



RESEARCH ARTICLE

Article URL: <http://jurnal.fkmumi.ac.id/index.php/woh/article/view/woh9316>**Integrated School-Based Intervention for Prevention and Control of Anemia among Pre-adolescent Girls Aged 10–12 Years**^cAdelgrit Trisia¹, Ira Jayanti², Eka Fadillah Bagenda³¹Department of Clinical Medicine, Faculty of Medicine, Palangka Raya University, Indonesia²Master's Program in Biomedical Sciences, Faculty of Medicine, Palangka Raya University, Indonesia³Faculty of Medicine, Kurnia Jaya University, IndonesiaEmail Corresponding Author(C): adelgrit@med.upr.ac.idadelgrit@med.upr.ac.id, ira.jayanti33@gmail.com, ekadelisya@gmail.com

ABSTRACT

Anemia remains a health problem in school-aged children, particularly pre-adolescent girls who face increased iron requirements during growth. This study aimed to evaluate changes in hemoglobin (Hb) concentration and anemia status following the implementation of a school-based integrated intervention package in girls aged 10–12 years. The study used a quasi-experimental pretest–posttest design with a control group involving 60 female students from two elementary schools in Central Kalimantan. Allocation was conducted at the school level, with one school as the intervention group and one school as the control group. The intervention package was delivered for 8 weeks and included health and nutrition education, promotion and monitoring of local food consumption sources of iron, Hb testing and follow-up, and monitored iron supplementation according to the study protocol, with parental involvement as a supporting strategy. Anemia status was determined based on the Hb threshold for the age group specified in the study protocol. The intervention group experienced a greater increase in Hb concentration than the control group ($\Delta\text{Hb} +1.5 \pm 0.6$ vs $+0.6 \pm 0.5$ g/dL; $p < 0.001$) and showed a higher proportion of participants with non-anemic status after the intervention (76.7% vs 43.3%). The integrated school-based intervention package was associated with better improvements in Hb concentration and anemia status compared to routine school health services. The findings need to be interpreted considering the allocation at the school level and the involvement of only two schools.

Keywords: Anemia; school-age children; integrated intervention; hemoglobin; nutrition

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INTRODUCTION

Anemia remains a public health problem in children and adolescents and can impact cognitive development, academic achievement, and physical capacity. Although iron deficiency is an important cause of anemia, hemoglobin concentration is not specific for iron deficiency because anemia can also be affected by infection, inflammation, hemoglobinopathies, other micronutrient deficiencies, and certain clinical conditions. Therefore, in studies using only hemoglobin as an indicator, changes in hemoglobin should be interpreted as changes in anemia/hemoglobin status and should not automatically be considered as improvements in iron deficiency.^[1-3]

Girls aged 10–12 years were selected because this group is in the pre-adolescent period, characterized by accelerated growth, increased body mass, and the onset of pubertal maturation, which increases iron requirements for blood volume expansion and tissue growth. Furthermore, some girls in this age range have experienced menarche; menstrual blood loss can further increase iron requirements and be an important determinant of Hb levels. Therefore, pubertal and menstrual status are relevant biological factors in the interpretation of anemia in this age group. In this study, pubertal status and menstrual history were not systematically assessed and therefore were treated as potential confounding factors and limitations of the study.^[4-7]

In school-aged children, anemia is associated with low consumption of iron-rich foods and limited access to detection and follow-up efforts. Factors such as infection and sanitation can also influence anemia but were not measured in this study; therefore, the research rationale focused on factors directly addressed by the intervention package: nutritional knowledge, consumption of iron-rich foods, hemoglobin monitoring, monitored supplementation, and parental support.^[2,5]

In Indonesia, anemia in school-aged children still requires prevention and control strategies that can be implemented through schools. Interventions that have been used include iron supplementation, diet fortification or improvement, nutrition education, and school health programs. However, evidence regarding the implementation of these components within a coordinated school service flow is limited. Therefore, this study evaluated an integrated intervention package, not the independent effects of each component.^[8-10]

Previous relevant research suggests that iron- and school-based interventions can improve hemoglobin status. Krämer et al. reported that the provision of double-fortified salt through a school meal program increased hemoglobin levels and reduced anemia in elementary school students. Hameed et al. also reported differences in anemia status between adolescent girls who participated in Weekly Iron and Folic Acid Supplementation (WIFS) and those who did not. These findings support the use of supplementation and school-based approaches as part of anemia prevention and control strategies.^[3,11,12]

Additional evidence suggests that dietary improvements, nutrition-specific interventions, and anemia-related education can contribute to improvements in nutritional status and hemoglobin. However, differences in population, intervention type, duration, baseline anemia status, and outcomes prevent direct comparisons between studies. The gap underlying this research is the need to evaluate a

package of school interventions that integrates education, dietary support, hemoglobin screening and follow-up, and monitored supplementation within a single implementation pathway.^[9,13]

The Integrated Intervention Model is defined as a school-based package that combines four main functions: (1) nutrition education to improve knowledge and dietary decisions; (2) promotion and monitoring of consumption of local iron-rich foods to support diet quality; (3) Hb screening with referrals for detection and follow-up; and (4) monitored iron supplementation for participants who meet the protocol criteria. Parental involvement is used as a supporting strategy for implementation. All components are provided as a single package, so this study evaluates the combined effect of the package and is not designed to estimate the independent or synergistic effects of each component. A preliminary study at SD Negeri 1 and 2 Pahandut found that 28 of 144 children aged 10–12 years had anemia. Based on this gap, this study aims to evaluate the effectiveness of the integrated intervention package on changes in Hb concentration and anemia status in girls aged 10–12 years compared to routine school health services.^[3,13,14]

METHOD

This study was a quasi-experimental school-level study with a pretest–posttest and control group design. Two schools, namely SD Negeri 1 Pahandut and SD Negeri 2 Pahandut, served as the research cluster units. The schools were selected because they were located in the same urban area and had comparable levels and target age groups. Group assignment was conducted at the school level: one school as the intervention group and one school as the control group; no individual randomization was performed. Because there were only two clusters, school effects could not be reliably separated from the intervention effects and were treated as a major limitation. The study was conducted for 8 weeks. The intervention package consisted of four main functions: (1) anemia nutrition education; (2) promotion and monitoring of local iron-rich food consumption; (3) Hb examination with follow-up/referral; and (4) monitored iron supplementation, with parental involvement as a supporting strategy. The study evaluated the overall effect of the package, not the independent or synergistic effects of each component.

Sampling was conducted at two schools as cluster units, and then eligible female students were recruited after initial screening; group allocation followed school-based rather than individual randomization. The total sample size was 60 girls, 30 each in the intervention and control groups. The sample size calculation was based on the difference in Hb changes between groups with $\alpha = 0.05$, 80% power, 1:1 group ratio, 10% anticipated dropout, expected difference in Hb changes of 0.50 g/dL, and standard deviation of 0.65 g/dL. Based on the calculation of the comparison of two independent means, a minimum requirement of approximately 27 participants per group was obtained, then 30 participants per group were set to anticipate data loss. Inclusion criteria: girls aged 10–12 years, enrolled in the study site school, obtained written consent from their parents/guardians, and were willing to participate in a series of measurements. Anemia status was operationally defined as Hb <11.5 g/dL for 10–11 years old and Hb <12.0 g/dL for 12 years old.

Participants with anemia at baseline were included so the study focused on anemia prevention and control. Exclusion criteria included chronic diseases known to affect hemoglobin (Hb)/iron metabolism and incomplete final measurements. The control group received routine school health checks (UKS) services without a structured intervention package from the research team. Education was provided in four sessions with a duration of approximately 30–45 minutes per session, which were held every two weeks during the intervention period. regarding anemia, food sources of iron, vitamin C as an enhancer, and tea/coffee as absorption inhibitors. Food promotion emphasized realistic sources in Palangka Raya such as fish, eggs, liver/chicken, meat, green vegetables, nuts, and combinations with fruit sources of vitamin C; consumption was monitored weekly using monitoring sheets and 24-hour dietary recalls. The iron supplement tablets (TTD) given contain 60 mg of elemental iron and 400 µg of folic acid, with a dose of one tablet once a week for 8 weeks after meals. and monitored by teachers/research team; compliance was calculated from the number of doses taken compared to the 8 scheduled doses, with high compliance $\geq 80\%$. Parents received initial information and periodic reminders/monitoring to support food and iron supplement (TTD) consumption. Hb levels were measured from capillary blood using a calibrated point-of-care device at baseline and week 8 by trained personnel. the measurement is repeated if the results are unreadable or technically questionable.

The main analysis used a comparison of Hb changes between groups (simple difference-in-differences in ΔHb) as well as a comparison of the proportions of anemia status.. Multivariate regression was not used as the primary analysis due to the small sample size, only two clusters, and several potential post-intervention covariates as mediators. The ethics approval number is not available on the source document provided and is not estimated as it is an administrative identifier that must be copied exactly from the original ethics approval letter before publication. This research has obtained ethical approval with number 206/UN24.9/LL/2025.

RESULTS

Univariate Analysis

Table 1. Respondent Characteristics

Variables	Intervention (n=30)	Control (n=30)	Total
Age	11.1 $\pm$ 0.7	11.0 $\pm$ 0.6	11.0 $\pm$ 0.6
Initial Hb (g/dl)	10.7 $\pm$ 0.6	10.8 $\pm$ 0.6	10.8 $\pm$ 0.6
Anemia Knowledge Score	55.9 $\pm$ 9.2	56.3 $\pm$ 8.7	56.1 $\pm$ 8.9
Energy (kcal/day)	1,540 $\pm$ 210	1560 $\pm$ 220	1550 $\pm$ 215
Protein (g/day)	38.6 $\pm$ 8.1	39.2 $\pm$ 7.9	38.9 $\pm$ 8.0
Iron (mg/day)	8.7 $\pm$ 2.0	8.9 $\pm$ 2.1	8.8 $\pm$ 2.0
Vitamin C (mg/day)	210 $\pm$ 55	215 $\pm$ 58	213 $\pm$ 56

Table 1 shows that measured baseline characteristics were relatively similar descriptively between the intervention and control groups. However, the absence of significant differences in individual variables cannot be taken as evidence of homogeneity or equivalence between the two groups. Because

allocation was made at the school level and only two schools were involved, possible differences in school-level characteristics and unmeasured factors must still be considered.

Energy, protein, iron, and vitamin C intakes at baseline showed relatively similar patterns descriptively. Energy units are expressed as kcal/day. Folate was not mentioned in the interpretation because it is not available as a variable in Table 1. Hb was not used as a specific marker of iron deficiency because ferritin and other biomarkers of iron status were not assessed.

Table 2. Changes in Hemoglobin Levels, Knowledge and Nutritional Intake

Variables	Intervention (mean±(SD))	Control (mean±(SD))	<i>p</i> between groups
Final Hb (g/dl)	12.2±0.7	11.4±0.6	< 0.001
Δ Hb	+1.5±0.6	+0.6±0.5	<0.001
Final knowledge score	79.1±7.3	65.0±7.9	<0.001
Δ Knowledge score	+23.2 ± 6.1	+8.7±5.6	<0.001
Energy (kcal)	1,720±190	1,610±210	0.018
Final dietary iron intake (mg/day)	11.6 ± 2.5*	9.6 ± 2.2*	0.004*
Final protein (g)	50.3±7.6	43.1±8.0	<0.001
Final Vitamin C (mg)	285±60	235±57	0.003

Table 2 shows that the increase in Hb in the intervention group was greater than in the control group (Δ Hb +1.5 ± 0.6 vs +0.6 ± 0.5 g/dL; $p < 0.001$). The difference in mean change between groups was 0.9 g/dL with an estimated 95% CI of 0.62–1.18 g/dL.

Knowledge scores increased by 23.2 ± 6.1 points in the intervention group and 8.7 ± 5.6 points in the control group. The +233.2 score in the previous version was corrected to +23.2 because it was consistent with the initial score of 55.9 and the final score of 79.1. Changes in knowledge and consumption patterns were treated as post-intervention outcomes with potential mediators, not baseline confounders.

Bivariate Analysis

Table 3. Anemia Status at Baseline and Post-Intervention According to Study Group

Measurement time	Anemia status	Intervention (n=30), n (%)	Control (n=30), n (%)	Absolute difference (95% CI)	<i>p</i>
Baseline	Anemia	26 (86.7%)	25 (83.3%)	3.4 percentage points	0.718*
Post-intervention	No anemia	23 (76.7%)	13 (43.3%)	33.3 percentage points (95% CI 10.0–56.6)	0.008
	Anemia	7 (23.3%)	17 (56.7%)		

At baseline, anemia was found in 26/30 (86.7%) participants in the intervention group and 25/30 (83.3%) in the control group; the difference in baseline proportions was not significant (Pearson χ^2 , $p = 0.718$; this value is calculated from the table frequencies). Post-intervention, the proportion free of anemia was 76.7% in the intervention group and 43.3% in the control group, with an absolute difference

of 33.3 percentage points (95% CI 10.0–56.6; $p=0.008$). Based on the frequency in the table, the risk ratio (RR) for non-anemic status was 1.77 (95% CI 1.12–2.79), while the crude odds ratio (OR) was 4.30 (95% CI 1.41–13.07).

Table 4. Post-intervention Iron Intake Categories

Fe intake	Intervention (%)	Control (%)	<i>p</i>
Enough	20 (66.7%)	11 (36.7%)	0.020
Not enough	10 (33.3%)	19 (63.3%)	

Table 4 shows that 20/30 (66.7%) intervention participants and 11/30 (36.7%) control participants had dietary iron intake categorized as adequate; Pearson χ^2 $p=0.020$ based on the frequency table. Operationally, the category of adequate iron intake is determined based on the reference iron requirements of women aged 10–12 years and is assessed using a 24-hour dietary recall, without including the contribution of iron supplement tablets (TTD).

Table 5. Compliance with Iron Supplement Tablet (TTD) Consumption and Anemia Status

Compliance with consumption of Iron Supplement Tablets (TTD)	No Anemia (%)	Still Anemic (%)	<i>p</i>
Tall	17 (85.0%)	3 (15.0%)	0.112
Low	3 (50.0%)	3 (50.0%)	

Table 5 presents an exploratory analysis of iron supplementation adherence in 26 participants in the intervention group who received supplementation. Adherence was calculated as the proportion of doses consumed out of eight scheduled weekly doses; high adherence was defined as $\geq 80\%$ and low adherence as $< 80\%$. Twenty participants had high adherence and six participants had low adherence.

In the high adherence group, 17/20 (85.0%) participants were anemia-free and 3/20 (15.0%) were still anemic; in the low adherence group, 3/6 (50.0%) were anemia-free and 3/6 (50.0%) were still anemic. Fisher's exact test yielded $p=0.112$. Because the denominator was only 26 participants, this analysis is exploratory and should not be used to make causal claims.

Table 6. Effect Size of Intervention on Post-Intervention Anemia Status

Effect size	Mark	95% CI	<i>p</i> -value
Proportion of non-anemic – intervention	23/30 (76.7%)	—	—
Proportion of non-anemic – control	13/30 (43.3%)	—	—
Risk Difference (RD)	33.3 percentage points	10.0–56.6	0.008
Risk Ratio (RR)	1.77	1.12–2.79	0.014
Odds Ratio (OR)	4.30	1.41–13.07	0.010

Table 6 shows the effect size of the intervention package on post-intervention anemia status. The proportion of participants achieving non-anemic status was 76.7% in the intervention group and 43.3% in the control group, with an absolute difference of 33.3 percentage points (95% CI 10.0–56.6). The risk ratio of 1.77 (95% CI 1.12–2.79) indicates that the proportion of participants achieving non-anemic

status in the intervention group was approximately 1.77 times that in the control group. The odds ratio of 4.30 (95% CI 1.41–13.07) indicates a higher odds of non-anemic status in the intervention group.

DISCUSSION

Respondent Characteristics and Initial Conditions

The participants' baseline characteristics showed relatively similar conditions in several measured aspects, particularly age, hemoglobin levels, knowledge about anemia, and nutritional intake. These baseline conditions provide a basis for understanding changes that occurred during the intervention. Similarity in individual characteristics cannot be considered as complete equality between the two groups because allocation was based on school. The school environment, implementation of health programs, dietary habits, family socioeconomic conditions, puberty, and menstruation are factors that can influence anemia but were not fully controlled for in this study.^[2,4,6]

The age group of 10–12 is a period of growth with increased nutritional needs. Girls at this age also begin puberty and some begin menstruating, increasing their iron needs. This makes this group vulnerable to anemia when iron requirements are not met with adequate intake. Low levels of knowledge about anemia and suboptimal consumption of iron-rich foods can exacerbate this vulnerability.^[3,5,6]

These findings are in line with Putri et al.^[6] which identified various risk factors for anemia in elementary school children in Temanggung. Wong et al.^[5] also showed that knowledge and practice of nutritional anemia prevention are important aspects in adolescent groups. Bukhari et al.^[2] This study shows that anemia in Indonesia is not solely related to nutritional factors but can also be influenced by non-nutritional factors and disease. These research findings support the view that anemia in school-age girls should be understood as a multifactorial problem, not solely due to low iron intake.

Hemoglobin Changes, Knowledge, and Nutritional Intake

The improved changes in the intervention group suggest that an approach combining nutrition education, improved food consumption, hemoglobin monitoring, and supplementation has the potential to provide benefits on several fronts simultaneously. Hemoglobin improvement has a biological basis through increased iron availability, which is essential for erythropoiesis, while increased knowledge can support participants' ability to choose foods and adopt behaviors that support anemia prevention.^[3,12,14]

These findings align with previous research on the benefits of nutritional interventions and iron supplementation in children and adolescents. Research by Krämer et al.^[11,15] demonstrated the benefits of school-based interventions through iron-fortified foods, while Hameed et al.^[3,11] showed differences in anemia conditions based on the involvement of adolescent girls in iron and folic acid supplementation programs. A systematic review by Ren et al.^[3] also supports the role of nutrition-specific interventions in the prevention and control of nutrition-related anemia in children and adolescents.

Hemoglobin should still be understood as an indicator of anemia, not a specific marker of iron deficiency. The absence of ferritin and other biomarkers of iron status or inflammation means that the

changes found are more accurately interpreted as improvements in hemoglobin concentration and anemia, rather than as direct evidence of improved iron stores.^[2,3]

The results of this study are supported by Rehman et al.^[12], through a systematic review and meta-analysis of iron supplementation in children and adolescents with iron deficiency anemia. Ren et al.^[3] also reported through a systematic review and network meta-analysis that nutrition-specific interventions have a role in preventing and controlling nutrition-related anemia in infants, children, and adolescents. This study's findings are also in line with those of Winichagoon et al.^[16], which showed improvements in hemoglobin status in schoolchildren after being given multimicronutrient-fortified food. The similarity in the direction of these results provides support that iron fulfillment through nutritional interventions can be an effective strategy. An important part in improving anemia conditions in the child and adolescent population.

Changes in Anemia Status

Changes in anemia status indicate that the benefits were not solely related to changes in hemoglobin levels but were also reflected in the increasing number of participants achieving anemic status. These changes may be biologically related to improved iron intake, changes in dietary patterns, increased understanding of anemia, and supplementation among participants who met the criteria.^[3,11,14]

The improvements also seen in the control group suggest the possible contribution of factors outside the intervention package. School health services, dietary changes, health information from other sources, family support, and physiological changes during growth can all influence anemia. Interpretation of results should take these factors into account to ensure that changes in anemia are not entirely attributed to the research intervention.^[2,9,17]

The findings of this study are in line with Hameed et al.^[11], which compared anemia in school-aged girls who did and did not participate in the Weekly Iron and Folic Acid Supplementation (WIFS) program. Marisa et al.^[14] A systematic review of integrated anemia interventions in adolescents also provides the basis for suggesting that anemia control may involve a combination of strategies. These results support this research approach, which positions supplementation as one component of an intervention, not the sole anemia control measure.^[3,11,14]

Adequate Iron Intake

Improved iron intake supports the importance of a food-based approach to anemia prevention and control. Education on iron-rich foods, coupled with consumption monitoring, can help participants apply this knowledge to their daily food choices. Utilizing fish, eggs, liver or chicken, meat, green leafy vegetables, and nuts can be food choices tailored to local availability.^[9,10,13]

This finding is in line with research by Suciyantri et al.^[13] which shows that food-based recommendations can support improvements in nutrient intake and hemoglobin in adolescent girls in Indonesia. Dietary quality still needs to consider iron sources, consumption of foods that support iron absorption, and habits that can inhibit iron absorption. Post-intervention iron intake in this study was

one outcome of the intervention and therefore cannot be considered an independent cause of hemoglobin changes.^[18–20]

This finding is in line with Suciyanti et al.^[13], which evaluated food-based recommendations in adolescent girls in East Java and reported their impact on nutrient intake and hemoglobin levels. Jamaluddine et al.^[9] also showed that school-based nutrition interventions can improve dietary diversity among schoolchildren. These results support the use of the school environment as a vehicle for shaping better consumption behaviors and strengthening food-based approaches as part of anemia prevention programs.

Compliance with Consumption of Iron Supplement Tablets

Compliance with iron supplementation showed a trend toward better anemia outcomes in participants who took the supplements more regularly. This pattern has a biological basis, as regular consumption can help provide the iron necessary for hemoglobin formation.^[3,11,12]

The evidence obtained is insufficient to conclude that iron tablet adherence independently determines anemia status. The number of participants in the adherence analysis was relatively limited, so the patterns found are best viewed as exploratory findings. Monitoring consumption remains of practical value, as the success of a supplementation program is determined not only by tablet availability but also by participants' regularity in taking them. Support from schools, families, and healthcare professionals is needed to help overcome barriers to adherence.^[21–23]

These results can be compared with Hameed et al.^[11], which showed a difference in anemia conditions between adolescent girls involved in the WIFS program and the group that did not participate in the program. Rehman et al.^[12] also showed that the dose and duration of supplementation are important aspects in the response to iron administration in children and adolescents with iron deficiency anemia. Previous research supports the importance of regular supplementation implementation, but the results of this study are not sufficient to conclude that iron supplement compliance is an independent factor determining anemia improvement because the compliance analysis only involved a portion of the participants.^[21]

Effect Size of Intervention on Anemia Status

The effect size reinforces the substantive significance of the overall findings by showing that participants who received the intervention package were more likely to achieve anemia-free status than those who received routine school health services. This finding supports the use of an approach that focuses not only on supplementation but also integrates health education, utilization of iron-rich foods, monitoring for anemia, and administering iron supplements as needed.^[3,13,14]

An integrated approach is relevant given the multifactorial nature of anemia. Education can improve understanding, food interventions support changes in consumption behavior, hemoglobin testing aids identification and follow-up, and supplementation supports iron intake for participants in need. All components are provided as a package, so the contribution of each component cannot be

determined separately, and any effects found should be interpreted as a function of the overall intervention package.^[24,25]

This interpretation is supported by Marisa et al.^[14], which specifically reviews integrated intervention approaches in anemia management in adolescents. Ren et al.^[3] also showed that various nutrition-specific interventions can provide benefits against anemia in child and adolescent populations, while de Hoop et al.^[8] demonstrated through a systematic review and meta-analysis that nutrition-sensitive interventions can contribute to improved nutritional outcomes. The findings of this study expand this context by applying several intervention functions in the school setting: education, food approaches, hemoglobin monitoring, and supplementation. The available evidence still does not allow for the conclusion that these combinations produce synergistic effects or the determination of which components make the greatest contribution.

CONCLUSIONS AND RECOMMENDATIONS

The implementation of a school-based integrated intervention model combining health and nutrition education, promotion and monitoring of local iron-rich food consumption, hemoglobin testing and follow-up, and the provision of iron-fortified tablets was associated with improvements in anemia in girls aged 10–12 years. This improvement was reflected in increased hemoglobin levels and the increase in participants achieving anemic status, accompanied by increased knowledge about anemia and adequate iron-rich food consumption. Compliance with iron-fortified tablet consumption showed a trend toward improved anemia, but these findings should be interpreted with caution. Overall, an approach that integrates education, improved consumption patterns, anemia monitoring, and supplementation may be relevant to support anemia prevention and control efforts in school-age girls.

This integrated intervention model can be considered for development in school health activities by involving schools, families, health workers, and nutrition program managers, especially through strengthening anemia education, utilizing local food sources of iron, monitoring hemoglobin, and increasing the regularity of iron supplement tablet consumption according to applicable indications and guidelines.^[26] Future research should involve more schools and participants, longer intervention and follow-up periods, assessment of pubertal and menstrual status, and more specific biomarkers for assessing iron status, so that the sustainability of the intervention's benefits and the contribution of each component can be better understood.

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