

Iron Supplement Adherence, Dietary Intake, and Anemia Risk among Adolescent Girls in Madiun Regency, Indonesia

Taufiqurrahman^{1*}, Fahmi Hafid¹, Mujayanto¹, Atika Nuswantari¹, Ratno², Rina Rahayuningtyas³, A.E. Prasetyawan³, Yayuk Sri Rahayu⁴

¹ Department of Nutrition, Poltekkes Kemenkes Surabaya, Indonesia

² Laboratory Department, Poltekkes Kemenkes Surabaya, Indonesia

³ Puskesmas Simo, Dinas Kesehatan Madiun, Indonesia

⁴ Dinas Kesehatan Kabupaten Madiun, Indonesia

Corresponding Author Email: taufiq@poltekkes-surabaya.ac.id

Copyright: ©2025 The author(s). This article is published by Media Publikasi Cendekia Indonesia.

ORIGINAL ARTICLES

Submitted: 18 August 2025

Accepted: 1 October 2025

Keywords:

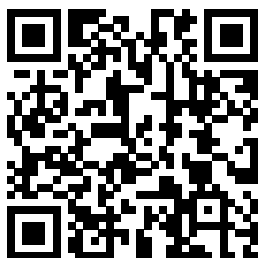
Adolescent Girls, Anemia, Iron Supplements, Nutritional Intake, Nutritional Status

OPEN  ACCESS



This work is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International License

Access this article online



Quick Response Code

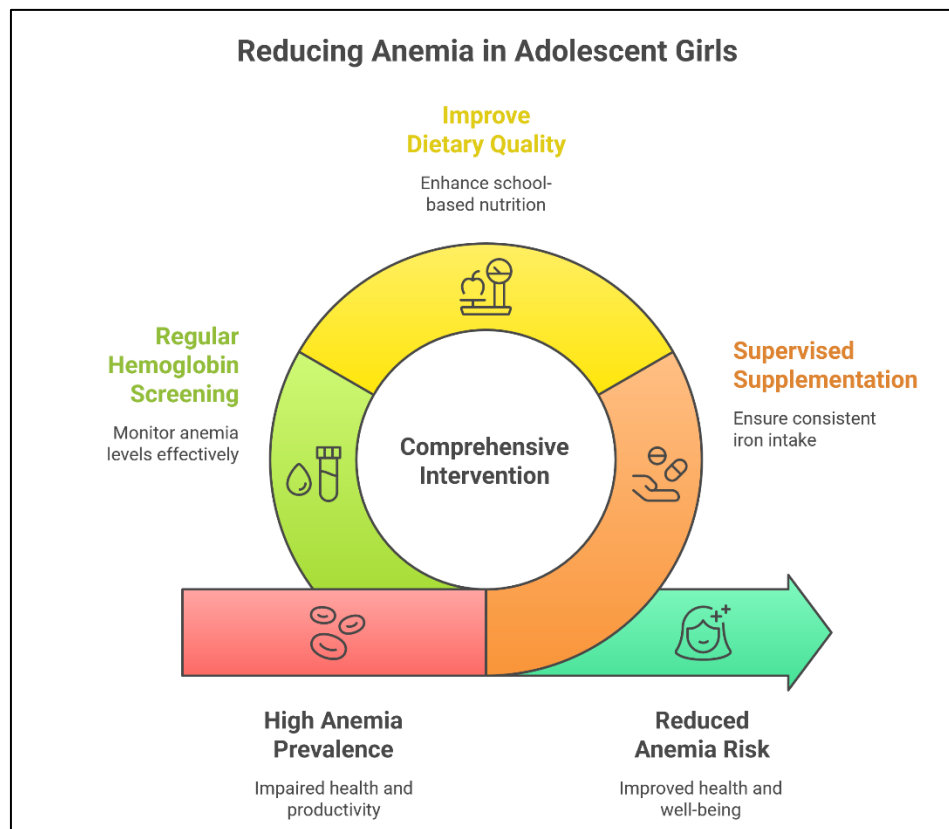
ABSTRACT

Anemia among adolescent girls remains a significant public health concern, impairing growth, learning, productivity, and reproductive health. This cross-sectional study examined the relationship between iron supplement adherence, dietary intake, nutritional status, and anemia among 105 female students aged 12–15 years in Madiun Regency, Indonesia, using a total sampling approach. Data collection included anthropometric measurements, dietary intake assessed with a semi-quantitative food frequency questionnaire (SQ-FFQ), hemoglobin levels measured by point-of-care testing, and iron supplement adherence, with anemia defined as hemoglobin <12 g/dL. The prevalence of anemia was 14.3%. While 88.6% of respondents adhered to iron supplements, non-adherence was associated with a 24.5-fold higher risk of anemia ($p < 0.001$). Most participants reported inadequate dietary intake, specifically in terms of energy (79.0%), protein (76.2%), zinc (62.9%), and iron (93.3%). Nutritional intake and BMI-based nutritional status showed no significant association with anemia, although non-chronic energy deficiency (non-KEK) was linked to a higher prevalence ($p = 0.030$). In conclusion, adherence to iron supplementation strongly protects against anemia; however, poor dietary quality remains a challenge. Therefore, strengthening supervised supplementation programs, improving school-based dietary quality, and implementing regular hemoglobin screening are recommended to reduce the risk of anemia among adolescent girls.

Key Messages:

- Adherence to iron supplementation is the primary determinant of anemia prevention among adolescent girls, with non-adherence presenting a statistically significant 24.5-fold increase in anemia risk.

GRAPHICAL ABSTRACT



INTRODUCTION

The quality of research that continues to improve and the birth of various new innovations in the field of adolescent health are very important concerns, especially related to nutritional aspects in adolescent girls who are prone to anemia (1). Anemia in adolescent girls remains a priority issue for public health (2–4) because it has a direct impact on physical development (5,6), learning capacity (7–9), productivity (10–12), to reproductive health readiness (13–15) in the future. Adolescence is characterized by accelerated growth, biological maturation, and lifestyle changes that increase the body's need for essential nutrients, particularly iron, protein, and zinc. When these needs are not met or disturbed by eating habits, morbidity, or menstrual patterns, iron reserves are depleted and hemoglobin levels decrease, leading to anemia. In the context of school, the consequences of anemia can be seen in decreased study concentration, fatigue, absenteeism, and suboptimal academic performance, making it a health problem as well as an educational (16–20).

Various studies show that the prevalence of anemia in adolescent girls is still relatively high and varies between regions and countries. The findings of Ashraf et al. (2024) show that anemia in the age group of 14–18 years is 80.7% (21) and it turns out that the prevalence of anemia in women is higher than in men, 18.0% vs 14.4% (22). The findings reveal variation in the prevalence of anemia across regions, groups, and sexes.

Various strategies have been implemented, including the supplementation of blood supplement tablets (TTD) in adolescent girls (18, 23, 24), nutrition education (25–28), and promoting healthy behaviors in schools. However, the effectiveness of these efforts is greatly influenced by adherence to TTD consumption and the quality of daily food intake. In addition, nutritional status, which reflects a balance between intake and needs, is also often assumed to be related to the risk of anemia, although this relationship is not always linear. In addition to adherence to supplementation, nutritional status measured through Body Mass Index (BMI) or mid-upper arm circumference (MUAC) is also believed to be associated

with the incidence of anemia, although studies show mixed results. Some studies found a significant association between nutritional status and anemia, while others found no direct link. This suggests that the causative factors of anemia are multifactorial and require examination in a more specific context.

Therefore, mapping anaemia determinants that considers TTD adherence, nutritional intake, and nutritional status at the local level is important for designing more targeted interventions. This study aims to identify the relationship between adherence to blood supplement tablet consumption, adequacy of nutritional intake, nutritional status, and the incidence of anemia in adolescent girls at SMP Negeri 2 Balerejo, Madiun Regency.

METHODS

This study uses an analytical observational design with a cross-sectional approach. The research activity took place from May 28, 2025 to August 08, 2025 at SMP Negeri 2 Balerejo, Madiun Regency. The school has 20 teachers, with a total of 90 males and 105 females spread across 6 classes. The learning process is carried out in the morning for six days a week. The school environment has an area of about 18,900 m², equipped with 13 classrooms, three laboratories, one library, and two special student sanitation units. In terms of institutional quality, this school has obtained accreditation. The Population and Sample in the study are all students of SMP Negeri 2 Balerejo, totaling 105 people, and all of them are made respondents. Thus, the total sample is the same as the population, namely 105 female students.

The sampling method is carried out through a total sampling approach. The inclusion criteria set include active female students in grades VII to IX with an age range of 12–15 years, willing to participate in research, and have no history of chronic diseases or special conditions such as hemoglobinopathy, worm infections, malaria, tuberculosis, cancer, and HIV. Meanwhile, the exclusion criteria include students who are menstruating, sick, or absent during data collection.

The study variables included respondent characteristics, nutrient intake, nutritional status, and hemoglobin levels. Nutrient intake was measured using the Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ) method(29), which assessed the consumption of 40 types of food in the last three months. Nutritional status was obtained through anthropometric measurements using digital scales. Hemoglobin levels are determined by the Point of Care Testing method (30–32). Anemia is defined based on Hb levels, with a limit of <12 g/dL categorized as anemia, while ≥ 12 g/dL is categorized as non-anemia.

Compliance in taking blood supplement tablets was assessed using a questionnaire with three question items that included frequency of consumption, consistency with the recommended dose, and regularity according to the advice of health workers. Each question item is scored on a scale of 0–2 (0 = never, 1 = sometimes, 2 = always), and a total score (0–6) is used to classify respondents as compliant (≥ 4) or non-compliant (<4). The risk of CED is determined by measuring the mid-upper arm circumference (MUAC). Respondents with a MUAC of <23.5 cm were categorized as at risk of CED, while those with a MUAC ≥ 23.5 cm were categorized as non-CED.

The operational definition of nutritional adequacy in this study refers to the 2019 Indonesian Nutrition Adequacy Rate (AKG) standard set by the Ministry of Health of the Republic of Indonesia. This is relevant because adolescent girls aged 13–18 years are in a phase of rapid growth that demands the availability of adequate amounts of energy, macronutrients, and micronutrients. Optimal nutritional adequacy in this phase is crucial to support physical development, reproductive health, and cognitive function.

Energy adequacy is set at 2,050 kcal per day as the average daily requirement for moderate physical activity. The adequacy of protein is set at 65 grams per day, which plays an important role in the formation of body tissues, hormones, and supports growth. In addition, the need for micronutrients is also defined operationally, especially minerals related to the growth and reproductive health of adolescent girls. For zinc, the requirement at the age of 13–15 years is set at 8 mg per day, while the requirement for iron (Fe) in the same age group is 15 mg per day.

Nutritional needs are considered to be met if an individual's daily intake meets at least 100% of the 2019 Nutritional Adequacy Rate (AKG). On the other hand, if the intake is below this threshold, it is categorized as inadequate. This definition is used to assess the level of nutritional adequacy in the

adolescent girls who are the subject of the study. Nutritional status based on Body Mass Index (BMI) or BMI by age (BMI/U) in the categories of normal, overweight, and obesity. The data collection procedure was carried out through interviews using the Semi Quantitative Food Frequency Questionnaire (SQ-FFQ), anthropometric measurements, and examination of hemoglobin levels from respondents' blood samples. Data analysis uses SPSS Statistics 25.0 software, with a univariate and bivariate approach for all research variables. Classification and assessment of anemia status is carried out based on hemoglobin levels. Respondents' compliance in consuming blood supplement tablets was assessed by summing the scores of three questions.

CODE OF HEALTH ETHICS

All stages of this research are carried out in accordance with applicable health ethical principles. The research has obtained ethical approval from the Health Research Ethics Committee, Faculty of Medicine, Sebelas Maret University, Surakarta, Indonesia, as stated in the approval letter No. 90/UN27.06.11/KEP/EC/2025 dated June 18, 2025. This approval ensures that research is carried out in accordance with applicable ethical standards. In addition, the research also received an official recommendation from the National Unity and Political Agency of Madiun Regency with letter number 000.9.2/220/402.301/2025, as a form of legality in the implementation of research activities.

RESULTS

Based on the characteristics of respondents in the study "Compliance with Blood Supplement Tablet Consumption, Nutritional Intake and Nutritional Status with the Incidence of Anemia in Adolescent Girls at SMP Negeri 2 Balerejo, Madiun Regency" involving 105 adolescent girls, an overview of the nutritional status and nutritional intake of the respondents was obtained. The average age of respondents was 13.48 ± 0.95 years, with an age range between 12 to 15 years that reflected the early adolescent group. The respondents' weight varied between 22.4–85.0 kg with an average of 45.04 ± 10.67 kg, while the height ranged from 118.5–165.0 cm with an average of 150.15 ± 6.19 cm. The body mass index (BMI) value showed an average of 19.9 ± 4.05 with a range of 12.4–34.1, which indicates a variation in nutritional status ranging from thin to obese. The respondents' average mid-upper arm circumference (MUAC) was 23.2 ± 2.29 cm, within the range of 17.8–27.9 cm, with some values still below the risk threshold for chronic energy deficiency. The average hemoglobin level of the respondents was 13.3 ± 1.50 g/dl with a range of 7.4–15.6 g/dl, indicating that some adolescents experienced anemia. In terms of nutritional intake, the average energy consumed by respondents was $1,519.8 \pm 532.14$ kcal with a range of 635.9–2500 kcal, still lower than the Nutritional Adequacy Rate (AKG). The average protein intake was 52.2 ± 18.3 grams per day, zinc 7.9 ± 3.37 mg, and iron 7.9 ± 4.32 mg per day. These results show that respondents' nutritional intake, especially in terms of energy, zinc, and iron, still does not meet the standard of nutritional adequacy for adolescent girls, which may contribute to the risk of anemia.

Table 1. Characteristics of the research respondents

Characteristics	n =105			
	Min	Max	Mean	SD
Age (years)	12	15	13,48	0,95
Weight (kg)	22,4	85,0	45,04	10,67
Height (cm)	118,5	165,0	150,15	6,19
IMT	12,4	34,1	19,9	4,05
Upper arm circumference (cm)	17,8	27,90	23,2	2,29
Hemoglobin	7,4	15,6	13,3	1,50
Energy (kcal)	635,9	2500	1519,8	532,14
Protein (gr)	15,2	85,1	52,2	18,3
Zink (mg)	5,1	16,5	7,9	3,37
Fe (mg)	4,1	25,1	7,9	4,32

Based on the frequency distribution of respondents, the adherence to the consumption of blood supplement tablets (TTD) in adolescent girls at SMP Negeri 2 Balerejo showed quite high results. As many as 88.6% of respondents were recorded to be compliant in consuming TTD, while only 11.4% were non-compliant. However, there are still 14.3% of respondents who experience anemia even though the majority (85.7%) are in a non-anemia condition. This indicates that compliance with TTD does not fully guarantee freedom from anemia, as other factors such as nutritional intake and nutritional status also play an important role. In terms of nutritional status, most of the respondents were in the normal category (56.2%), but there were 19.0% who were underweight and 24.8% who were overweight. These findings show that there are multiple nutritional problems in the adolescent group. Analysis of nutritional intake showed that most of the respondents had not reached the level of adequacy. As many as 62.9% had inadequate zinc intake, 93.3% lacked iron, 76.2% did not meet the adequacy of protein, and 79.0% did not meet energy needs. This condition shows that the quality of the respondents' nutritional intake is still far from optimal, especially in the fulfillment of essential micronutrients such as iron and zinc which are closely related to the incidence of anemia. In addition, the risk of chronic energy shortage (CED) is also quite high, with 64.8% of respondents identified as experiencing SEZs. Overall, although TTD consumption adherence is quite good, macro and micronutrient intake deficiencies and unbalanced nutritional status are important determinants that can explain the high prevalence of anemia and nutritional risk in adolescent girls.

Table 2. Distribution of Respondent Frequency Based on Variables

Variables		n =105	%
Consumption of Iron Supplements	Non-compliant	12	11.4
	Compliant	93	88.6
Anemia Status	Anemia	15	14.3
	Non-Anemia	90	85.7
Nutritional Status	Underweight	20	19.0
	Normal	59	56.2
	Overweight	26	24.8
Intake of Zinc	Not Adequate	66	62.9
	Adequate	39	37.1
Intake of Fe	Not Adequate	98	93.3
	Adequacy	7	6.7
Intake of Protein	Not Adequate	80	76.2
	Adequacy	25	23.8
Intake of Energy	Not Adequate	83	79.0
	Adequate	22	21.0
Risk of CED	CED	68	64.8
	Non CED	37	35.2

The results of cross-tabulation analysis showed that adherence to the consumption of blood-boosting tablets (TTD) had a very significant relationship with the incidence of anemia ($p < 0.001$). Adolescent girls who did not obedient and took TTD had a 24.5-fold higher risk of anemia than those who did (95% CI: 5.9–102.2). Of the total non-compliant respondents, as many as 66.7% experienced anemia, while in the compliant group, only 7.5% experienced anemia. Meanwhile, nutritional status based on BMI/U did not show a meaningful association with anemia ($p = 0.670$), because the distribution of anemia was relatively similar between underweight, normal, and overweight groups. Nutrient intake variables (energy, protein, zinc, and iron) were also not significantly associated with the incidence of anemia ($p > 0.05$). Although the prevalence of anemia tended to be higher in the zinc sufficiency (20.5%) and iron sufficiency (28.6%) groups, the results did not reach statistical significance. In contrast, there was a significant association between the risk of KEK and anemia ($p = 0.030$), although the direction of association was not as expected. The prevalence of anemia was actually higher in the non-CED group (24.3%) than in the group at risk of CED (8.8%). Overall, these results confirm that TTD consumption adherence is the strongest protective factor against anemia, while nutritional status and adequacy of nutrient intake require further study.

Table 3. Cross-tabulation of research variables

Variables		N =105				n	p-value
		Anemia		Non-Anemia,			
		n	%	n	%		
Consumption of Iron supplements	Non-compliant	8	66,7	4	33,3	12	0.000*
	Compliant	7	7,5	86	92,5	93	
Nutritional Status	Underweight	2	10,0	18	90,0	20	0.670
	Normal	10	16,9	49	83,1	59	
	Overweight	3	11,5	23	88,5	26	
Intake of Zinc	Not Adequate	7	10,6	59	89,4	66	0,161
	Adequacy	8	20,5	31	79,5	39	
Intake of Fe	Not Adequate	13	13,3	85	86,7	98	0,264
	Adequacy	2	28,6	5	71,4	7	
Intake of Protein	Not Adequate	11	13,8	69	86,3	80	0,779
	Adequacy	4	16,0	21	84,0	25	
Intake of Energy	Not Adequate	13	15,7	70	84,3	83	0,434
	Adequate	2	9,1	20	90,9	22	
Risks of CED	CED	6	8,8	62	91,2	68	0,030*
	Non CED	9	24,3	28	75,7	37	

DISCUSSION

This study confirms the importance of TTD adherence as a key determinant of anemia prevention. Statistically, non-adherence to taking TTD was strongly associated with the incidence of anemia ($p=0.000$), with an estimated risk of anemia 24.5 times higher in the non-adherent group than in the adherent group (95%CI 5.9–102.2). In relatively homogeneous school populations, the strength of this association confirms that the regularity of TTD consumption is not just a programmatic component, but a real protective factor at the individual level. With a compliance rate of 88.6% and an anemia prevalence of 14.3%, which is lower than the national prevalence of female anemia according to the 2023 SKI of 18%, tightening behavioral interventions to maintain and strengthen compliance has the potential to have a significant epidemiological impact.

However, the presence of 14.3% anemia amid high TTD adherence reminds us that supplementation is not a "silver bullet". Among the factors that may play a role are variations in iron bioavailability from daily food, consumption habits of inhibitors (e.g. tannins in tea/coffee) or low consumption of enhancers (e.g. vitamin C), to variations in iron loss through menstruation. Although some of the disruptive factors have been minimized through exclusion criteria (e.g., certain chronic diseases), the biological characteristics and daily behavior of adolescents can still significantly affect hemoglobin status. Therefore, intervention packages need to combine regular supplementation, contextual nutrition education, and school environment modifications that facilitate healthy eating practices.

The finding that adherence to blood-boosting tablets had a greater effect than variations in daily iron intake was consistent with the results of Silitonga (2023), who reported that supervised intervention studies showed adherence >80% and a significant impact on reducing anemia compared to the unsupervised group (33). As well as a study by Madanijah et al. (2020) in Indonesia which found that schools that organized joint supplementation and teacher education had higher adherence and a marked decrease in anemia (34). A study in Ethiopia by Yewodias et al. (2025) also showed that the prevalence of anemia was significantly lower in schools that implemented the Weekly Iron Folic Acid Supplementation (WIFAS) program than in non-Weekly Folic Acid Supplementation (WIFAS) programs (34).

The respondents' intake profile showed a serious challenge: an average energy of 1,520 kcal/day, protein 52.2 g, zinc 7.9 mg, and iron 7.9 mg. Furthermore, 79.0% did not achieve energy sufficiency, 76.2% did not have enough protein, 62.9% did not have enough zinc, and 93.3% did not have enough iron. These figures illustrate a wide deficit, especially in micronutrients that play a direct role in erythropoiesis. Theoretically, the condition should increase the risk of anemia. However, in bivariate analysis, the intake adequacy variables (energy, protein, iron, zinc) did not show a significant association with anemia ($p>0.05$). There are at least three possible methodological and biological explanations: (1) the "ceiling/floor" effect,

because the majority of respondents are in the inadequate category—variation between groups becomes narrow and the strength of the test decreases; (2) the possibility of under-reporting in SQ-FFQ, common in adolescents; (3) the threshold of " $\geq 100\%$ AKG" may be too strict to differentiate the risk in this population so that it loses sensitivity to intake gradations below 100%.

This study did not find a significant relationship between energy, protein, zinc, or iron intake and the incidence of anemia. Daily diet type' is not always significant after controlling for other variables in the model ($p > 0.05$) (34). Likewise, the study of Yilma, et. al. (2021) showed a high prevalence of inadequate iron intake and micronutrients, although the correlation with anemia was not always strong or statistically significant (35). One of the reasons is methods such as FFQ or nutritional recall that are prone to bias, as well as evenly distributed low-intake populations that make variation between individuals too small to show a significant effect.

The finding that nutritional status (underweight, normal, overweight) was not associated with anemia ($p = 0.670$) is in line with the literature, which states that the relationship between BMI and anemia is not always direct. BMI is an indicator of medium-long term energy balance, while anemia in adolescents is strongly influenced by the daily dynamics of iron intake/bioavailability and iron loss. This means that adolescents with normal/higher BMI are not automatically protected from anemia if the quality of the diet is poor in iron and absorption-inhibiting factors are dominant. On the other hand, underweight adolescents are not always anemic when exposure to inhibitors is low and their diets are sufficiently rich in bioavailable iron. This is where the relevance of a more specific approach to diet quality and daily consumption behavior, rather than focusing solely on body mass index, is relevant.

A finding that seems paradoxical is the relationship between CED risk and anemia: the non-CED group actually has a higher proportion of anemia (24.3% vs 8.8%; $p=0.030$). Several hypotheses can be considered. First, the definition of CED in adolescents and how it is measured (e.g., using MUAC/risk CED) may be less sensitive to capturing specific micronutrient deficiencies such as iron. In other words, the "adequacy" of energy/protein to prevent CED is not necessarily equivalent to adequate iron adequacy. Second, there can be misclassification or differences in physical activity that affect hemodilution/momentary hemoconcentration. Third, the non-CED group may have a high-energy but low-quality diet (energy-dense, nutrient-poor) that does not support iron status. Fourth, variations in menstrual phases when Hb is measured can play a role. These findings require further studies with more specific markers of iron status (e.g. ferritin, sTfR, CRP to assess inflammation) and more detailed dietary measurements related to absorption enhancers/inhibitors.

A recent review of fast food consumption and anemia confirms that foods high in energy but low nutritional quality can mask micronutrient deficiencies (36). The same thing is also shown by research by Suciyantri et al. (2025) in East Java, that increased energy intake is not always directly proportional to an increase in hemoglobin status. Thus, a nutritional status that appears normal does not always reflect the adequacy of micronutrients, so the quality of the diet should be a concern in the prevention of anemia (37).

In terms of strength, this study encompasses the entire student population of the target school (total sample of 105 individuals), utilizes practical POCT-based Hb measurement tools, and adheres to adequate ethical and licensing procedures. The school setting provides high practical value because the findings can be directly translated into the UKS program and TTD's routine activities. However, limitations are also worth noting: the cross-section design limits causal inference; SQ-FFQ 3 months prone to memory bias; The adequacy threshold of " $\geq 100\%$ AKG" may be too absolute for association analysis; detailed information on menstrual patterns, tea/coffee consumption, vitamin C, and subclinical infections is not comprehensively collected; and TTD adherence measures based on a three-question score may not capture the dimensions of duration, weekly consistency, and consumption patterns (e.g., with certain foods/beverages). Generalizations are also limited to one school with specific environmental characteristics.

The policy and program implications of these findings are quite clear. First, strengthening TTD compliance is a priority, which involves implementing supervised weekly dosing in schools, providing counseling to manage side effects, issuing class-based reminders, and involving guardians/UKS teachers, and student cadres. Second, the quality of the diet needs to be improved through local menu-based

education—encouraging sources of heme iron (when available), sources of non-heme iron combined with vitamin-rich fruits/vegetables, while reducing the consumption of inhibitors of absorption around the time of TTD drinking. Third, the integration of periodic Hb screening in schools can facilitate early detection and prompt referral. Fourth, school nutrition interventions (such as nutritious snacks and healthy canteens) that focus on iron and protein content can provide a more consistent daily supply. Fifth, monitoring and evaluation should add indicators of consumption quality (enhancers/inhibitors), specific iron status, and objective compliance measures. Integrated efforts like this have the potential to reduce the prevalence of anemia in a sustainable manner.

As a next research direction, longitudinal studies or school-based controlled trials can test a combination of interventions (supervised TTD, nutrition education, and healthy canteen strengthening) against changes in ferritin, sTfR, and Hb. Intake measurements can be reinforced with repeated multiple-pass 24-hour recall or short food records to validate SQ-FFQ, as well as specific assessments of tea/coffee consumption and vitamin C-rich fruits around the time of TTD consumption. Thus, the evidence produced will be stronger to develop operational guidelines that are applicable to schools and regional health centers.

CONCLUSION

This study shows that adherence to the consumption of blood-boosting tablets (TTD) is the most influential factor in the incidence of anemia in adolescent girls, much stronger than the variation in daily nutrient intake. The prevalence of anemia at 14.3% is still a public health problem that needs serious attention, although it is lower than the national figure. These findings underscore the importance of strengthening TTD supplementation programs with supervision in schools, as well as integrating nutrition education and a healthy food environment as part of school health programs. The integrated intervention is expected to be able to increase adolescent girls' adherence to consuming TTD and significantly reduce the prevalence of anemia.

FUNDING

This research was funded by Poltekkes Kemenkes Surabaya, and the APC was funded by Poltekkes Kemenkes Surabaya.

ACKNOWLEDGMENTS

The authors would like to express sincere gratitude to the Director of Poltekkes Kemenkes Surabaya, the Heads of Health Offices of Madiun Regency, the Heads of Education Offices of Madiun Regency, Simo Public Health Center, and all student respondents for their valuable support, coordination, and participation in the successful implementation of this research. We also extend our heartfelt thanks to the Dean of the Life and Science Faculty, Management and Science University, Malaysia, for the academic guidance and institutional support provided throughout the study.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Direktorat Jenderal Tenaga Kesehatan Direktorat Penyediaan Tenaga Kesehatan K. Pedoman Penelitian Poltekkes Kemenkes. I. Jakarta: Kemenkes RI; 2023. 142 p.
2. Chakravarty M, Venugopal R, Chakraborty A, Kumar Mehta S, Varoda A. A Study of Nutritional Status and Prevalence of Anaemia among the Adolescent girls and Women of Reproductive age of Baigatribe accessing Antenatal Clinic in Public Health Sector in Chhattisgarh, India. *Res J Pharm Technol.* 2022 Feb;15(2):598–604.
3. Kedir S, Hassen Abate K, Mohammed B, Lemnuro K, Kemal A, Khelil Geda S, et al. Animal source food consumption and anaemia among school adolescent girls in Silti District, Central Ethiopia: a public health perspective. *J Nutr Sci.* 2024 Dec;13:e89.

4. Anbesu E, Mulaw G, Mare K, Kahssay M. Anemia, a moderate public health problem among adolescent school girls in Aysaita district, the pastoral community of the Afar region, Ethiopia. *Nutr Food Sci.* 2022 Nov;52(8):1289–301.
5. Cheng BL. Effect of anemia and small red blood cells on the physical and neuropsychological development of infants. *Zhongguo Ertong Baojian Zazhi.* 2022;30(5):495–9.
6. Suryana, Madanijah S, Sukandar D, Fitri Y, Ahmad A. Assessment of Anemia Status on Physical Development Skills of Children Under Two Years Old in Aceh, Indonesia. *J Nutr Sci Vitaminol (Tokyo).* 2020;66(Supplement):S463–7.
7. Chemhaka G, Mbunge E, Dzinamarira T, Musuka G, Batani J, Muchemwa B, et al. Socioeconomic and demographic factors associated with anaemia among women of reproductive age in Zimbabwe: a supervised machine learning approach. *Discov Public Heal.* 2025 Apr;22(1):142.
8. Taqwin T, Purwita sari E, Asrawati A, Hadriani H, Imelda Tondong H, Batjo SH, et al. Anemia Associated with Student Learning Achievement: Cross-Sectional Study. *J Public Heal Pharm.* 2025 Feb;5(1):22–8.
9. Mariyani, Patriani H, Novitawati E, Lestari IM, Mistaria. The Impact of Anaemia Prevention Apps on Sleep Quality and Learning Concentration Among Female Junior High School Students. *Malaysian J Nurs.* 2025;16(02):118–25.
10. Ito K, Mitobe Y, Inoue R, Momoeda M. The quality of life and work productivity are affected by the presence of nausea/vomiting in patients taking iron preparations for heavy menstrual bleeding or anemia: a population-based cross-sectional survey in Japan. *BMC Womens Health.* 2024 May;24(1):303.
11. Takeshima T, Yamamoto Y, Iwasaki K, Ha C, Oishi M, Sato A, et al. Prevalence, treatment status, medical costs, quality of life, and productivity loss in Japanese adult patients with anemia: a real-world database study. *J Med Econ.* 2023 Dec;26(1):1386–97.
12. Bulduk T. Aplastic anemia from past to the present: A bibliometric analysis with research trends and global productivity during 1980 to 2022. *Medicine (Baltimore).* 2023 Sep;102(36):e34862.
13. Ibrahim AAA, El-Farargy SH, Shaheen RS, Shaaban Abdelgalil M. Prevalence and sociodemographic determinants of anemia among ever-married women of reproductive age in Jordan: insights from the 2023 Jordan population and family health survey. *BMC Public Health.* 2025 Apr;25(1):1537.
14. Armah-Ansah EK, Budu E, Oga-Omenka C, Kolosnitsyna M. Trends and factors associated with anemia among women of reproductive age in Mali: analysis of data from 2001 to 2018 Mali demographic and health surveys. *Arch Public Heal.* 2025 Jul;83(1):201.
15. Acharya SR, Timilsina D, Pahari S, Acharya S, Ray N. The relationship between hypertension, anemia, and BMI in women of reproductive age: evidence from a nationwide health study. *BMC Cardiovasc Disord.* 2025 Jul;25(1):553.
16. Partap U, Tadesse AW, Shinde S, Sherfi H, Mank I, Mwanyika-Sando M, et al. Burden and determinants of anaemia among in-school young adolescents in Ethiopia, Sudan and Tanzania. *Matern Child Nutr.* 2025 Jul;21(S1).
17. Hu Y, Mao Y, Wang W. Relationship between Anemia and Academic Performance in Chinese Primary School Students: Evidence from a Large National Survey. Greco G, editor. *Health Soc Care Community.* 2024 Jan;2024(1).
18. Asriyanti R, Azrimaidaliza A, Elda F, Dwinatrana K. Program for Providing Iron Tablets in Schools and Reducing the Incidence of Anemia among Adolescent Girls in Padang City. *Amerta Nutr.* 2024 Dec;8(3SP):162–9.
19. Gena A, Asnake S, Menjetta T. Prevalence of malaria, anemia and associated factors among school children in Hawassa city, Sidama, Ethiopia. Badeso MH, editor. *PLoS One.* 2025 Jul;20(7):e0327378.
20. Mbou ASM, Djoko GRP, Ketchaji A, Dama SA, Irita F, Ngodem VCK, et al. Determinants of anemia in school-going adolescents: a case study in Douala, Cameroon. *BMC Public Health.* 2025 Jan;25(1):32.
21. Ashraf F, Nafees Uddin MM, Mustafa MS, Mughal ZUN, Atif Aleem S. Prevalence and factors influencing anemia in women of reproductive age visiting a tertiary care hospital (Jinnah Postgraduate Medical Center) in Karachi: A cross-sectional study. *Women's Heal.* 2024 Jan;20.

22. Munira S, Puspasari D, Trihono, Thaha R, Musadad A, Junadi P, et al. Survei Kesehatan Indonesia (SKI). Kementerian Kesehat RI. 2023;1–964.
23. Salim L, Silitonga H, Nurmala I, Muthmainnah M, Devi Y, Salsabila A, et al. The Effect of Self Identity on Increasing Iron Tablet Adherence Among High School Adolescent Girls Through Health Belief Model as Mediator Variables. *J Multidiscip Healthc*. 2025 Jul;Volume 18:4173–83.
24. Meilani N, Setiyawati N. Directly Observed Treatment for Iron Tablet Supplements Consumption Among Female Senior High School Students. *J Kesehat Masy*. 2023 Jan;18(3):375–82.
25. Wiafe MA, Apprey C, Annan RA. Impact of nutrition education and counselling on nutritional status and anaemia among early adolescents: A randomized controlled trial. *Hum Nutr Metab*. 2023 Mar;31:200182.
26. Lisnawati N, Rizkika A. The effect of giving nutrition education regarding anemia using social media based in adolescent. In: *Aip Conference Proceedings*. 2023. p. 080009.
27. Kusuma ZN, Noviyanti RD, Kusudaryati DPD, Marfuah D. The effect of nutrition education on anemia through animated video media and leaflets on the knowledge of adolescent girls at MTs Muhammadiyah 2 Kalijambe Sragen. In: *Aip Conference Proceedings*. 2025. p. 020128.
28. Febrianti KD, Ayu WC, Anidha Y, Mahmudiono T. Effectiveness of Nutrition Education on Knowledge of Anemia and Hemoglobin Level in Female Adolescents Aged 12-19 Years: a Systematic Reviews and Meta-Analysis. *Amerta Nutr*. 2023 Sep;7(3):478–86.
29. Liu D. A new method for developing an efficient, regional semi-quantitative food frequency questionnaire. *Asia Pac J Clin Nutr*. 2025;34(4):647–64.
30. Hasan MN. Paper-based microchip electrophoresis for point-of-care hemoglobin testing. *Analyst*. 2020;145(7):2525–42.
31. Pohanka M. Glycated hemoglobin and methods for its point of care testing. *Biosensors*. 2021;11(3).
32. Li D. Portable liquid chromatography for point-of-care testing of glycated haemoglobin. *Sensors Actuators B Chem*. 2020;305.
33. Hasianna Silitonga HT, Salim LA, Nurmala I, Wartiningsih M. Compliance of Iron Supplementation and Determinants among Adolescent Girls: A Systematic Review. *Iran J Public Health [Internet]*. 2023 Jan 14; Available from: <https://publish.kne-publishing.com/index.php/ijph/article/view/11664>
34. Apriningsih, Madanijah S, Dwiriani Cm, Kolopaking R. Determinant of Highschool Girl Adolescent' Adherence to Consume Iron Folic Acid Supplementation in Kota Depok. *J Nutr Sci Vitaminol (Tokyo) [Internet]*. 2020;66(Supplement):S369–75. Available from: https://www.jstage.jst.go.jp/article/jnsv/66/Supplement/66_S369/_article
35. Yilma B, Endris BS, Mengistu YG, Sisay BG, Gebreyesus SH. Inadequacy of nutrient intake among adolescent girls in south central Ethiopia. *J Nutr Sci [Internet]*. 2021 Oct 7;10:e90. Available from: https://www.cambridge.org/core/product/identifier/S2048679021000628/type/journal_article
36. Soans JS, Noronha JA, Mundkur SC, Nayak BS, Garg M, Jathanna RD, et al. Mapping evidence on the impact of junk food on anaemia among adolescent and adult population: a scoping review. *BMC Nutr [Internet]*. 2025;11(1):1–20. Available from: <https://doi.org/10.1186/s40795-025-01079-1>
37. Suciyantri D, Kolopaking R, Mustafa A, Iwan S, Witjaksono F, Fahmida U. Effect of optimized food-based recommendations on nutrient intakes, hemoglobin levels, and memory performance of adolescent girls in East Java, Indonesia. *Nutr J [Internet]*. 2025;24(1). Available from: <https://doi.org/10.1186/s12937-024-01061-w>