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Determination of Hb Levels in Adolescent Girls in Depok City: The Role of Sociodemographics, Attitudes, and Knowledge of Iron Tablets

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ABSTRACT

Introduction: Anemia in adolescent girls leads to decreased academic achievement, productivity, and quality of life. Low adherence to Iron Supplement Tablet (IST) consumption, low dietary iron intake, and parental sociodemographic factors are the main risk factors for anemia. This study aims to analyze the relationship between parental sociodemographic factors, attitudes, and knowledge about IST and hemoglobin (Hb) levels among students at SMA IT Raflesia, Depok City.

Methods: This analytical observational study with a cross-sectional approach was conducted in September 2025 at SMAIT Raflesia, Depok City. A sample of 70 adolescent girls was selected using purposive sampling. Primary data were collected through questionnaires and Hb level examinations. Data analysis using SPSS included univariate analysis, bivariate analysis (Pearson correlation), and multivariate analysis (multiple linear regression).

Results: The mean Hb level of the respondents was 11.89 g/dL. Correlation tests showed a significant relationship between the Hb levels of adolescent girls and parental education (p=0.001), adolescent attitude (p=0.001), and knowledge about TTD (p=0.026). Conversely, there was no significant relationship between parental occupation and respondents' Hb levels.

Conclusion: Parental education, adolescent attitudes, and knowledge about Iron Supplement Tablets (IST) are variables that show a significant association with hemoglobin levels in adolescent girls, while parental occupation does not show any relationship. Strengthening education about IST and increasing family support are necessary to optimize hemoglobin levels in adolescents.

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INTRODUCTION

Anemia among adolescent girls remains a major global public health challenge with potentially substantial implications for long-term health and human capital development. Globally, approximately 33% of adolescent girls and women of reproductive age are estimated to be affected by anemia (WHO, 2024; Global Nutrition Report, 2020). The burden is particularly pronounced in developing countries and low- and middle-income settings, where nutritional deficiencies and other underlying health conditions remain prevalent (Corrons & Krishnevskaya, 2021; Sefaya et al., 2017). In Indonesia, national data indicate that anemia remains a considerable nutritional problem among adolescent girls. According to the 2022 national nutrition survey data cited in this study, the prevalence of anemia among adolescent girls was 23% (Ministry of Health of the Republic of Indonesia, 2022). At the local level, hemoglobin (Hb) screening conducted by the Depok City Health Office among female students in Grades 7 and 10 found that 36.34% were identified as having anemia, a proportion higher than the reported national prevalence (Dinas Kesehatan Kota Depok, 2023).

The consequences of anemia during adolescence extend beyond immediate hematological and nutritional concerns. Anemia may adversely affect academic performance and cognitive functioning during adolescence and may have longer-term implications for health and productivity in adulthood (Corrons & Krishnevskaya, 2021; Tarini et al., 2020). Moreover, inadequate nutritional status during adolescence may have implications across the life course and potentially across generations as adolescent girls transition into women of reproductive age. Consequently, addressing anemia among adolescent girls is important not only for improving individual health outcomes but also for supporting human capital development and socioeconomic productivity (Owais et al., 2021; Alfiah & Dainy, 2023).

Despite the implementation of specific government interventions, including the distribution of iron supplementation tablets (Tablet Tambah Darah, TTD) through educational institutions, the relatively high prevalence of anemia among adolescent girls in Depok City suggests that challenges remain in program implementation and adherence. The effectiveness of iron supplementation programs may be influenced by individual-level factors, including adolescents' willingness to consume iron supplements, inadequate knowledge regarding anemia and iron supplementation, and unfavorable attitudes toward healthy dietary and anemia-prevention practices (Leung et al., 2024; Primantika & Noorratri, 2023; Munawaroh et al., 2024). These factors may affect adolescents' acceptance of and adherence to recommended iron supplementation and other preventive behaviors.

In addition to individual factors, adolescents' knowledge, attitudes, and health behaviors are influenced by their family and social environments. Parental sociodemographic characteristics, including educational attainment and employment status, may contribute to parenting practices, supervision of supplement consumption, access to health information, and the provision of nutritious foods within the household (Anggraini et al., 2022; Pibriyanti et al., 2024; Situmeang et al., 2022). Therefore, understanding variations in hemoglobin status among adolescent girls requires consideration of both adolescent-level psychosocial characteristics and the broader family environment.

Previous studies have often examined adolescents' internal factors, such as knowledge and attitudes, separately from external factors, including parental sociodemographic characteristics. Consequently, evidence integrating family sociodemographic characteristics with adolescents' psychosocial factors in relation to objectively measured hemoglobin concentrations remains limited. Examining these factors simultaneously may provide a more comprehensive understanding of the multiple factors associated with hemoglobin status among adolescent girls. Such a multidimensional perspective may also support the development of anemia-prevention programs that not only target adolescents but also actively involve parents and families as important sources of support.

Schools also play a critical role in anemia prevention by providing nutrition education, facilitating and supervising the distribution and consumption of iron supplementation tablets, and strengthening school-based health programs *Usaha Kesehatan Sekolah* (UKS). These strategies may contribute to reducing anemia among adolescent girls while supporting concentration, learning capacity, and academic performance (Nabilah et al., 2025). Therefore, coordinated interventions involving adolescents, families, schools, and healthcare services may be necessary to strengthen anemia-prevention efforts.

Accordingly, this study aimed to examine the associations between parental sociodemographic factors, specifically parental education and employment status, adolescents' attitudes toward anemia prevention, and knowledge regarding iron supplementation with hemoglobin (Hb) concentrations among female students at SMA IT Raflesia, Depok City, Indonesia. The findings are expected to provide empirical evidence to support the development of more targeted family- and school-based strategies for anemia prevention among adolescent girls.

METHODS

Study Design

This quantitative study employed an analytical observational design with a cross-sectional approach and was conducted in September 2025. Primary data were collected on adolescent characteristics, parental employment and educational status, attitudes toward anemia prevention, and knowledge regarding the consumption of iron supplementation tablets (Tablet Tambah Darah, TTD).

The target population consisted of female students enrolled at SMA IT Raflesia in Depok City, Indonesia. Participants were selected using purposive sampling based on predefined eligibility criteria. Students who were present during the hemoglobin (Hb) screening conducted at SMA IT Raflesia, Cimanggis District, Depok City, were invited to participate. A total of 70 adolescent girls were included in the study.

The inclusion criterion was being an active female student enrolled at SMA IT Raflesia. Students who were menstruating at the time of data collection and/or had a known hematological disorder that could affect hemoglobin concentrations, such as thalassemia, were excluded from the study. The independent variables included parental sociodemographic characteristics (employment and educational status), adolescents' attitudes toward anemia prevention, and knowledge regarding iron supplementation. The dependent variable was hemoglobin concentration.

Outcome Variable

Hemoglobin concentrations were measured directly among participating adolescent girls using a portable hemoglobinometer reported in the original study protocol as an Easy Touch hemoglobinometer with CE/ISO 9001 certification and the Lysun brand. The measurements were performed with the assistance of healthcare personnel working within the service area of the Cimanggis Community Health Center (Puskesmas Cimanggis). Hemoglobin concentration was recorded as a continuous numerical variable on a ratio scale and expressed in grams per deciliter (g/dL).

Independent Variables

The independent variables included parental sociodemographic characteristics, knowledge regarding iron supplementation, and attitudes toward anemia prevention. Parental sociodemographic characteristics included employment and educational attainment. Employment status was categorized as employed or unemployed, whereas educational attainment was categorized as senior high school or lower (≤ senior high school) and bachelor's degree or higher (≥ bachelor's degree).

Knowledge regarding iron supplementation was assessed using a structured questionnaire evaluating adolescents' understanding of the functions, recommended dosage, and appropriate consumption of iron supplementation tablets (Tablet Tambah Darah, TTD). Knowledge scores were analyzed as continuous

variables. Attitudes toward anemia prevention were assessed using a Likert-type questionnaire measuring participants' perceptions of anemia-prevention practices. Although the original study protocol categorized attitudes using the median score, attitude scores were treated as continuous variables in the correlation and multiple linear regression analyses.

Validity and Reliability of the Questionnaire

Prior to the main data collection, the questionnaire was pilot-tested among 30 adolescent girls who were not included in the final study sample but had characteristics comparable to those of the study population. The validity of the questionnaire items was assessed using Pearson's product–moment correlation. The calculated correlation coefficient (r-value) for each questionnaire item was compared with a critical r-value of 0.182 (df = N − 2; N = 30), as specified in the original study protocol. All questionnaire items were considered valid because their calculated r-values exceeded the predefined critical value. Reliability analysis was subsequently performed for all valid questionnaire items using Cronbach's alpha. The analysis yielded a Cronbach's alpha coefficient of 0.822 (>0.60), indicating good internal consistency of the questionnaire for use as a measurement instrument in this study.

Statistical Analysis

Descriptive analyses were performed to summarize the characteristics of the study participants. Continuous variables, including hemoglobin concentrations, knowledge scores, and attitude scores, were summarized using means, medians, and standard deviations (SDs), as appropriate. Parental sociodemographic characteristics were presented as frequencies and percentages.

Prior to conducting the independent-samples t-test, the normality assumption was assessed. Given the sample size of 70 participants ($N < 100$), the Kolmogorov–Smirnov test was used to assess the distribution of the dependent variable. The results indicated that hemoglobin concentrations were normally distributed ($p > 0.05$).

Bivariate analyses were conducted to examine the relationships between the independent variables and hemoglobin concentrations. Pearson's correlation analysis was used to assess the relationships between continuous variables knowledge regarding iron supplementation and attitudes toward anemia prevention and hemoglobin concentrations. Independent-samples t-tests were used to compare mean hemoglobin concentrations according to the dichotomous categories of parental employment and educational status. Multiple linear regression analysis was subsequently performed to examine the simultaneous associations of parental employment status, parental educational attainment, knowledge regarding iron supplementation, and attitudes toward anemia prevention with hemoglobin concentrations.

Before performing multiple linear regression analysis, the relevant statistical assumptions were assessed, including normality, homoscedasticity, multicollinearity, linearity, and independence. Multicollinearity was evaluated using the variance inflation factor (VIF) and tolerance values, with VIF values ≤ 10 and tolerance values ≥ 0.10 considered acceptable according to the criteria applied in the study. All assessed assumptions were reported to have been met; therefore, the data were considered appropriate for multiple linear regression analysis.

The results of the multiple linear regression analysis were reported as unstandardized regression coefficients (B), standard errors (SEs), standardized regression coefficients (β), 95% confidence intervals (CIs), and p-values. The coefficient of determination (R^2) was used to indicate the proportion of variance in hemoglobin concentrations explained collectively by the independent variables included in the regression model. Statistical significance was set at $p < 0.05$.

Ethical Considerations

The study protocol received ethical approval from the Health Research Ethics Committee of Universitas Muhammadiyah Prof. Dr. Hamka, with approval number KEPK-NK/02/07/2025/0334.

RESULTS

A total of 70 adolescent girls participated in the study. As presented in Table 1, the mean hemoglobin (Hb) concentration was 11.89 ± 1.23 g/dL, ranging from 8.80 to 14.60 g/dL. The participants had a mean knowledge score of 10.66 ± 1.34 and a mean attitude score of 63.79 ± 6.06. Regarding parental sociodemographic characteristics, 41 (58.6%) participants had employed parents, whereas 29 (41.4%) had unemployed parents. In terms of parental educational attainment, 45 (64.3%) participants had parents with a bachelor's degree or higher, while 25 (35.7%) had parents with a senior high school education or lower.

Tabel 1. Characteristics of the study participants (n = 70)

Characteristics	Mean ± SD or n (%)	Range
Hemoglobin concentration (g/dL)	11.89 ± 1.23	8.80–14.60
Knowledge score	10.66 ± 1.34	6–11
Attitude score	63.79 ± 6.06	48–74
Parental employment status		
Employed	41 (58.6)	—
Unemployed	29 (41.4)	—
Parental educational attainment		
≥ Bachelor's degree	45 (64.3)	—
≤ Senior high school	25 (35.7)	—

Data are presented as mean ± standard deviation (SD) for continuous variables and n (%) for categorical variables.

Pearson's correlation analysis showed that knowledge regarding iron supplementation was positively correlated with Hb concentration ($r = 0.266$, $p = 0.026$), although the magnitude of the correlation was weak. Attitudes toward anemia prevention showed a stronger positive correlation with Hb concentration ($r = 0.452$, $p = 0.001$), indicating a moderate correlation. These findings suggest that higher knowledge scores and more favorable attitudes toward anemia prevention were associated with higher Hb concentrations in the unadjusted bivariate analyses (Table 2).

Tabel 2. Correlations of knowledge and attitudes with hemoglobin concentrations

Variables	*r*	*p*-value
Knowledge regarding iron supplementation	0.266	0.026
Attitudes toward anemia prevention	0.452	0.001

Pearson's correlation coefficients are presented. Statistical significance was set at $p < 0.05$.

Independent-samples *t*-tests were performed to examine differences in Hb concentrations according to parental sociodemographic characteristics (Table 3). Among the participants, 41 (58.6%) had employed parents and 29 (41.4%) had unemployed parents. The mean Hb concentration was slightly higher among participants with employed parents than among those with unemployed parents (12.064 ± 1.356 vs. 11.744 ± 0.941 g/dL); however, the difference was not statistically significant ($p = 0.298$). Regarding parental educational attainment, 45 (64.3%) participants had parents with a bachelor's degree or higher, whereas 25 (35.7%) had parents with a senior high school education or lower. Participants whose parents had a bachelor's degree or higher had a significantly higher mean Hb concentration than those whose parents had

a senior high school education or lower (12.351 ± 1.171 vs. 11.382 ± 1.112 g/dL; $p = 0.001$). These findings indicate that parental educational attainment, but not parental employment status, was significantly associated with Hb concentrations in the unadjusted bivariate analysis.

Tabel 3. Hemoglobin concentrations according to parental sociodemographic characteristics

Variable	n (%)	Mean Hb ± SD (g/dL)	t	p-value
Parental employment status				
Employed	41 (58.6)	12.064 ± 1.356	−1.160	0.298
Unemployed	29 (41.4)	11.744 ± 0.941		
Parental educational attainment				
≥ Bachelor's degree	45 (64.3)	12.351 ± 1.171	−3.479	0.001*
≤ Senior high school	25 (35.7)	11.382 ± 1.112		

**Statistically significant at $p < 0.05$.*

In the multiple linear regression analysis, parental employment status, parental educational attainment, knowledge regarding iron supplementation, and attitudes toward anemia prevention were simultaneously included in the model. After adjustment for the other variables, parental employment status was significantly associated with Hb concentration (B = −1.056; 95% CI: −1.810 to −0.301; $p = 0.007$), although the direction of this association should be interpreted according to the reference category used in the regression coding. Parental educational attainment was positively associated with Hb concentration (B = 1.593; 95% CI: 0.855 to 2.330; $p < 0.001$). Attitudes toward anemia prevention also remained positively associated with Hb concentration (B = 0.074; 95% CI: 0.034 to 0.114; $p < 0.001$). In contrast, knowledge regarding iron supplementation was no longer independently associated with Hb concentration after adjustment for the other variables in the model (B = 0.015; 95% CI: −0.005 to 0.035; $p = 0.133$) (Table 4).

Table 4. Multiple linear regression analysis of factors associated with hemoglobin concentrations

Predictor	B	SE	Standardized β	95% CI for B	*p*-value
Parental employment status	−1.056	0.378	−0.415	−1.810 to −0.301	0.007
Parental educational attainment	1.593	0.369	0.644	0.855 to 2.330	<0.001
Knowledge regarding iron supplementation	0.015	0.010	0.150	−0.005 to 0.035	0.133
Attitudes toward anemia prevention	0.074	0.020	0.366	0.034 to 0.114	<0.001

The overall regression model explained 40.6% of the variance in Hb concentrations ($R^2 = 0.406$), indicating that the four variables included in the model collectively accounted for a substantial proportion of the observed variability in Hb concentrations. The remaining 59.4% of the variance was not explained by the variables included in the present model.

DISCUSSION

The present study examined the associations between parental sociodemographic characteristics, adolescents' knowledge regarding iron supplementation, attitudes toward anemia prevention, and hemoglobin (Hb) concentrations among adolescent girls in Depok City. The mean Hb concentration was 11.89 ± 1.23 g/dL, indicating that, on average, the participants had Hb concentrations close to the commonly used anemia threshold of 12 g/dL for non-pregnant adolescent girls. This finding should be considered within the broader local context, as anemia screening conducted by the Depok City Health Office reported

that 36.34% of junior and senior high school female students in Depok City were identified as having anemia (Depok City Health Office, 2024). This proportion indicates that anemia remains an important public health concern among adolescent girls in this setting, particularly when considered against international criteria for assessing the population-level burden of anemia (WHO, 2025).

Parental educational attainment emerged as an important factor associated with Hb concentrations in both the bivariate and multivariable analyses. Adolescent girls whose parents had a bachelor's degree or higher had significantly higher mean Hb concentrations than those whose parents had a senior high school education or lower. This association also remained significant after adjustment for parental employment, knowledge, and attitudes. Higher parental education may facilitate greater access to health information and improve parents' ability to communicate health-related information in ways that are appropriate for their children's developmental stage. Previous research has highlighted the importance of effective family-centered educational approaches in improving health knowledge and disease management among children and adolescents (Plett et al., 2023). Similarly, a cross-sectional study among school-aged children in Guangzhou, China, demonstrated the relevance of maternal and family characteristics in understanding anemia and dietary patterns, further supporting the potential role of the family environment in shaping children's nutritional outcomes (Ma et al., 2023).

The association between parental education and Hb concentrations may reflect several interrelated pathways, including nutrition literacy, household dietary practices, access to health information, and parental involvement in preventive health behaviors. Parents with higher educational attainment may be better positioned to understand nutritional recommendations, recognize the importance of iron-rich foods, and support adherence to iron supplementation. Nevertheless, because the present study used a cross-sectional design, the observed association should not be interpreted as evidence that higher parental education directly causes higher Hb concentrations. Rather, parental education may serve as a proxy for broader social, economic, and health-related resources that were not fully measured in this study.

Attitudes toward anemia prevention showed a moderate positive correlation with Hb concentrations in the bivariate analysis and remained independently associated with Hb concentrations after adjustment for the other variables in the regression model. This finding suggests that favorable attitudes toward anemia prevention may be particularly relevant to the health behaviors of adolescent girls. From the perspective of the Health Belief Model (HBM), preventive health behaviors may be influenced by individuals' perceived susceptibility to a health condition and their perceived severity of its consequences (Akbar et al., 2025). Adolescent girls who perceive anemia as a meaningful health concern may be more motivated to engage in preventive behaviors, including adherence to iron supplementation and the consumption of nutritionally adequate foods.

Positive attitudes toward anemia prevention and iron supplementation may therefore facilitate greater acceptance of recommended preventive practices. Previous research has also demonstrated associations between attitudes toward anemia and adherence to iron supplementation among adolescent girls (Niza et al., 2024). Consistent with this evidence, studies by Diani et al. (2024) and Nuzrina (2021) reported that more favorable attitudes were associated with better adherence to iron tablet consumption. Collectively, these findings suggest that strengthening adolescents' attitudes toward anemia prevention may complement the provision of iron supplements, although the present study did not directly measure adherence to supplementation as a potential behavioral pathway (Diani et al., 2024; Nuzrina, 2021).

Knowledge regarding iron supplementation was significantly and positively correlated with Hb concentrations in the bivariate analysis; however, this association was no longer statistically significant after adjustment for parental sociodemographic characteristics and attitudes in the multivariable model. This distinction is important because it suggests that knowledge alone may not independently explain variations in Hb concentrations when other relevant factors are considered simultaneously. Knowledge remains an

important prerequisite for informed health behavior, as adolescents need to understand the purpose, dosage, and appropriate consumption of iron supplements. For example, knowledge of dietary factors that may affect iron absorption and appropriate iron supplementation practices may contribute to more effective anemia-prevention behaviors (Nuraina & Sulistyoningsih, 2023). Nevertheless, adequate knowledge does not necessarily translate directly into consistent supplement consumption or improved biological outcomes.

Previous evidence indicates that adolescents with better knowledge of anemia and iron supplementation may demonstrate greater adherence to iron supplementation recommendations (Niza et al., 2024). Nutritional literacy may similarly support healthier dietary and lifestyle behaviors during adolescence. However, the attenuation of the association between knowledge and Hb concentrations in the adjusted model in the present study suggests that the relationship may operate through other behavioral or contextual pathways, including attitudes, adherence to iron supplementation, dietary iron intake, or family support. Peer-based interventions may also provide a potentially relevant strategy for strengthening adolescent health behaviors by leveraging social support within adolescent networks (Yurtdas Depboylu et al., 2023; Tjahjono Moedji Widodo & Inayah, 2025). Therefore, interventions should not be limited to increasing knowledge but should also aim to translate knowledge into sustained preventive behaviors.

Parental employment status showed a different pattern of association. In the unadjusted bivariate analysis, mean Hb concentrations did not differ significantly according to parental employment status (p = 0.298). However, parental employment status became statistically significant in the multivariable regression model after adjustment for parental education, knowledge, and attitudes (p = 0.007). This change suggests that the association between parental employment and Hb concentrations may be influenced by the simultaneous consideration of other covariates in the model. The finding should therefore be interpreted cautiously, particularly because the direction of the regression coefficient depends on the reference category used for parental employment coding. Globally, socioeconomic disadvantage and inadequate access to micronutrient-rich diets remain important structural contributors to micronutrient inadequacy, particularly among vulnerable populations (Passarelli et al., 2024). However, employment status alone may not adequately represent household socioeconomic conditions because it does not directly capture income level, household expenditure, food security, or access to nutritious foods.

The overall regression model explained 40.6% of the variance in Hb concentrations, indicating that a substantial proportion of the variability remained unexplained by the factors included in the present study. Hemoglobin status is multifactorial and may be influenced by dietary iron intake, iron bioavailability, adherence to iron supplementation, menstrual blood loss, infection and inflammation, nutritional status, and household socioeconomic circumstances. These factors were not comprehensively assessed in the present analysis. The findings therefore highlight the importance of future studies incorporating both biological and behavioral determinants of Hb concentrations, including dietary iron intake, infection status, household income, and objectively or prospectively measured adherence to iron supplementation.

The present findings have potential implications for school- and family-based anemia-prevention strategies. Educational interventions may be more effective when they extend beyond the transfer of information and address adolescents' attitudes, perceptions, and motivation toward anemia prevention. Strengthening nutrition literacy may help adolescents understand and apply health information in everyday dietary and supplementation practices. In addition, peer-support approaches may offer opportunities to reinforce positive health behaviors within adolescent social networks. These approaches could complement school-based iron supplementation programs by integrating nutrition education, behavioral support, family engagement, and mechanisms to encourage adherence.

Several limitations should be considered when interpreting these findings. First, the cross-sectional design precludes conclusions regarding temporality or causality between parental sociodemographic characteristics, knowledge, attitudes, and Hb concentrations. Second, the relatively small sample size and

recruitment of participants from a single school may limit statistical power and the generalizability of the findings to the broader population of adolescent girls in Depok City. Third, several important determinants of Hb concentrations, including dietary iron intake, menstrual characteristics, infection and inflammation, household income, and actual adherence to iron supplementation, were not included in the analysis. Future studies should therefore involve larger and more representative samples across multiple schools and incorporate more comprehensive assessments of dietary, biological, socioeconomic, and behavioral factors associated with anemia among adolescent girls.

CONCLUSIONS

This study found that parental sociodemographic characteristics and adolescents' attitudes toward anemia prevention were associated with hemoglobin (Hb) concentrations among adolescent girls at SMA IT Raflesia, Depok City. In the bivariate analyses, parental educational attainment, knowledge regarding iron supplementation, and attitudes toward anemia prevention were significantly associated with Hb concentrations, whereas parental employment status was not. However, after adjustment for all variables included in the multiple linear regression model, parental educational attainment, parental employment status, and attitudes toward anemia prevention remained significantly associated with Hb concentrations, while knowledge regarding iron supplementation was no longer independently associated with Hb concentrations. Among the variables included in the adjusted model, parental educational attainment showed the strongest association based on the standardized regression coefficient.

These findings highlight the importance of integrating family and behavioral components into anemia-prevention strategies for adolescent girls. School-based interventions should extend beyond the distribution of iron supplementation tablets by incorporating nutrition education and strategies that promote favorable attitudes and sustained preventive behaviors. Family involvement, particularly parental support, may further strengthen these efforts. Peer-based education and interactive digital approaches may also be considered to enhance adolescents' engagement with anemia-prevention programs. Future studies with larger and more representative samples should examine additional dietary, biological, socioeconomic, and behavioral factors to provide a more comprehensive understanding of variations in Hb concentrations among adolescent girls.

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CONFLICTS OF INTEREST

The authors declare that they have no competing interests.

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Generative AI was used exclusively for English language editing and grammatical improvement. The authors reviewed, verified, and approved all scientific content and accept full responsibility for the integrity and accuracy of the manuscript.

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