



School Availability of Iron Supplements and Peer Support as Key Determinants of Iron Supplementation Adherence among Adolescent Girls in Urban Indonesia

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Abstract

Iron and folic acid supplementation for adolescent girls is essential for preventing anemia in countries such as Indonesia, where the prevalence of anemia ranges from 20% to 40%. The iron supplementation coverage rate in Bekasi City is 13.29%. However, only 8.3% of adolescent girls adhere to iron supplementation. This study aimed to analyze relationships between predisposing, enabling, reinforcing factors and adherence to iron supplementation among adolescent girls in Bekasi, Indonesia. A descriptive cross-sectional study was conducted between June and August 2023 using validated questionnaires to assess predisposing, enabling, and reinforcing factors. A total of 400 participants were selected using the multistage sampling method consisting of cluster random sampling followed by consecutive sampling. Chi-square tests and multiple logistic regression analyses were used to establish the relationship between the variables. The availability of iron supplementation at schools, peer support, family support, attitude, and teacher support were found to be significantly associated with adjusted odds ratios (AOR) consecutively of 4.738 (2.654–8.460), 4.218 (2.150–8.275), 2.463 (1.379–4.398), 2.291 (1.273–4.112), and 2.089 (1.058–4.124). The availability of supplements in schools emerged as the strongest factor associated with adherence to iron supplementation. Anemia prevention strategies for adolescent girls should prioritize interventions targeting the most influential determinants of adherence.

INTRODUCTION

Anemia among adolescent girls remains a significant public health problem in Indonesia. Adolescent girls aged 10 to 19 years are particularly vulnerable to this condition (Rahmatina et al., 2025). According to the Basic Health Research (*Riset Kesehatan Dasar* [Riskesdas]), the prevalence of anemia in Indonesia is alarmingly high, affecting 26.8% of individuals aged 5–14 years and 32.0% of those aged 15–24 years. Iron deficiency is estimated to account for approximately 50% of anemia cases (Numan & Kaluza,

2020). Among menstruating individuals, including adolescent girls, iron loss occurs regularly through menstrual bleeding (Fernandez-jimenez et al., 2020). Without sufficient iron intake, this loss can lead to iron deficiency and, as a result, lower hemoglobin levels (Aleed et al., 2024).

The short-term consequences of anemia include an increased risk of illness and school absenteeism, particularly among adolescent girls. Previous research has demonstrated that cognitive performance is lower in adolescent girls with anemia compared to their counterparts without

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the condition (Bahrami et al., 2020). Anemia also has long-term effects for adolescent girls who become pregnant, as it impairs their ability to nourish both themselves and the developing fetus. This condition can cause complications during pregnancy and labor, as well as higher maternal mortality rates. Additionally, mothers with anemia have a higher risk of preterm birth, low birth weight, and perinatal mortality (Alemu & Gashu, 2020).

The World Health Organization (WHO) recommends intermittent (weekly) iron and folic acid supplementation as a public health intervention for adolescent girls and menstruating women living in areas where the prevalence of anemia ranges from 20% to 40% to improve hemoglobin concentrations and iron status while reducing the risk of anemia (WHO, 2011). The coverage of iron supplementation among adolescent girls in West Java Province, Indonesia, has reached 74.4%, but the prevalence of anemia in Bekasi City, West Java Province, Indonesia, remains relatively high at 26.4% (El Mahmudiyah & Kurniasari, 2024; Ministry of Health of the Republic of Indonesia, 2024). A study on iron and folic acid supplements adherence in Bekasi City discovered that only 26% of adolescent girls were adherent (Syah et al., 2022). This indicates that adolescent girls should be more aware of the importance of iron supplementation in preventing anemia (Ministry of Health of the Republic of Indonesia, 2019).

Several factors have been identified as influencing adherence to iron supplementation, including school support, adolescent knowledge, age, motivation, self-efficacy, hemoglobin levels, and teacher education regarding the benefits of iron supplementation. Among these factors, student motivation, school support, and knowledge about anemia and iron supplementation have been identified as the most influential determinants (Apriningsih et al., 2020). In addition, concerns regarding the side effects of iron supplements have also been identified as barriers to adherence among adolescent girls (Kassa et al., 2019; Y. et al., 2024).

Several studies in Indonesia have examined iron supplementation adherence among adolescent girls, particularly focusing on knowledge, attitudes, and anemia prevalence (Apriningsih et al., 2020; Silitonga, Salim, Nurmala, Hargono, & Purwandini, 2023; Syah et al., 2022). Previous studies have identified the roles of family support, school support, peer influence, and awareness in anemia prevention. However, most of these studies have primarily examined determinants at

the individual level or analyzed influencing factors separately, without comprehensively exploring the interplay among predisposing, enabling, and reinforcing factors within a single analytical framework. Furthermore, systematic reviews suggest that adherence to iron supplementation is influenced by a combination of personal, social, environmental, and institutional factors. These findings underscore the need for a more comprehensive behavioral approach to better understand adherence to iron supplementation among adolescent girls (Feriyantri et al., 2022; Silitonga, Salim, Nurmala, Hargono, Notobroto, et al., 2023).

In addition to this analytical gap, evidence regarding adherence to iron and folic acid supplementation among adolescent girls in metropolitan and densely populated urban settings remains limited. The majority of previous research was undertaken in semi-urban or district-level settings, which may not sufficiently capture the complex social and environmental dynamics of large urban areas (Hidayanty et al., 2025; Tando et al., 2024; Winarni et al., 2024). Urban environments may present unique influences on health behaviors, including greater exposure to diverse information sources, stronger peer interactions, varying access to health services, and competing academic and social demands, all of which may affect adherence to iron supplementation.

Bekasi City represents an important setting for investigating these factors due to its rapid urbanization, high population density, substantial adolescent population, and persistent anemia burden despite the implementation of school-based iron supplementation programs (BPS-Statistics of Bekasi Municipality, 2023a; El Mahmudiyah & Kurniasari, 2024; Ministry of Health of the Republic of Indonesia, 2024). Within the city, East Bekasi District is one of the most densely populated areas and has a large population of adolescent girls enrolled in secondary schools. The district is supported by 57 secondary schools, comprising junior high schools, senior high schools, and vocational high schools, providing a strategic setting for evaluating adherence to iron and folic acid supplementation among school-aged girls (BPS-Statistics of Bekasi Municipality, 2023b). Understanding adherence behavior in this context is important for strengthening adolescent health interventions in metropolitan areas of Indonesia.

This study offers several novel contributions. First, it addresses an important research gap by applying Lawrence Green's behavioral framework to simultaneously examine the relationships among predisposing factors (knowl-

edge, attitudes, and demographic characteristics), enabling factors (availability of iron supplements at school and access to health services), and reinforcing factors (family support, peer support, and teacher guidance) in influencing adherence to iron supplementation. Second, this study specifically highlights the role of school-level supplement availability and social support systems as key determinants of adherence among urban adolescent girls, which have received less attention in previous Indonesian studies. Therefore, this study aims to identify factors significantly associated with iron supplementation adherence among adolescent girls in Bekasi City, Indonesia.

METHOD

This study employed an analytical cross-sectional design and was conducted in four junior high schools in Bekasi City, Indonesia, between July and August 2023. East Bekasi District was purposively selected as the study location because it represents a typical urban district within Bekasi City in terms of population density and educational infrastructure. According to regional statistics, the district has 37 lower-secondary schools, including public, private, and Islamic junior high schools, reflecting a diverse educational environment comparable to that of other urban districts in the city (BPS-Statistics of Bekasi Municipality, 2023a). In addition, East Bekasi is one of the densely populated districts in Bekasi City, with a population density of 17,317 persons/km², making it an appropriate setting for examining adherence to iron supplementation among adolescent girls in an urban context (BPS-Statistics of Bekasi Municipality, 2023a). Although the study was conducted in a single district, its demographic and educational characteristics are broadly similar to those of other urban areas within Bekasi City, supporting the relevance of the findings to comparable urban settings. Participants were adolescent girls who had experienced menarche and had participated in the iron supplementation program for at least 16 weeks. Adolescent girls aged under 12 or those unwilling to participate were excluded from the study.

This study employed a multistage sampling design, combining cluster random sampling and consecutive sampling. In the first stage, five schools were randomly selected as clusters from a total of 37 schools (32 state and five private junior high schools). However, one school declined to participate, therefore the study was completed at four schools. In the second stage, eligible participants were recruited consecutively from the selected schools until the required sample size (n

$= 400$) was reached. Inclusion criteria comprised adolescent girls who had attained menarche and had been taking iron supplements for at least four months (16 weeks). The sample size was determined using the formula proposed by Lwanga & Lemeshow (1991), which is appropriate for studies that compare two proportions.

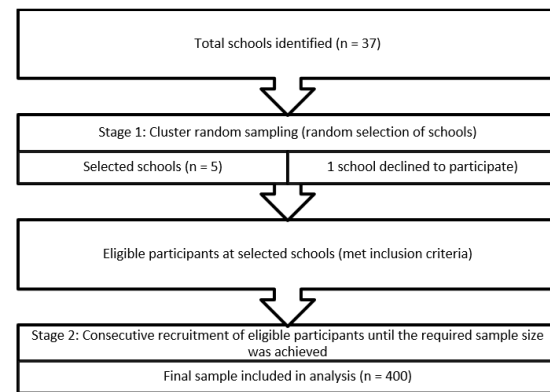


Figure 1. Flow diagram of the multistage sampling procedure used in this study

Several measures were implemented to minimize bias, including the use of validated instruments, pilot testing before data collection, anonymous self-administration through Google Forms to reduce social desirability bias, standardized instructions provided by trained enumerators, and mandatory responses to minimize missing data and ensure data completeness. Adolescent girls completed the questionnaire online using the survey form. Participants were asked to complete the questionnaire immediately after receiving instructions to minimize recall bias. To prevent missing data, all questions were set as mandatory. Before accessing the research questionnaire, participants were asked to read and understand the electronic informed consent included in the link and indicate their agreement to participate.

The research instrument comprised several components, including an adherence questionnaire with three items. Adherence was considered satisfactory if the respondent scored more than 2 and unsatisfactory if the score was less than 2 (Utomo et al., 2020). The knowledge questionnaire for adolescent girls regarding anemia prevention consisted of 20 items, and its validity and reliability were tested and confirmed, yielding a correlation coefficient of $r > 0.381$ and a Cronbach's alpha of 0.864. Knowledge was classified as good if the correct response rate exceeded 80% and poor if the score was below 80% (Dewanti, 2022). The questionnaire assessing adolescent

girls' attitudes toward anemia prevention included 10 items, with validity and reliability testing revealing a correlation coefficient of $r > 0.174$ and a Cronbach's alpha of 0.726. A positive attitude was indicated by a score of 50% or higher (30-50 points), while a negative attitude was indicated by a score below 50% (10-29 points) (Indriasari et al., 2022).

The questionnaire assessing the availability of iron supplements in schools comprised four items. A score greater than 3 indicated good availability of iron supplementation, while a score less than 3 indicated poor availability (Rahayuningtyas et al., 2021). The side effects questionnaire consisted of a single item. In adolescents, side effects were identified when one of the following three symptoms occurs after iron supplementation: stomach pain, nausea, or black stools (Ministry of Health of the Republic of Indonesia, 2018). The teacher support questionnaire comprised five items. Validity and reliability tests indicated a correlation coefficient (r) greater than 0.361 and a Cronbach's alpha (α) of 0.601. The family support questionnaire included seven questions, with validity and reliability tests revealing a correlation coefficient (r) greater than 0.361 and a Cronbach's alpha (α) of 0.920. The peer support questionnaire consisted of five items, and validity and reliability tests showed a correlation coefficient (r) greater than 0.361 and a Cronbach's alpha (α) of 0.639 (Utomo et al., 2020).

Descriptive statistics were used to examine the distribution of adherence to iron supplements, understanding of anemia, attitudes toward anemia, availability of iron supplements in schools, side effects, teacher support, family support, and peer support. Pearson's chi-square test was utilized to assess the relationships among these variables. Additionally, multiple logistic regression analyses were conducted to identify the factors most strongly associated with adherence to iron supplements. Statistical significance was set at $p < 0.05$. The study received approval from the Health Research Ethics Committee of Bani Saleh College of Health Sciences in Indonesia, under approval number EC.133/KEPK/STKBS/V/2023. Respondents were informed about the objectives and purposes of the study before data collection. Electronic informed consent was obtained from all participants before questionnaire completion.

RESULT AND DISCUSSION

Among the 400 adolescent girls included in this study, most were aged 14 years (57.3%), with

nearly half experiencing menarche at the age of 12 years (45.8%). Only 28.5% of participants demonstrated good adherence to iron supplementation. The majority of respondents had poor knowledge regarding anemia (89.8%), negative attitudes toward anemia prevention (70.0%), and perceived the availability of iron supplements at school as inadequate (71.3%). Most participants also reported experiencing side effects after iron supplementation (83.3%). In addition, inadequate family support (67.3%) and peer support (81.0%) were common among respondents, although teacher support was generally reported as good (63.0%) (Table 1).

Bivariate analysis demonstrated significant associations between attitude toward anemia, the availability of iron supplementation in schools, teacher support, family support, peer support, and adherence to iron supplementation ($p < 0.05$). However, no significant associations were found between knowledge and side effects with adherence behavior (Table 2).

Multivariable logistic regression analysis revealed that the availability of iron supplementation at school was the strongest factor associated with adherence (AOR=4.738; 95% CI=2.654–8.460). Peer support also showed a strong association with adherence (AOR=4.218; 95% CI=2.150–8.275), followed by family support (AOR=2.463; 95% CI=1.379–4.398), positive attitudes toward anemia (AOR=2.291; 95% CI=1.273–4.121), and teacher support (AOR=2.089; 95% CI=1.058–4.124) (Table 3).

This study identified several factors associated with adherence to iron supplementation among adolescent girls, including attitudes toward anemia, the availability of iron supplements at school, teacher support, family support, and peer support. The findings revealed a 71.5% non-adherence rate to iron supplementation among adolescent girls, indicating that adherence to iron tablet supplementation remains a substantial public health challenge in urban settings (Hidayanty et al., 2025). Among these factors, the availability of iron supplementation at school and peer support had the strongest associations with adherence behavior.

Adherence to iron supplementation among adolescent girls is influenced by a complex interplay of personal, social, environmental, and programmatic factors. This finding is consistent with previous studies reporting that adherence remains suboptimal across various settings and is shaped by multiple determinants operating at individual, social, and institutional levels. In Bekasi City, adherence behavior appears to be sha-

Table 1. Baseline characteristics and descriptive analysis of the study participants (n = 400)

Variable	Frequency (n)	Percentage (%)
Current age		
12 years old	16	4.0
13 years old	137	34.3
14 years old	229	57.3
15 years old	18	4.5
Age at first menstruation		
8 years old	1	0.3
9 years old	5	1.3
10 years old	34	8.5
11 years old	137	34.3
12 years old	183	45.8
13 years old	38	9.5
14 years old	2	0.5
Adherence		
Yes	114	28.5
No	286	71.5
Knowledge about anemia		
Good	41	10.3
Not good	359	89.8
Attitude towards anemia		
Positive	120	30.0
Negative	280	70.0
Availability of blood supplement tablets in schools		
Good	115	28.8
Not good	285	71.3
Adverse effects		
No	67	16.8
Yes	333	83.3
Teacher support		
Good	252	63.0
Not good	148	37.0
Family support		
Good	131	32.8
Not good	269	67.3
Peer support		
Good	76	19.0
Not good	324	81.0

ped not only by individual characteristics but also by access to school-based health services and the availability of social support within adolescents' immediate environments. These findings suggest that improving adherence requires a broader perspective that extends beyond individual-level determinants and incorporates contextual influences operating within schools and social networks (Apriningsih et al., 2020; Sari et al., 2022).

At the individual level, knowledge about anemia, beliefs regarding iron supplementation, and menstrual patterns have all been identified as important determinants of adherence. Although

most respondents had poor knowledge regarding anemia prevention, knowledge was not significantly associated with adherence to iron supplementation. This finding suggests that cognitive understanding alone may not be sufficient to influence preventive health behavior among adolescents. Similar findings have been reported in previous studies, indicating that knowledge does not always lead to consistent iron supplement consumption (Khomsan et al., 2025). In contrast, other studies found that adolescents with better knowledge were more likely to adhere to supplementation programs (Abebaw et al., 2020). These

Table 2. The bivariate chi-square analysis of factors associated with iron supplementation adherence (n = 400)

Variables	Iron supplementation adherence		OR (CI 95%)	P
	Good (%)	Poor (%)		
Predisposing Factors				
	Anemia knowledge			
Good	13 (31.7)	28 (68.3)	1.186	0.631
Poor*	101 (28.1)	258 (71.9)	(0.591 – 2.381)	
	Attitude towards Anemia			
Positive	45 (37.5)	75 (62.5)	1.835	0.009**
Negative*	69 (24.6)	211 (75.4)	(1.160 – 2.903)	
Enabling Factors				
	Iron supplementation availability in school			
Good	68 (59.1)	47 (40.9)	7.517	0.0001**
Poor*	46 (16.1)	239 (83.9)	(4.616 – 12.242)	
	Side effects			
Yes	17 (25.4)	50 (74.6)	0.827	0.534
No*	97 (29.1)	236 (70.9)	(0.454 – 1.506)	
Reinforcing Factors				
	Teacher support			
Good	99 (39.3)	153 (60.7)	5.737	0.0001**
Poor*	15 (10.1)	133 (89.9)	(3.178 – 10.357)	
	Family support			
Good	71 (54.2)	60 (45.8)	6.219	0.0001**
Poor*	43 (16.0)	226 (84.0)	(3.872 – 9.989)	
	Peer support			
Good	53 (69.7)	23 (30.3)	9.935	0.0001**
Poor*	61 (18.8)	263 (81.2)	(5.657 – 17.447)	

*Reference category. **Variables with $P < 0.2$, were entered in multiple logistic regression.

inconsistent findings imply that knowledge may function as a predisposing factor but requires reinforcing and enabling factors to facilitate behavioral change.

Among the predisposing factors examined, attitudes toward anemia prevention were the only factor that showed a significant relationship with adherence. Adolescent girls with positive attitudes were 2.29 times more likely to adhere to iron supplementation than those with negative attitudes. This finding is consistent with previous studies, which found that favorable perceptions regarding anemia and iron supplementation improve adherence among adolescent girls (Isnaini et al., 2024; Silitonga, Salim, Nurmala, Hargono, Notobroto, et al., 2023).

From a theoretical perspective, the findings of this study support the Health Belief Model (HBM), Social Cognitive Theory (SCT),

and Theory of Planned Behavior (TPB), which identify perceived benefits, beliefs regarding the effectiveness of health actions, and subjective acceptance as key determinants of behavioral intentions (Ajzen, 1991; Bandura, 1986; Rosenstock, 1974)1985, Ajzen, 1987. According to the HBM, individuals may fail to perform preventive health behaviors despite having adequate knowledge when perceived barriers outweigh perceived benefits (Rosenstock, 1974). Similarly, SCT explains that health behavior is shaped through reciprocal interactions among personal, environmental, and behavioral factors (Bandura, 1986). Empirical studies based on the TPB and the HBM shows that attitude formation and perceived benefits strengthen intentions to consume iron tablets, and TPB-based or HB-based interventions can improve both attitudes and adherence, HBM-based counseling interventions (Apriningsih et al.,

Table 3. The multivariable logistic regression to determine the association between predisposing, enabling, and reinforcing factors to iron supplementation adherence (n = 400)

Variables	Iron supplementation adherence		AOR (CI 95%)	P
	Good (%)	Poor (%)		
Attitude towards Anemia				
Positive	45 (37.5)	75 (62.5)	2.291	0.006***
Negative*	69 (24.6)	211 (75.4)	(1.273 – 4.121)	
Iron supplementation availability in school				
Good	68 (59.1)	47 (40.9)	4.738	0.0001***
Poor*	46 (16.1)	239 (83.9)	(2.654 – 8.460)	
Teacher support				
Good	99 (39.3)	153 (60.7)	2.089	0.034***
Poor*	15 (10.1)	133 (89.9)	(1.058 – 4.124)	
Family support				
Good	71 (54.2)	60 (45.8)	2.463	0.002***
Poor*	43 (16.0)	226 (84.0)	(1.379 – 4.398)	
Peer support				
Good	53 (69.7)	23 (30.3)	4.218	0.0001***
Poor*	61 (18.8)	263 (81.2)	(2.150 – 8.275)	

*Reference category. ***Variables with $P < 0.05$ in multiple logistic regression. Statistics: univariable chi-square and multivariable logistic regression

2020; Rakhshani et al., 2025). In the context of iron supplementation, positive attitudes may reflect adolescents' perceptions that iron tablets have practical benefits for their health, energy levels, and academic performance. In the present study, the availability of supplements at school and social support from peers, teachers, and families proved to have stronger influences on adherence than knowledge alone, suggesting that supportive environments may play a more substantial role in shaping adolescent behavior.

Adolescent health practices are strongly influenced by emotional responses, peer acceptance, social interactions, and daily routines within the school environment. Positive attitudes may encourage adolescents to incorporate iron supplementation into their daily routines, whereas negative attitudes may arise from misconceptions, fear of side effects, low perceived susceptibility to anemia, or the belief that supplementation is unnecessary in the absence of symptoms. Biologically, adolescents may also cease supplementation because iron tablets can cause gastrointestinal symptoms such as nausea, abdominal discomfort, constipation, and black stools, which may negatively influence perceptions of continued consumption (Ciont et al., 2025).

The availability of iron supplementation at school was identified as the strongest determinant of adherence in this study. Adolescents

who perceived supplement availability as adequate were substantially more likely to adhere to supplementation programs. This finding highlights the importance of enabling factors in promoting preventive health behavior. According to Green's PRECEDE-PROCEED Model, access to health resources and supportive environments are essential components that facilitate the adoption and maintenance of health behaviors (Green & Kreuter, 2005). Previous research has found that providing iron-folic acid supplements on a consistent basis enhances adherence among adolescents (Handiso et al., 2021). In school, readily accessible supplements may reduce practical barriers, facilitate routine consumption, and normalize supplementation behavior among peers.

Interestingly, this study found no significant association between side effects and adherence to iron supplementation. This finding differs from previous studies, which found that adverse gastrointestinal effects were important barriers to supplementation adherence (Kassa et al., 2019). One possible explanation is that the adolescents in this study perceived side effects as tolerable or temporary. Another possibility is that supportive social and school environments mitigated the negative influence of side effects on adherence behavior. Nevertheless, gastrointestinal symptoms remain clinically important because they may discourage long-term adherence if not

appropriately managed through counseling and education on proper iron tablet consumption.

Reinforcing factors, including teacher support, family support, and peer support were all significantly associated with adherence to iron supplementation. Adolescents who received adequate support from teachers, parents, and peers were more likely to adhere consistently to supplementation. Teachers may contribute by providing supervision, reminders, and health education during school-based supplementation activities. Family involvement may improve adherence through emotional encouragement, monitoring, and health-related communication at home. Peer support may also reinforce positive health practices through shared experiences, social modeling, and group influence. These findings are consistent with SCT, which emphasizes the importance of interpersonal reinforcement and observational learning in shaping health behavior (Bandura, 1986).

The strong influence of peer support observed in this study is particularly relevant throughout adolescence, a developmental stage characterized by increased peer conformity and social dependence. Adolescents are more likely to adopt behaviors that are socially accepted within their peer groups. Therefore, peer-led interventions and adolescent health ambassador programs may represent effective strategies for improving adherence to iron supplementation programs.

The findings of this study have important implications for public health policy and school-based anemia prevention programs. Educational interventions alone may not be sufficient to improve adherence behavior if adolescents continue to face environmental and social barriers. Schools and community health centers should therefore integrate health education with supportive strategies, including consistent supplement distribution, teacher involvement, family engagement, peer-support initiatives, and monitoring systems. Interactive and behavior-oriented educational approaches may also be more effective than conventional information delivery methods in promoting sustainable adherence among adolescent girls.

Critically, this study contains several limitations that should be considered when evaluating the findings. The cross-sectional design limits causal inferences regarding the relationships between the associated factors and adherence behavior. In addition, adherence and related factors were assessed using self-reported questionnaires, which may introduce recall bias and social

desirability bias. The study was conducted in a single sub-district of Bekasi City, which may limit the direct generalizability of the findings to other geographic or rural settings. However, East Bekasi is a densely populated urban district with a heterogeneous school environment, allowing the findings to provide relevant insights for similar urban and metropolitan contexts. Furthermore, broader contextual factors such as cultural beliefs, school policy implementation, media exposure, and socioeconomic conditions were not comprehensively explored. Therefore, future studies should use longitudinal or mixed-method approaches to better understand the complex interaction among behavioral, social, environmental, and structural determinants influencing iron supplementation adherence among adolescent girls.

CONCLUSION

This study identified that the availability of iron supplementation at school, peer support, family support, teacher support, and attitudes toward anemia were significantly associated with adherence to iron supplementation among adolescent girls. Among these factors, the availability of iron supplements in schools and peer support demonstrated the strongest associations with adherence behavior, highlighting the important role of supportive environments and social reinforcement in promoting adherence among adolescents. The findings suggest that improving knowledge alone may not be sufficient to increase adherence to iron supplementation programs. Comprehensive interventions that integrate accessible supplementation services, school support, family involvement, peer engagement, and behavior-oriented health education are needed to strengthen adherence among adolescent girls. Strengthening collaboration between schools and community health centers is also essential to ensure the effective implementation, supervision, and monitoring of school-based iron supplementation programs and to support adolescent anemia prevention efforts.

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DECLARATION OF GENERATIVE AI

This manuscript received limited assistance from an AI-based language tool (Quillbot and ChatGPT) for language refinement and grammar checking. The authors critically reviewed and finalized all content and accept full responsibility for the published work. No AI tools were used in data analysis or the interpretation of findings.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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