

The Effectiveness of School-Based Nutrition Education Programs in Improving Adherence to Iron Supplementation Among Adolescent Girls

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Article Information

Received: September 03, 2026

Revised: September 24, 2026

Online: September 30, 2026

Keywords

Adolescent Girls, Iron Supplementation, Nutrition Education, WIFAS, School Health, Adherence

ABSTRACT

Background: Weekly iron and folic acid supplementation (WIFAS) is a key school-based strategy for preventing iron deficiency among adolescent girls, yet adherence remains suboptimal. Nutrition education may improve knowledge, attitudes, and adherence by addressing behavioral barriers. Purpose: This study evaluated the effectiveness of an eight-week school-based nutrition education program in improving nutrition knowledge, attitudes toward iron supplementation, and adherence to weekly iron tablet consumption among adolescent girls. Methods: A quasi-experimental pretest–posttest control group study involved 180 female students aged 15–18 years from two public senior high schools in Padang City, West Sumatra, Indonesia. Ninety students received the intervention; 90 received routine school health services. The intervention comprised weekly interactive education, audiovisual materials, peer-group discussions, educational booklets, and teacher-supported monitoring. Knowledge and attitudes were assessed via questionnaires; adherence was evaluated using weekly monitoring records, supervised supplementation, and teacher-verified consumption. Adherence was defined as consuming $\geq 80\%$ of prescribed weekly tablets. Results: Nutrition knowledge increased significantly in the intervention group from 61.8 ± 10.5 to 86.7 ± 8.4 ($p < .001$), versus 62.4 ± 9.8 to 67.2 ± 9.1 in controls ($p = .061$). Attitude scores rose from 52.6 ± 6.7 to 66.9 ± 5.3 in the intervention group ($p < .001$), versus 53.1 ± 6.5 to 55.0 ± 6.1 in controls ($p = .087$). Adherence increased from 46.7% to 84.4% in the intervention group and from 48.9% to 58.9% in controls. Logistic regression indicated intervention participation was associated with higher adherence (adjusted OR=4.73; 95% CI: 2.41–9.28; $p < .001$). Conclusion: The school-based nutrition education program was associated with improved knowledge, attitudes, and adherence to weekly iron supplementation among adolescent girls.

Keywords: *Adolescent Girls, Iron Supplementation, Nutrition Education, WIFAS, School Health, Adherence*

INTRODUCTION

Iron deficiency and anemia remain important nutritional concerns during adolescence, particularly among girls whose iron requirements increase because of rapid growth and menstrual blood loss. Iron deficiency can affect cognitive performance, physical capacity, and educational participation, making adolescence an important period for preventive intervention (Christian & Smith, 2018; Samson et al., 2022; Stevens et al., 2022).

Weekly iron and folic acid supplementation is used in many school health programs as a preventive strategy. Evidence from intervention studies indicates that supervised or supported supplementation can improve iron intake and, in some settings, hematological outcomes (Gupta et al., 2021; Handiso et al., 2021). However, the behavioral component of supplementation is important because possession of tablets does not guarantee consumption. Factors such as knowledge, perceived need, side effects, taste, forgetfulness, peer influence, family support, and supervision can affect adherence (Fitriana et al., 2022; Susanti et al., 2022; Viyanti et al., 2024). Related Indonesian evidence also highlights health-information exposure as relevant to adherence to disease-prevention programs (Adriani & Hadjo, 2026).

School-based nutrition education provides an opportunity to address these barriers because schools can reach adolescents repeatedly and can combine health information with teacher and peer support. Reviews of adolescent nutrition interventions indicate that education, counseling, and supportive school environments can improve nutrition-related knowledge and behaviors, although effects vary according to intervention content, duration, implementation quality, and context (Das et al., 2018; Salam et al., 2019; Lassi et al., 2022). This broad approach is also consistent with public health, community nursing, and health-promotion perspectives that emphasize structured education and behavior-oriented interventions (Nainggolan et al., 2025; Christina et al., 2025; Hadjo, Dalimunthe, Tasnim, et al., 2025).

In Indonesia, evidence specifically evaluating comprehensive school-based education together with adherence monitoring remains limited. Previous work has often focused on prevalence, knowledge, or associated factors rather than examining an intervention with adherence as the primary behavioral outcome. The present study therefore evaluated an eight-week school-based nutrition education program in two public senior high schools in Padang City. The primary outcome was adherence to weekly iron supplementation; nutrition knowledge and attitudes were secondary outcomes. Related Indonesian work has also examined adolescent health behavior using self-determination constructs in school settings (Hadjo, Kasenda, & Hadjo, 2025).

The study does not assess whether the intervention changed hemoglobin, ferritin, or anemia status after the intervention. Baseline hemoglobin status was recorded as a participant characteristic, but no post-intervention biomarker was measured. Accordingly, claims in the original manuscript implying a direct reduction in anemia have been removed. The study instead focuses on the



behavioral pathway of improving adherence, which may be relevant to but cannot by itself establish future biological effects.

The study aimed to determine whether participation in the school-based nutrition education program improved nutrition knowledge, attitudes toward iron supplementation, and adherence compared with routine school health services. We hypothesized that students receiving the intervention would demonstrate greater improvement in these outcomes than students receiving routine services.

METHODS

1. Study Design and Setting

This study used a quasi-experimental pretest–posttest control group design. It was conducted from January to March 2026 in two public senior high schools in Padang City, West Sumatra, Indonesia. One school was assigned to the intervention group and the other to the control group to reduce direct contamination between study groups. Because the schools were located within the same city, complete prevention of information exchange outside school could not be guaranteed; geographical distance and social-media interaction were not measured and are acknowledged as potential sources of contamination.

2. Participants and Sampling

The study population comprised female students in grades 10 and 11 who participated in the national WIFAS program. Eligibility criteria were age 15–18 years, active enrollment, having experienced menarche, and willingness to participate with written parental or guardian consent. Students receiving therapeutic iron treatment or having chronic conditions affecting iron metabolism were excluded. The protocol also specified exclusion for absence from more than two intervention sessions. A total of 180 students were included, with 90 in each group.

All 180 enrolled participants had both pretest and posttest outcome assessments, producing a 100% outcome-completion rate in the analytic dataset. Thus, there were no post-enrollment losses to follow-up in the reported dataset. Because no participants with missing posttest outcomes were identified, a separate missing-outcome ITT analysis could not be meaningfully performed. Nevertheless, the session-attendance exclusion rule could introduce selection bias if students who were absent from multiple sessions had been removed before analysis; this possibility is now explicitly acknowledged.

3. Intervention

The intervention was an eight-week School-Based Nutrition Education Program integrated into routine school health activities. Sessions were conducted once per week, approximately 60 minutes per session. The documented intervention components were: (1) interactive classroom education on iron deficiency anemia, including causes, symptoms, consequences, and prevention; (2) nutrition education on iron-rich foods, vitamin C, and dietary factors affecting iron absorption;

(3) audiovisual videos and infographic presentations; (4) small-group peer discussions; and (5) teacher-assisted weekly monitoring of iron tablet consumption using adherence monitoring cards.

Participants also received illustrated educational booklets summarizing the messages delivered during the program. The intervention was delivered by trained public-health educators and school health teachers, with peer-group activities facilitated by trained peer educators. The original study records provided in the submitted manuscript do not specify the facilitators' professional credentials or a formal session-by-session fidelity score. These details cannot be reconstructed without the study implementation log; therefore, the revised manuscript does not invent such information. Fidelity was supported operationally through the fixed weekly schedule, standardized educational materials, teacher-supported monitoring, and research-assistant supervision, but no quantitative fidelity index was collected.

The control group continued the routine school health/WIFAS program without the additional nutrition education, peer discussion, audiovisual package, or educational booklet. No parallel attention-control sessions were provided.

4. Variables and Measurement

The independent variable was participation in the School-Based Nutrition Education Program. The primary dependent variable was adherence to weekly iron supplementation. Secondary outcomes were nutrition knowledge and attitudes toward iron supplementation. Baseline hemoglobin status was included only as a baseline characteristic and was not analyzed as a post-intervention outcome.

5. Knowledge Assessment

Knowledge was assessed using 20 multiple-choice questions covering causes and symptoms of anemia, risk factors, iron-rich foods, benefits of supplementation, and appropriate tablet consumption. Each correct answer received one point and total scores were converted to percentages. The questionnaire had been adapted from previously validated adolescent nutrition education instruments and translated using forward-backward procedures. A pilot test was conducted with 30 adolescent girls from another school. Item validity was assessed with Pearson's product-moment correlation, with reported item correlations above 0.30, and internal consistency was $\alpha = 0.86$.

6. Attitude Assessment

Attitudes toward iron supplementation were assessed using 15 Likert-scale items scored from 1 (strongly disagree) to 5 (strongly agree), with higher scores indicating more positive attitudes. The reported Cronbach's alpha was 0.91.

7. Adherence Definition and Calculation

Adherence was assessed using weekly iron-tablet monitoring cards, direct observation during supervised supplementation sessions, and monthly tablet-consumption records verified by



teachers. The adherence percentage for an individual was defined as: $\text{adherence (\%)} = (\text{number of prescribed weekly tablets consumed} \div \text{number of prescribed weekly tablets expected during the observation period}) \times 100$. Because the program prescribed one weekly tablet, the expected number over eight weeks was eight tablets for a participant who completed the full observation period. Participants consuming at least 80% of prescribed tablets were classified as adherent, whereas those consuming less than 80% were classified as non-adherent. The reported 46.7% and 84.4% figures represent the proportions of students meeting this adherence criterion at baseline and post-intervention, respectively; they are not mean percentages of tablets consumed.

The available study dataset did not include an independent pill-count measure or biological verification of adherence. Teacher involvement and monitoring cards may therefore introduce social-desirability or reporting bias. In addition, reasons for non-adherence after the intervention were not systematically collected. These limitations are explicitly considered in the Discussion.

8. Data Collection Procedure

Baseline data were collected before the intervention, including demographic characteristics, nutrition knowledge, attitudes, baseline adherence, and baseline hemoglobin status. The intervention group then received the eight-week education program, while the control group continued routine school health services. Post-intervention assessments used the same questionnaires and adherence-monitoring procedures. Research assistants supervised data collection and were described in the original protocol as blinded to the study objectives.

9. Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 27.0. Descriptive statistics included means, standard deviations, frequencies, and percentages. Normality was assessed with the Shapiro–Wilk test. Independent-samples t-tests and chi-square tests were used for between-group comparisons, and paired t-tests were used for within-group pretest–posttest comparisons. A multiple logistic regression model was used to identify factors associated with post-intervention adherence, adjusting for age, parental education, nutrition knowledge, and attitude. The use of descriptive and inferential statistical procedures is also consistent with general statistical approaches applied in educational research (Purba et al., 2026).

The submitted manuscript did not document the exact cut-points used to categorize 'good nutrition knowledge' and 'positive attitude', nor did it report formal multicollinearity diagnostics, logit-linearity testing, or outlier diagnostics. These analytical details cannot be reconstructed reliably without the original analysis file. The revised manuscript therefore treats the regression findings for these categorized predictors as exploratory and avoids claiming that the reported model constitutes a fully validated predictive model. A re-analysis using the original participant-level dataset should document the exact cut-points, variance-inflation or correlation diagnostics, model specification, and sensitivity analyses before these predictors are interpreted as robust independent determinants.

Statistical significance was set at $p < .05$, and adjusted odds ratios (AORs) with 95% confidence intervals were reported. analytic dataset.

RESULTS

A total of 180 adolescent girls were included, with 90 in the intervention group and 90 in the control group. All 180 participants had pretest and posttest outcome data. No post-enrollment loss to follow-up was reported in the analytic dataset.

1. Baseline Characteristics

Baseline characteristics are shown in Table 1. The groups were similar with respect to age, grade, parental education, baseline hemoglobin status, and baseline adherence; all reported p-values were greater than .05.

Table 1. Baseline characteristics of participants (n = 180)

Characteristic	Intervention (n=90)	Control (n=90)	p-value
Age, mean $\pm$ SD	16.4 $\pm$ 0.8	16.3 $\pm$ 0.7	0.481
Grade 10	48 (53.3%)	46 (51.1%)	0.764
Grade 11	42 (46.7%)	44 (48.9%)	—
Parents completed senior high school or above	61 (67.8%)	58 (64.4%)	0.635
Baseline anemia, Hb <12 g/dL	34 (37.8%)	32 (35.6%)	0.756
Baseline adherence to iron tablets	42 (46.7%)	44 (48.9%)	0.771

Baseline hemoglobin status was available as a participant characteristic, but no post-intervention hemoglobin or ferritin measurement was performed. Therefore, baseline anemia status is not interpreted as an intervention outcome.

2. Changes in Nutrition Knowledge

Table 2. Nutrition knowledge scores before and after intervention

Group	Pre-test mean $\pm$ SD	Post-test mean $\pm$ SD	Mean difference	p-value
Intervention	61.8 $\pm$ 10.5	86.7 $\pm$ 8.4	+24.9	<0.001
Control	62.4 $\pm$ 9.8	67.2 $\pm$ 9.1	+4.8	0.061

The intervention group showed a statistically significant within-group increase in knowledge score of 24.9 points ($p < .001$). The control group showed a smaller, non-significant increase of 4.8 points ($p = .061$). The reported data support a substantial improvement within the intervention group; a formal between-group difference-in-change estimate was not reported in the submitted dataset.

3. Changes in Attitudes Toward Iron Supplementation

Table 3. Attitude scores before and after intervention

Group	Pre-test mean $\pm$ SD	Post-test mean $\pm$ SD	p-value
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Intervention	52.6 ± 6.7	66.9 ± 5.3	<0.001
Control	53.1 ± 6.5	55.0 ± 6.1	0.087

Attitude scores increased significantly within the intervention group ($p < .001$), whereas the increase in the control group was not statistically significant ($p = .087$).

4. Adherence to Weekly Iron Supplementation

Table 4. Adherence to weekly iron supplementation

Group	Baseline adherent	Post- intervention adherent	Absolute increase	Within-group p- value
Intervention	42 (46.7%)	76 (84.4%)	+37.7 percentage points	<0.001
Control	44 (48.9%)	53 (58.9%)	+10.0 percentage points	0.118

The proportion classified as adherent increased by 37.7 percentage points in the intervention group and by 10.0 percentage points in the control group. The reported p-values are within-group comparisons. Because individual-level paired transitions were not provided, a separate paired comparison of the change in binary adherence between groups could not be reconstructed from the summary table alone.

5. Factors Associated with Post-Intervention Adherence

Table 5. Multiple logistic regression analysis of factors associated with adherence

Variable	Adjusted OR	95% CI	p-value
Nutrition education intervention	4.73	2.41–9.28	<0.001
Good nutrition knowledge	2.68	1.37–5.25	0.004
Positive attitude	2.21	1.18–4.17	0.013
Parents' education	1.36	0.74–2.51	0.319
Age	1.08	0.81–1.43	0.612

Participation in the nutrition education program had the largest reported adjusted association with post-intervention adherence (AOR 4.73, 95% CI 2.41–9.28, $p < .001$). Good nutrition knowledge and positive attitude were also statistically associated with adherence in the reported model. Because the original analysis documentation did not provide the categorization thresholds or model diagnostics, these estimates should be interpreted as reported associations rather than as a fully validated prediction model.

DISCUSSION

The study found substantial improvements in nutrition knowledge, attitudes, and the proportion of students classified as adherent following an eight-week school-based education program. Knowledge increased from 61.8 to 86.7 points in the intervention group, and the proportion meeting the adherence criterion increased from 46.7% to 84.4%. These findings are consistent with the broader literature indicating that school-based education and supportive supplementation strategies can improve adolescent nutrition-related knowledge and behaviors (Das et al., 2018; Salam et al., 2019; Lassi et al., 2022).

The increase in knowledge is plausible because the intervention used repeated exposure to information through classroom teaching, audiovisual materials, peer discussion, and printed booklets. Repetition and multiple communication channels may help adolescents understand why weekly supplementation is recommended and how iron intake is related to anemia prevention. Previous studies have similarly reported that education and supervision can improve adherence to iron supplementation among adolescent girls (Singh et al., 2020; Fitriana et al., 2022; Viyanti et al., 2024). In a broader adherence context, Indonesian research has examined the relationship between exposure to health misinformation and adherence to disease-prevention programs (Adriani & Hadjo, 2026).

The improvement in attitudes is also relevant. Misconceptions, unpleasant taste, concerns about side effects, and low perceived need can reduce willingness to take preventive supplements. The educational sessions provided opportunities to discuss these issues and may have increased perceived benefits and reduced misconceptions. However, because the study did not include a qualitative assessment of beliefs or reasons for non-adherence, the mechanisms underlying the observed attitude change cannot be determined directly.

The increase in adherence was the main behavioral finding. The intervention group increased from 46.7% to 84.4%, whereas the control group increased from 48.9% to 58.9%. The regression model also reported an adjusted odds ratio of 4.73 for participation in the intervention. These findings are compatible with evidence that supplementation programs may be more effective when tablets are accompanied by education, supervision, and behavioral support rather than relying only on distribution (Gupta et al., 2021; Handiso et al., 2021; Marisa et al., 2025).

Importantly, the findings should not be interpreted as evidence that the intervention reduced anemia or improved iron stores. The study did not measure post-intervention hemoglobin, ferritin, or another biological indicator. Baseline hemoglobin status was recorded only to describe the participants. Therefore, the present results demonstrate improvement in a behavioral indicator adherence to supplementation and do not establish a biological effect. Future trials should include repeated hemoglobin and, where feasible, ferritin measurements to test whether improved adherence translates into improved iron status.

The adherence measurement also requires cautious interpretation. Monitoring cards, supervised sessions, and teacher verification provide several sources of information, but they do not constitute independent biochemical confirmation. Teacher involvement may increase social-desirability reporting, and no independent pill count was available. The revised analysis therefore



avoids treating the adherence measure as a direct biomarker of tablet ingestion. Future studies could strengthen measurement by combining supervised observation, independent pill counts, electronic reminders or logs, and biological outcomes.

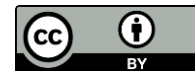
The study did not systematically record reasons for post-intervention non-adherence. Consequently, it cannot determine whether remaining non-adherence was driven by side effects, forgetting, taste, family support, peer influence, access to tablets, or other barriers. This is a limitation because understanding residual barriers is important for designing more targeted interventions.

The two-school design also limits generalizability. Padang City has its own social, educational, health-service, and cultural context, and WIFAS implementation may differ across provinces and school systems. Students from the two schools could potentially interact through social media or other activities, but the study did not measure the extent of such interaction. The single-city setting and non-randomized school allocation therefore mean that the findings should be interpreted as context-specific evidence rather than as proof that the program will have the same effect nationally.

Family support and broader socioeconomic conditions were not measured, although these factors can influence adolescent supplementation behavior. Their absence from the model means residual confounding is possible. The reported logistic regression should therefore be interpreted cautiously. In particular, the original analysis did not document the cut-points used to define 'good nutrition knowledge' and 'positive attitude' or formal tests of multicollinearity, logit linearity, and outliers. A participant-level re-analysis is recommended before these variables are used for definitive predictive inference.

Despite these limitations, the study provides practical evidence that a school-based program combining education, peer engagement, and teacher-supported monitoring can improve behavioral adherence in the participating schools. The most appropriate implication is to strengthen the behavioral and educational component of WIFAS rather than to claim that education alone prevents anemia. Implementation in other regions should be adapted to local school structures, adolescent needs, health-service capacity, and patterns of family and peer support. The emphasis on local adaptation is also consistent with Indonesian work on community-based health promotion, participatory village-level health preparedness planning, and health-service capacity planning (Rahmawati Shoufiah et al., 2026; Hadjo & Fadly, 2026; Hadjo & Rasyada, 2026).

First, the quasi-experimental design with one intervention school and one control school does not provide the same level of causal inference as individual or cluster randomized allocation. Second, the intervention lasted eight weeks and did not assess whether adherence was maintained after the program ended. Third, adherence was assessed without an independent pill count or post-intervention biomarker, so reporting and social-desirability bias remain possible. Fourth, reasons for non-adherence were not systematically collected. Fifth, geographical distance, inter-school interaction, family support, and socioeconomic conditions were not measured. Sixth, no post-intervention hemoglobin or ferritin outcome was available, so biological effects cannot be inferred. Seventh, the logistic regression documentation did not include the exact categorization thresholds



for knowledge and attitude or full diagnostic testing. Finally, the study involved only two schools in Padang City, limiting generalizability to other settings.

CONCLUSIONS

The eight-week School-Based Nutrition Education Program was associated with significant improvements in nutrition knowledge and attitudes and a substantial increase in the proportion of adolescent girls classified as adherent to weekly iron supplementation in the participating schools. Participation in the intervention had the largest reported adjusted association with post-intervention adherence. These findings support strengthening education, peer engagement, and teacher-supported monitoring within school-based WIFAS implementation.

The study does not demonstrate a reduction in anemia or an improvement in iron status because post-intervention hemoglobin and ferritin were not measured. Future multicenter randomized studies should use longer follow-up, independent adherence verification, systematic assessment of reasons for non-adherence, family and socioeconomic variables, and repeated biological measures. Such studies would provide stronger evidence about whether improved adherence translates into measurable hematological benefits.

ACKNOWLEDGMENT

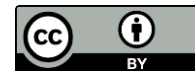
The authors thank the participating schools, students, parents or guardians, school health personnel, research assistants, and colleagues who supported the study. The authors also acknowledge the researchers and institutions whose published work informed the background and interpretation of this study.

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Miracle Get Journal, Vol. 03, No. 3, August 2026

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