in adolescent girls. The findings from Ghana, Vietnam, and India support this guideline. These findings align with recent evidence emphasizing the importance of targeting psychosocial determinants to improve adolescent nutrition behaviors (WHO, 2023).

Despite these positive findings, most interventions focused primarily on education and supplementation without explicitly tailoring strategies based on individual readiness to change. The Transtheoretical Model offers a framework for addressing this gap by allowing interventions to be adapted according to behavioral stages. Recent global recommendations support the use of stage-based and adolescent-centered approaches to strengthen the sustainability of nutrition

programs (UNICEF, 2023; WHO, 2023). However, empirical applications of the Transtheoretical Model in school-based iron supplementation programs remain scarce.

Why Adolescent Girls Respond Well to Behavioral Interventions

Several mechanisms explain positive responses:

1) Cognitive readiness: Adolescents are developing autonomy and can absorb health information.
2) Social influence: Peers and teachers strongly shape behavior.
3) Routine environment: Schools provide structure for consistent supplementation.
4) Motivation: Adolescents respond to benefits related to appearance, performance, and energy levels.

These features align particularly well with TT, which emphasizes readiness, reinforcement, and progression through behavior change stages.

Implications for Applying the Transtheoretical Model (TTM)

A TTM-based intervention in schools should include:

1) Precontemplation stage: addressing myths (e.g., fear of weight gain, side effects)
2) Contemplation stage: enhancing risk perception (link anemia to academic performance)
3) Preparation stage: goal-setting for weekly tablet intake
4) Action stage: supervised supplementation + peer support
5) Maintenance stage: relapse prevention, habit tracking apps, teacher reinforcement

Because no reviewed study used TTM, implementing such an approach would represent a novel and evidence-informed contribution to the adolescent health literature.

Strengths and Limitations of the Reviewed Evidence

1) Strengths

   Consistent Hb and adherence improvements.

   High methodological quality in several cluster RCTs.

   Behavior-change components repeatedly demonstrated effectiveness.

2) Limitations

   Lack of biochemical iron markers (limited ferritin data).

   Short intervention durations.

   Limited cultural tailoring in some studies.

   Absence of stage-based models like TTM.

Implications for Future Research

Future studies should:

1) Develop TTM-based modules tailored to adolescent readiness stages.
1) Incorporate digital tools (apps, SMS reminders) to improve adherence.
2) Measure biochemical markers (ferritin, transferrin saturation).
3) Use longitudinal designs to assess sustained behavior change.
4) Include peer educators or mother–daughter partnerships.

This review demonstrates that school-based iron supplementation programs work, but theory-driven approaches significantly improve adherence, and TTM remains untested in this context. The evidence supports the development of a stage-matched TTM-based intervention that could optimize adherence and hematologic outcomes among adolescent girls.

4. CONCLUSION

This literature review was conducted to synthesize existing evidence on school-based interventions aimed at improving iron supplementation adherence and hemoglobin levels among adolescent girls, while examining the potential role of behavioral-theory–based approaches, particularly the Transtheoretical Model (TTM). The findings demonstrate that school settings offer a highly effective platform for delivering iron supplementation and nutrition education programs. Across multiple countries and study designs, consistent improvements in hemoglobin levels and reductions in anemia prevalence were reported when supplementation was integrated into structured school routines. These results highlight the critical importance of school-based health strategies in addressing iron deficiency anemia among adolescents.

The review also reveals that interventions incorporating behavioral change components, especially those grounded in the Theory of Planned Behavior (TPB) and community-empowerment frameworks, significantly enhance adherence to iron supplementation. By addressing determinants such as attitude, perceived behavioral control, subjective norms, and social support, these interventions lead to measurable improvements in supplement intake and iron-related behaviors. The evidence confirms that behavioral theory strengthens the effectiveness of anemia-prevention programs, underscoring the need to move beyond supplementation alone and to integrate psychological and social determinants of health behavior.

Despite the demonstrated benefits of behavioral approaches, a notable gap emerges in the application of the Transtheoretical Model within school-based iron supplementation interventions. None of the reviewed studies employed TTM to guide educational modules, counseling strategies, or adherence support mechanisms. This gap suggests that existing programs do not sufficiently address the varying stages of readiness among adolescent girls, even though motivation, ambivalence, and fluctuating engagement are common at this developmental stage. The absence of TTM presents a significant opportunity for future interventions to incorporate stage-matched strategies that differentiate between students who are unmotivated, contemplating change, preparing to take action, or attempting to maintain long-term adherence.

The overall evidence indicates that the combination of iron supplementation and theory-driven education leads to the most substantial improvements in hematologic outcomes. However, the lack of TTM-based interventions limits the ability to tailor strategies to individual differences in readiness for behavior change. Applying TTM in future school programs could enhance engagement, strengthen adherence, and promote long-term maintenance of iron supplementation behaviors. Such tailored stage-based approaches also hold potential to address persistent barriers such as forgetfulness, concerns about side effects, limited risk perception, and low motivation.

In conclusion, school-based iron supplementation programs are effective, and interventions guided by behavioral theories further enhance their impact. The unmet need for the integration of the Transtheoretical Model highlights an important direction for future research, providing an opportunity to develop innovative, stage-sensitive interventions that may achieve greater and more sustainable improvements in adolescent health. This review confirms the importance of combining biochemical, educational, and behavioral components to comprehensively address iron deficiency anemia among adolescent girls and emphasizes the potential of TTM to fill existing gaps in program design and implementation.

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