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Prevalence and associated factors of anemia among female high school students in Depok City

Prevalensi dan faktor yang berhubungan dengan anemia pada remaja putri SMA di Kota Depok

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Abstract

Anemia among adolescent girls remains a public health issue that can affect their nutritional status, learning abilities, and reproductive health. However, studies that simultaneously analyze nutritional intake, behavioral, and physiological factors associated with anemia among high school girls in Depok City are limited. This study aimed to identify the factors associated with anemia among female high school students in Depok City, Indonesia. Methods: This cross-sectional study included 165 students from 15 public high schools selected by quota sampling between February and April 2024. Data were collected through hemoglobin measurements using the HemoCue Hb 201+, anthropometry, two 24-hour dietary recalls, and structured questionnaires. Data were analyzed using chi-square tests and multiple logistic regressions. Results: The prevalence of anemia was 53.3%. Low protein intake had the strongest independent association with anemia (odds ratio [OR] = 6.18; 95% confidence interval [CI]: 2.74–13.94; P < 0.001). Other associated factors included undernutrition (OR = 5.27; p = 0.015), low energy intake (OR = 4.84; p = 0.001), insufficient iron intake (OR = 4.76; p = 0.002), nonadherence to weekly iron supplementation (OR = 4.50; p = 0.009), irregular menstrual cycles (OR = 3.95; p = 0.004), and low zinc intake (OR = 2.51; p = 0.034). In conclusion, anemia was prevalent and was associated with nutritional, behavioral, and menstrual factors. Integrated interventions should improve dietary quality, supplementation adherence, menstrual health education, and counseling for undernourished female students.

Keywords: Adolescent health, anemia, dietary intake, iron supplementation, menstruation, nutritional status.

Abstrak

Anemia pada remaja putri masih menjadi masalah kesehatan masyarakat yang dapat memengaruhi status gizi, kemampuan belajar, dan kesehatan reproduksi. Namun, kajian yang menganalisis secara bersamaan faktor asupan gizi, perilaku, dan fisiologis yang berhubungan dengan anemia pada siswi sekolah menengah atas di Kota Depok masih terbatas. Penelitian bertujuan mengidentifikasi faktor-faktor yang berhubungan dengan anemia pada siswi sekolah menengah atas di Kota Depok, Indonesia. Metode, penelitian potong lintang ini melibatkan 165 siswi dari 15 sekolah menengah atas negeri yang dipilih dengan teknik *quota sampling* pada Februari–April 2024. Data dikumpulkan melalui pemeriksaan hemoglobin menggunakan HemoCue Hb 201+, pengukuran antropometri, dua kali *food recall* 24 jam, dan kuesioner terstruktur. Data dianalisis menggunakan uji chi-square dan regresi logistik berganda. Hasil, prevalensi anemia ditemukan sebesar 53,3%. Asupan protein rendah menunjukkan hubungan paling kuat dengan anemia (OR=6,18; 95% CI: 2,74–13,94; p<0,001). Faktor lain yang berhubungan ialah status

gizi kurang (OR=5,27; p=0,015), asupan energi rendah (OR=4,84; p=0,001), asupan zat besi tidak mencukupi (OR=4,76; p=0,002), ketidakpatuhan mengonsumsi tablet tambah darah mingguan (OR=4,50; p=0,009), siklus menstruasi tidak teratur (OR=3,95; p=0,004), dan asupan seng rendah (OR=2,51; p=0,034). Kesimpulan, anemia banyak ditemukan dan berhubungan dengan faktor gizi, perilaku, serta menstruasi. Intervensi terpadu diperlukan untuk memperbaiki kualitas konsumsi pangan, kepatuhan suplementasi, edukasi kesehatan menstruasi, dan konseling bagi siswi dengan gizi kurang.

Kata Kunci: **A**nemia, asupan pangan, kesehatan remaja, menstruasi, status gizi, suplementasi zat besi

Introduction

Anemia is a major global public health concern, particularly among adolescent girls (World Health Organization [WHO], 2014). Approximately 29.9% of adolescent girls worldwide are affected, with iron deficiency being the most common nutritional cause (Kolarš, et al., 2025). Anemia reduces the oxygen-carrying capacity of blood and may be associated with fatigue, impaired cognitive performance, reduced concentration, and weakened immune function. The burden is generally higher in low- and middle-income countries, where inadequate dietary intake and limited access to health services remain important challenges (Mengistu et al., 2019).

In Indonesia, anemia among adolescent girls continues to be a substantial nutrition and public health problem. The 2023 Indonesian Health Survey reported a prevalence of 26.8% among adolescent girls (Kementerian Kesehatan RI, 2023). Although this estimate was lower than the 32% reported in earlier national Basic Health Research data, both figures indicate that anemia is common in this population. Therefore, the Indonesian Ministry of Health has identified anemia prevention and control as a national priority because of its potential implications for adolescent development, future maternal health, and child outcomes (Kementerian Kesehatan RI, 2021).

Adolescent girls are particularly vulnerable to anemia because of increased nutritional requirements during rapid growth and regular menstrual blood loss. Inadequate intake of energy, protein, iron, zinc, and vitamin C may contribute to poor hemoglobin levels (Mengistu et al., 2019). Dietary behaviors, including irregular meal patterns and frequent consumption of tea or coffee near mealtimes, may reduce iron availability or absorption (Belay et al., 2025). In addition, menstrual characteristics, nutritional status, limited nutritional knowledge, household economic constraints, and low adherence to weekly iron supplementation programs have been associated with anemia in adolescent populations (Gebremedhin et al., 2022; Wirth et al., 2022).

The consequences of anemia extend beyond its physical symptoms. During adolescence, anemia may be associated with reduced attention, learning capacity, academic performance, and productivity. Persistent anemia may also increase vulnerability to adverse maternal and neonatal outcomes later in life, including maternal complications and low birth weight (Kementerian Kesehatan RI, 2021). Therefore, prevention during adolescence is important not only for current health and educational development but also for future reproductive and intergenerational health.

In Depok City, the prevalence of anemia among female high school students was reported to have reached 36.34% in 2023, indicating a considerable local public health burden (Dinas Kesehatan Kota Depok, 2023). This prevalence was higher than the national estimate reported in the 2023 Indonesian Health Survey and may reflect variations in dietary practices, socioeconomic conditions, menstrual health, nutritional status, and participation in iron supplementation programmes. However, local surveillance data have primarily described the prevalence and provided limited evidence regarding the relative contributions of multiple associated factors.

Previous studies have often examined dietary, behavioral, and physiological determinants separately. Consequently, evidence remains limited on how macronutrient and micronutrient intake, menstrual patterns, iron supplementation adherence, and nutritional status are jointly associated with anemia among

adolescent girls in Depok. An integrated multivariate analysis is needed to identify the factors most strongly associated with anemia and to support the prioritization of context-specific school-based interventions.

Therefore, this study aimed to determine the prevalence of anemia and analyze its associated dietary, behavioral, and physiological factors among female high school students in Depok City in 2024. Specifically, this study examined the intake of energy, protein, iron, zinc, and vitamin C; adherence to weekly iron supplementation; menstrual characteristics; and nutritional status. The findings are expected to provide locally relevant evidence for strengthening anemia screening, nutrition education, dietary improvement, supplementation adherence, and targeted counseling for adolescent girls.

Methods

Study Design and Setting

This cross-sectional study assessed the prevalence of anemia and its associated factors among adolescent girls attending public high schools in Depok, Indonesia. Data were collected from February to April 2024 from 15 public high schools in Depok City. The schools were included to reflect the socioeconomic diversity of the public school student population.

Population and Sampling

The target population comprised female students in grades 10 and 11 at public high schools in Depok. The minimum sample size was calculated using the single-population proportion formula: $n=Z^2P(1-P)/d^2$.

The calculation used an expected anemia prevalence of 36.3%, based on the 2023 Depok City Health Profile, a 95% confidence level, and a precision of 0.08. The minimum required sample size was approximately 140 participants. This number was increased to 165 to account for potentially incomplete data and to permit proportional allocation across participating schools.

Participants were recruited using quota sampling methods. The quota for each school was allocated proportionally according to the number of female students enrolled in Grades 10 and 11. Within each school, eligible students were recruited consecutively from the class attendance lists until the assigned quota was reached.

Students were eligible if they were female, enrolled in grades 10 or 11, aged 15–17 years, present during data collection, and willing to participate. Written informed consent was obtained from all participants, with additional parental or legal guardian consent for participants aged < 18 years. Students were excluded if they had a known chronic condition that could affect their hematological status, were currently taking iron supplements outside the school iron–folic acid supplementation program, or had incomplete data on hemoglobin concentration, anthropometric measurements, or dietary intake.

Data Collection

Primary data were collected through hemoglobin assessment, anthropometric measurements, two 24-hour dietary recalls, and using a structured questionnaire.

Hemoglobin concentration was measured using a HemoCue Hb 201+ analyzer. Capillary blood samples were obtained by finger prick and collected by trained health personnel. Anemia was defined as a hemoglobin concentration below 12 g/dL, whereas participants with hemoglobin concentrations of 12 g/dL or higher were classified as non-anemic.

Body weight and height were measured to assess the nutritional status. Body mass index-for-age was calculated and categorized according to the World Health Organization and Indonesian Ministry of Health standards. The participants were classified as underweight, normal weight, or overweight.

Dietary intake was assessed using two non-consecutive 24-hour food recalls. The participants reported all the foods and beverages consumed during each recall period. Dietary data were analyzed using food composition tables to estimate the daily intakes of energy, protein, iron, zinc, vitamin C, and calcium. Nutrient intake was compared with the 2019 Indonesian Recommended Dietary Allowances for the relevant age and sex groups and expressed as a percentage of recommended intake. Low intake of energy, protein, iron, zinc, and vitamin C was defined as an intake below 80% of the age- and sex-specific recommended dietary allowance.

A structured questionnaire was used to collect information on menstrual patterns, tea or

coffee consumption during meals, adherence to weekly iron–folic acid supplementation, nutritional knowledge, and parental income. The questionnaire was adapted from previously validated instruments used in Indonesian adolescent nutrition surveys. The instrument was pilot-tested on 20 students who were not included in the study sample. The nutrition knowledge subscale demonstrated acceptable internal consistency, with a Cronbach's alpha of 0.78.

Statistical Analysis

Univariate analyses were conducted to summarize the frequency distributions and proportions of the study variables. The associations between each independent variable and anemia status were examined using the chi-square test. Statistical significance was defined as a two-sided *p-value* < 0.05.

Variables with a *p-value* below 0.25 in the bivariate analysis were included in the initial multiple logistic regression model. Backward stepwise elimination was then applied, and variables with *p-values* below 0.05 were retained in the final model. Nutritional status and parental income, which were considered potential confounders a priori, were retained, regardless of statistical significance.

Multicollinearity was assessed using variance inflation factors, with values below 10 considered to be acceptable. Model calibration was evaluated using the Hosmer–Lemeshow goodness-of-fit test. Associations were reported as odds ratios (ORs) with 95% confidence intervals (CIs) and corresponding *p-values*.

Ethical Considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Public Health, Universitas Indonesia, under approval number [Ket-XX/UN2.F10.D11/PPM.00.02/2024].

Participants received information about the study objectives, procedures, confidentiality protections, and their right to withdraw without any consequences. Written informed consent was obtained from each participant, and parental or legal guardian consent was obtained for participants aged < 18 years. Personal information and study data were kept confidential throughout the study.

Result and Discussion

Participant Characteristics and Anemia Prevalence

The study included 165 female students aged 15–17 years from 15 public high schools in Depok. Hemoglobin concentration, anthropometric status, dietary intake, menstrual characteristics, tea and coffee consumption, adherence to weekly iron–folic acid (IFA) supplementation, nutritional knowledge, and parental income were assessed.

Of the 165 participants, 88 (53.3%) were classified as anemic and 77 (46.7%) as nonanemic participants. Among all participants, 51 (30.9%) had mild, 36 (21.8%) had moderate, and 1 (0.6%) had severe anemia. Thus, most cases of anemia were classified as mild or moderate.

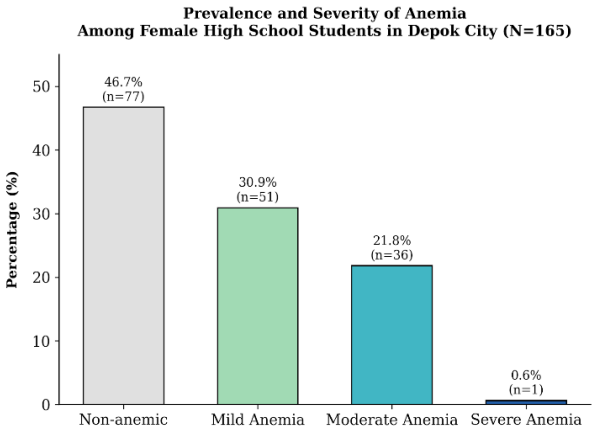

Figure 1. Prevalence and severity of anemia among female high school students in Depok City

Bivariate Analysis of Factors Associated with Anemia

Bivariate analysis showed that low intakes of energy, protein, iron, and zinc were significantly associated with anemia. Participants with low energy intake had 3.20 times the odds of anemia compared with those with adequate energy intake (odds ratio [OR] = 3.20; 95% confidence interval [CI]: 1.67–6.12; p < 0.001). Low protein intake was also associated with higher odds of anemia (OR = 3.92; 95% CI: 2.03–7.61; p < 0.001), as was low iron intake (OR = 3.02; 95% CI: 1.59–5.76; p = 0.001) and low zinc intake (OR = 3.54; 95% CI: 1.86–6.74; p < 0.001).

Low vitamin C intake was not significantly associated with anemia (OR = 1.34; 95% CI: 0.46–3.89; p = 0.587). Tea and coffee

consumption with meals was associated with a higher risk of anemia (OR = 2.35; 95% CI: 1.25–4.43; p = 0.007).

Irregular menstrual cycles were significantly associated with anemia (OR 2.92; 95% CI 1.52–5.61; p < 0.001). Participants who did not consume IFA supplements weekly had higher odds of anemia than those who adhered to the supplementation (OR = 2.61; 95% CI: 1.22–5.59; p = 0.012). Undernutrition was also associated with anemia (OR = 3.97; 95% CI: 1.40–11.20; p = 0.006).

Table 1. Bivariate associations between nutritional, behavioral, and physiological factors and anemia

Factor	Anemia, n (%)	Non-anemia, n (%)	OR	95% CI	p-value
Low energy intake	52 (59.1%)	24 (31.2%)	3.2	1.67–6.12	<0.001
Low protein intake	48 (54.5%)	18 (23.4%)	3.92	2.03–7.61	<0.001
Low iron intake	56 (63.6%)	28 (36.4%)	3.02	1.59–5.76	0.001
Low zinc intake	49 (55.7%)	20 (26.0%)	3.54	1.86–6.74	<0.001
Low vitamin C intake	51 (58.0%)	39 (50.6%)	1.34	0.46–3.89	0.587
Tea/coffee with meals (≥150 ml)	41 (46.6%)	21 (27.3%)	2.35	1.25–4.43	0.007
Irregular menstrual cycle	40 (45.5%)	17 (22.1%)	2.92	1.52–5.61	<0.001
No weekly TTD consumption	34 (38.6%)	15 (19.5%)	2.61	1.22–5.59	0.012
Undernutrition	25 (28.4%)	7 (9.1%)	3.97	1.40–11.2	0.006

odds ratio; CI: confidence interval; IFA: iron–folic acid.

Furthermore, the bivariate analysis showed that low intakes of energy, protein, iron, and zinc were significantly associated with anemia, with the strongest association being that of low protein intake. The consumption of tea or coffee with meals was also associated with a higher risk of anemia, possibly because these beverages reduce iron absorption. Irregular menstrual cycles, nonadherence to weekly iron–folic acid supplementation, and undernutrition were also significantly associated with anemia in this study. In contrast, low vitamin C intake was not significantly associated with anemia. Overall, these findings highlight the importance of dietary adequacy, menstrual health, and adherence to supplementation in this population.

Multivariable Analysis (Predictors of Anemia)

In the final multiple logistic regression model, low protein intake exhibited the strongest independent association with anemia. Participants with low protein intake had approximately six times the adjusted odds of anemia compared with those with adequate protein intake (adjusted odds ratio [AOR] = 6.18; 95% confidence interval [CI]: 2.74–13.94; p < 0.001).

Table 3. Factors independently associated with anemia in the final multivariable model

Predictor	Adjusted OR (AOR)	95% CI (Lower – Upper)	p-value
Low protein intake	6.18	2.74–13.94	<0.001
Low energy intake	4.84	2.11–11.09	0.001
Low iron intake	4.76	2.05–11.05	0.002
Low zinc intake	2.51	1.07–5.88	0.034
Irregular menstrual cycle	3.95	1.56–10.01	0.004
No weekly IFA supplementation	4.5	1.46–13.88	0.009
Undernutrition	5.27	1.37–20.25	0.015

Note: AOR = adjusted odds ratio; CI = confidence interval; IFA = iron–folic acid.

Low energy intake (AOR = 4.84; 95% CI: 2.11–11.09; p = 0.001), low iron intake (AOR = 4.76; 95% CI: 2.05–11.05; p = 0.002), and low zinc intake (AOR = 2.51; 95% CI: 1.07–5.88; p = 0.034) remained independently associated with anemia after adjusting for other variables in the model.

Behavioral and physiological factors were also significant. Participants with irregular menstrual cycles had higher adjusted odds of anemia (AOR = 3.95; 95% CI: 1.56–10.01; p = 0.004). Those who did not consume weekly IFA supplements had 4.50 times the adjusted odds of anemia compared with those who adhered to

the supplementation (95% CI: 1.46–13.88; p = 0.009). Undernutrition was also independently associated with anemia (AOR = 5.27; 95% CI: 1.37–20.25; p = 0.015).

This study identified a substantial burden of anemia among female public high school students in Depok. More than half of the participants were anemic, and most cases were classified as mild or moderate. The observed prevalence of 53.3% was higher than the national estimate of 26.8% reported in the 2023 Indonesian Health Survey and the global estimate of approximately 29.9% (Kolarš, et al., 2025; Kementerian Kesehatan RI, 2023). Based on the World Health Organization threshold cited in this study, an anemia prevalence above 40% represents a severe public health problem. These findings indicate that anemia prevention among adolescent girls should receive greater attention in school health and nutrition programs in Depok City.

Low protein intake had the strongest independent association with anemia in this study. Proteins contribute to hemoglobin formation and are required for the synthesis of proteins involved in iron transport and storage, including transferrin and ferritin. Therefore, inadequate protein intake may occur alongside impaired erythropoiesis and less efficient iron metabolism (Wirth et al., 2022). However, because the study was cross-sectional, the observed association should not be interpreted as evidence that low protein intake causes anemia. Low protein intake may also reflect broader dietary inadequacy or household-level constraints that were not fully captured in this analysis.

Low energy intake was independently associated with anemia after adjusting for other variables. Inadequate energy intake may indicate insufficient overall food consumption and may coexist with inadequate protein and micronutrient intake. Prolonged energy inadequacy may also increase the use of dietary and body proteins for energy rather than for tissue maintenance and hematopoietic functions. The simultaneous association of low energy and protein intakes with anemia suggests that interventions should address overall dietary adequacy rather than focusing exclusively on individual micronutrients.

As expected, insufficient iron intake was independently associated with anemia in the present study. Iron is an essential component of hemoglobin, and inadequate intake can compromise hemoglobin synthesis when body iron stores become insufficient. This finding is consistent with evidence highlighting iron inadequacy as an important nutritional factor associated with anemia among adolescents (Gebremedhin et al., 2022; Hossain et al., 2023). However, the present study did not assess serum ferritin or other biomarkers of iron status. Therefore, it was not possible to determine whether the participants had iron deficiency anemia or anemia related to other nutritional, inflammatory, genetic, or clinical conditions.

Low zinc intake was also independently associated with anemia. Zinc participates in numerous enzymatic and cellular processes related to growth, immunity, and hematopoiesis. Low zinc intake may also indicate a diet with limited animal-source foods, which are important sources of both zinc and highly bioavailable heme iron (Jeng & Chen, 2022; Al Rahmad, 2023). The association between zinc intake and anemia should be interpreted carefully because nutrient inadequacies frequently cluster within poor-quality diets. Further research using biochemical indicators would help determine whether zinc status is independently related to hemoglobin concentration.

Vitamin C intake was not significantly associated with anemia in the bivariate analysis. Although vitamin C can enhance non-heme iron absorption, its contribution may depend on the amount and form of iron consumed, meal composition, and the presence of absorption inhibitors. The absence of a significant association may also have resulted from limited variation in vitamin C intake or measurement errors associated with the two 24-hour food recalls. Therefore, the findings should not be interpreted as evidence that vitamin C-rich foods are unimportant for preventing anemia. Including vitamin C-rich fruits and vegetables with plant-based iron sources remains nutritionally appropriate.

Tea or coffee consumption with meals was associated with anemia in the bivariate analysis but was not retained in the final multivariate model. Polyphenols in tea and coffee can bind to non-heme iron and reduce its absorption when consumed close to meals (Gebremedhin et al., 2022). However, the attenuation of this association after adjustment suggests that the observed bivariate relationship may overlap with other dietary factors. Nutrition education

should include practical information on separating tea and coffee consumption from iron-containing meals, particularly among adolescents whose diets rely heavily on plant-based iron.

Irregular menstrual cycles were independently associated with anemia in this study. Menstrual characteristics may be related to variations in blood loss, hormonal function, nutritional status, and underlying health conditions of the individual. However, cycle irregularity alone does not directly quantify the menstrual blood loss. Therefore, the findings should be interpreted as an association between menstrual characteristics and anemia rather than proof that irregular cycles caused lower hemoglobin concentrations. Future studies should include validated measures of menstrual duration and blood loss volume to clarify this relationship (Belay et al., 2025; Sekiyama et al., 2022).

Nonadherence to weekly IFA supplementation was also independently associated with anemia. This finding supports the importance of the effective implementation of school-based supplementation programs. Distribution alone may not ensure consumption because adherence can be affected by forgetfulness, side effects, inadequate knowledge, concerns about supplementation, inconsistent availability, and limited supervision. Strategies such as supervised weekly consumption, reminder systems, counseling on side effect management, and coordination between schools and health services may improve adherence (Kementerian Kesehatan RI, 2021; UNICEF, 2023).

Undernutrition was strongly associated with anemia, although the corresponding confidence intervals were relatively wide. This imprecision may reflect the limited number of participants classified as undernourished in our study. A low body mass index-for-age can indicate prolonged inadequacy in dietary quantity or quality and may coexist with deficiencies of iron, protein, zinc, and other nutrients (Yani et al., 2023). This finding suggests that adolescents with undernutrition may require more comprehensive assessment and support rather than anemia supplementation alone.

The wide confidence intervals for undernutrition and nonadherence to weekly IFA indicate uncertainty regarding the exact magnitude of these associations. Although the directions of association were statistically significant, the estimates should not be interpreted as precise measures of the effect. Studies with larger probability-based samples are required to obtain more stable estimates.

Implications and Limitations

These findings support an integrated school-based approach to anemia prevention among adolescent girls in Depok City by combining weekly iron–folic acid supplementation with improved dietary quality, menstrual health education, screening, and individualized nutrition counseling. Programs should promote affordable sources of protein, iron, and zinc, such as eggs, fish, poultry, legumes, tofu, tempeh, and fortified foods while encouraging the consumption of vitamin C-rich foods and avoiding tea or coffee with iron-containing meals. School canteen policies may also help increase access to nutrient-dense food. Students with undernutrition, persistent anemia, menstrual problems, or poor adherence to supplementation should receive targeted follow-up and referral through school health services and primary healthcare facilities. Effective implementation requires coordination among schools, families, healthcare providers, local health authorities and policymakers.

This study was limited by its cross-sectional design, which prevented causal inferences. Two 24-hour dietary recalls may not have reflected habitual intake and were subject to recall bias. Quota sampling limited generalizability and may have introduced a selection bias. The absence of iron status and inflammatory biomarkers prevented the identification of the etiology of anemia. Questionnaire-based variables were vulnerable to reporting errors, and wide confidence intervals for some estimates indicated limited statistical precision.

Conclusion

Anemia was highly prevalent among female students attending public high schools in Depok City in 2024. Low intakes of protein, energy, iron, and zinc, irregular menstrual cycles, nonadherence to weekly iron–folic acid supplementation, and undernutrition were independently associated with anemia, with low

protein intake showing the strongest association with anemia.

These findings support integrated school-based programs that combine dietary improvement, supplementation adherence, menstrual health education, anemia screening, and targeted nutritional counseling for students at greater nutritional risk. Because this study was cross-sectional and used quota sampling, the findings should be interpreted as associations within the study population rather than causal or population-wide effects.

School health programs should integrate weekly iron–folic acid supplementation monitoring with nutrition education, improved access to protein-, iron-, and zinc-rich foods, menstrual health support, anemia screening, and counseling for students with undernutrition or poor adherence to supplementation. Future studies should use longitudinal designs, probability sampling, repeated dietary assessments, and biochemical indicators, such as serum ferritin and inflammatory markers, to clarify temporal relationships and distinguish iron-deficiency anemia from other forms of anemia.

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References

Adamu, A. L., Crampin, A., Kayuni, N., Amberbir, A., Koole, O., Phiri, A., Nyirenda, M., & Fine, P. (2017). Prevalence and risk factors for anemia severity and type in Malawian men and women: Urban and rural differences. *Population Health Metrics, 15*(1), Article 12. https://doi.org/10.1186/s12963-017-0128-2

Al Rahmad, A. H. (2023). Scoping Review: The Role of Micronutrients (Fe, Zn, Iodine, Retinol, Folate) During Pregnancy. *Jurnal Kesehatan Manarang*, *9*(1), 1–13. https://doi.org/https://doi.org/10.33490/jkm.v9i1.812

Azzeh, F. S., Alazzeh, A. Y., Wazzan, H., Jazar, A. S., Obaid, R. S., & Subih, H. S. (2023). Dietary protein intake and anemia risk among adolescent girls: A cross-sectional study. *Nutrients, 15*(3), Article 612. https://doi.org/10.3390/nu15030612

Balarajan, Y., Ramakrishnan, U., Özaltin, E., Shankar, A. H., & Subramanian, S. V. (2022). Anaemia in low-income and middle-income countries: Determinants and intervention strategies. *The Lancet Global Health, 10*(3), e312–e322. https://doi.org/10.1016/S2214-109X(22)00084-3

Baye, K., Laillou, A., & Chianu, J. (2021). Food fortification for reducing anemia in low- and middle-income countries: A systematic review. *Maternal & Child Nutrition, 17*(2), Article e13096. https://doi.org/10.1111/mcn.13096

Dinas Kesehatan Kota Depok. (2023). *Profil kesehatan Kota Depok 2023*.

Belay, D. G., Amlak, B. T., Chilot, D., Alem, A. Z., & Merid, M. W. (2025). Pooled prevalence of anaemia and its associated factors among adolescent girls in East and West Africa: A systematic review and meta-analysis. *BMC Public Health, 25*, Article 2482. https://doi.org/10.1186/s12889-025-23701-4

Gebremedhin, S., Bekele, A., & Tadesse, T. (2022). Dietary risk factors of anemia among adolescent girls in sub-Saharan Africa: A systematic review and meta-analysis. *Nutrients, 14*(7), Article 1423. https://doi.org/10.3390/nu14071423

GBD 2021 Anaemia Collaborators. (2023). Prevalence, years lived with disability, and trends in anaemia burden by severity and cause, 1990–2021: Findings from the Global Burden of Disease Study 2021. *The Lancet Haematology, 10*(9), e713–e734. https://doi.org/10.1016/S2352-3026(23)00160-6

Geng, F., Mai, X., Zhan, J., Xu, L., Zhao, Z.,

Georgieff, M. K., Shao, J., & Lozoff, B. (2015). Impact of fetal-neonatal iron deficiency on recognition memory at 2 months of age. *The Journal of Pediatrics, 167*(6), 1226–1232. https://doi.org/10.1016/j.jpeds.2015.08.035

Hossain, M. S., Shanta, Z., Islam, R., & Begum, F. (2023). Dietary diversity and anemia among adolescent girls in rural Bangladesh: A cross-sectional study. *BMC Nutrition, 9*(1), Article 45. https://doi.org/10.1186/s40795-023-00698-4

Jeng, S., & Chen, W. (2022). Zinc–iron interactions and implications for adolescent hematologic health. *Journal of Clinical Nutrition, 41*(3), 215–223. https://doi.org/10.1016/j.jcn.2022.03.001

Kementerian Kesehatan Republik Indonesia. (2021). *Mengenal dampak anemia pada remaja*.

Kementerian Kesehatan Republik Indonesia. (2023). *Survei Kesehatan Indonesia 2023*.

Kinyoki, D., Osgood-Zimmerman, A. E., Bhattacharjee, N. V., Local Burden of Disease Anaemia Collaborators, Kassebaum, N. J., & Hay, S. I. (2021). Anemia prevalence in women of reproductive age in low- and middle-income countries between 2000 and 2018. *Nature Medicine, 27*(10), 1761–1782. https://doi.org/10.1038/s41591-021-01498-0

Kolarš, B., Mijatović Jovin, V., Živanović, N., Minaković, I., Gvozdenović, N., Dickov Kokeza, I., & Lesjak, M. (2025). Iron Deficiency and Iron Deficiency Anemia: A Comprehensive Overview of Established and Emerging Concepts. *Pharmaceuticals*, *18*(8), 1104. https://doi.org/10.3390/ph18081104

Low, M. S. Y., Speedy, J., Styles, C. E., De-Regil, L. M., & Pasricha, S.-R. (2016). Daily iron supplementation for improving anaemia, iron status and health in menstruating women. *Cochrane Database of Systematic Reviews, 2016*(4), Article CD009747. https://doi.org/10.1002/14651858.CD009747.pub2

Mengistu, G., Azage, M., & Gutema, H. (2019). Iron deficiency anemia among in-school adolescent girls in rural area of Bahir Dar City Administration, North West Ethiopia. *Anemia, 2019*, Article 1097547. https://doi.org/10.1155/2019/1097547

Prentice, A. M., Mendoza, Y. A., Pereira, D., Cerami, C., Wegmüller, R., Constable, A., & Spieldenner, J. (2017). Dietary strategies for improving iron status: Balancing safety and efficacy. *Nutrition Reviews, 75*(1), 49–60. https://doi.org/10.1093/nutrit/nuw055

Sekiyama, M., Jiang, H., Gunawan, B., Dewi, M., Ermayani, E., & Abdoellah, O. S. (2022). Menstrual health and anemia among adolescent girls in rural Indonesia: Implications for school-based interventions. *International Journal of Environmental Research and Public Health, 19*(8), Article 4612. https://doi.org/10.3390/ijerph19084612

UNICEF. (2023). *The state of the world's children 2023: For every child, vaccination*. https://www.unicef.org/reports/state-worlds-children-2023

World Health Organization. (2014). *Global nutrition targets 2025: Anaemia policy brief*.

World Health Organization. (2025). *Anaemia in women and children: WHO global anaemia estimates*. https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_children

Wirth, J. P., Woodruff, B. A., Engle-Stone, R., & Namaste, S. M. (2022). Anemia, micronutrient deficiencies, and menstrual health in adolescent girls: Evidence and implications for programs. *The Journal of Nutrition, 152*(3), 670–681. https://doi.org/10.1093/jn/nxab350

Yani, M., Azhari, A., Al Rahmad, A. H., Bastian, F., Ilzana, T. M., Rahmi, C. R., Andriaty, S. N., Chanda, A., & Salsabila, S. (2023). The relationship between menarche and nutritional status in Junior High School students in Aceh Besar. A study from 30 years of armed conflict area, Aceh, Indonesia. *AcTion: Aceh Nutrition Journal*, *8*(4), 635–641. https://doi.org/10.30867/action.v8i4.1310