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The role of iron enhancer intake frequency in iron-deficiency anemia among adolescent girls in Purwokerto

Peran frekuensi konsumsi enhancer zat besi terhadap anemia defisiensi zat besi pada remaja putri di Purwokerto

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Abstract

Iron-deficiency anemia remains a critical health concern among adolescents, primarily influenced by dietary patterns that affect the bioavailability of iron. A 2023 screening in the Banyumas District reported a 36.7% prevalence of anemia among adolescent girls. This cross-sectional analytical study, conducted from August to September 2025, aimed to examine the association between the frequency and timing of meals of dietary iron enhancers and inhibitors and the risk of iron-deficiency anemia. Seventy-eight female students aged 14–17 years were selected using proportional purposive sampling. Hemoglobin levels were measured using a Hemoglobin Meter, with anemia defined as Hb <12 g/dL. Dietary intake was assessed using a Food Frequency Questionnaire (FFQ) and 24-hour recalls, focusing on enhancer intake frequency (rarely: score <2.1; frequently: score ≥2.1) and the timing of consumption for both enhancers and inhibitors. Data analysis employed Chi-square and Fisher's exact tests, with associations reported as Prevalence Ratios (PR). The prevalence of anemia was 39.3%. Frequent consumption of iron enhancers significantly reduced the risk of anemia by 84.7% compared with rare intake (PR = 0.153, p = 0.016). Conversely, frequent intake of inhibitors increased the odds of anemia (OR = 2.315, p = 0.008). Meal timing for both enhancers and inhibitors showed no significant association with anemia (p > 0.05). In conclusion, the frequency of iron enhancer intake is the primary dietary factor influencing anemia risk, outweighing the significance of its timing of consumption.

Keywords: Iron deficiency anemia, Adolescents, Iron enhancers, Iron inhibitors, School-based study

Abstrak

Anemia defisiensi besi tetap menjadi tantangan kesehatan masyarakat yang serius pada remaja, terutama dipicu oleh pola makan yang mempengaruhi asupan dan penyerapan besi. Survei hemoglobin tahun 2023 di Kabupaten Banyumas menunjukkan prevalensi anemia 36,7% pada remaja putri. Penelitian ini bertujuan menganalisis hubungan frekuensi dan waktu konsumsi *enhancer* serta *inhibitor* besi dengan kejadian anemia defisiensi besi. Studi observasional analitik dengan desain potong lintang ini dilakukan Agustus–September 2025 terhadap 78 siswi berusia 14–17 tahun yang dipilih secara *proportional purposive*. Kadar hemoglobin diukur dengan Hemoglobin Meter (anemia: Hb <12 g/dL), sedangkan pola makan dinilai menggunakan FFQ dan recall 24 jam. Asupan enhancer besi dikategorikan menjadi Jarang (skor <2,1) dan Sering (skor ≥2,1). Waktu konsumsi *enhancer* (saat atau <1 jam setelah makan) dan *inhibitor* (<1 jam atau >1 jam setelah makan) juga dinilai. Analisis data menggunakan uji *Chi-Square/Fisher's Exact* dengan *Prevalence Ratio* (PR). Prevalensi anemia adalah 39,3%. Konsumsi *enhancer* yang sering secara signifikan menurunkan risiko anemia sebesar 84,7% dibandingkan konsumsi jarang (PR=0,153; p=0,016). Sebaliknya, asupan inhibitor yang sering meningkatkan odds anemia

(OR=2,315; p=0,008). Waktu konsumsi *enhancer* dan *inhibitor* tidak berhubungan signifikan dengan anemia (p>0,05). Disimpulkan bahwa frekuensi asupan *enhancer* besi merupakan faktor diet kunci yang mempengaruhi anemia, lebih penting daripada waktu konsumsinya.

Kata Kunci: Anemia defisiensi besi; Remaja; Asupan penghambat zat besi; Asupan penguat zat besi; Studi berbasis sekolah

Introduction

Iron-deficiency anemia (Hb <12 g/dL), which impairs oxygen transport (Nair et al., 2016), remains a significant health concern among adolescent girls, primarily due to inadequate dietary iron intake and absorption (Kumar et al., 2022). In Indonesia, national health surveys have reported a 15.5% prevalence of anemia among women aged 15–24 years (Kementerian Kesehatan [Kemenkes], 2023). However, provincial-level assessments indicate higher localized burdens; for example, hemoglobin screening in the Banyumas District, Central Java, in 2023 identified anemia in 36.7% of adolescent girls (Dinas Kesehatan Provinsi Jawa Tengah, 2023). If unaddressed, anemia can impair immunity, physical capacity, cognitive function and academic performance (Samson et al., 2022).

The risk factors for iron-deficiency anemia include inadequate iron intake, irregular eating patterns, and inappropriate consumption of iron absorption enhancers and inhibitors (Zulfikar et al., 2025). During adolescence, iron requirements increase substantially because of rapid growth and menstruation. Therefore, dietary iron needs to be supported by enhancers such as vitamins C and A (Marya, 2013; Wahyurin & Rahmah, 2021). Conversely, inhibitors, including tannins, caffeine, phytates, and calcium, can reduce iron absorption when consumed alongside iron-rich foods (Kolarš et al., 2025).

Many adolescent girls exhibit unfavorable dietary behaviors, characterized by infrequent consumption of iron enhancers (e.g., vitamin C-rich fruits) and frequent intake of inhibitors, often due to restrictive diets or meal skipping practices (Al Rahmad, 2023; Wati et al., 2023). Evidence suggests that maintaining at least a 30-minute interval between inhibitor intake and main meals improves iron absorption, whereas consuming tea with meals can reduce non-heme iron absorption by up to 37% (Ahmad et al., 2017).

In West Purwokerto, 24.3% of adolescent girls are affected by anemia, with students at SMK Muhammadiyah 1 Purwokerto exhibiting the highest prevalence: 59.3% of the 10th graders show signs of anemia. While previous studies have largely focused on the quantity and frequency of iron consumption, the timing of enhancer and inhibitor consumption relative to meals has been underexplored. Consequently, evidence is limited regarding the temporal patterns of these dietary factors and their effects on iron status and anemia risk.

To address this gap, the present study examined both the frequency and meal timing of iron enhancer and inhibitor intake, providing a novel perspective on dietary behavior. This comprehensive approach may inform more precise and targeted interventions to prevent anemia in adolescent girls. Accordingly, this study aimed to analyze the relationship between the frequency and timing of iron enhancer and inhibitor consumption and the occurrence of iron-deficiency anemia among students at SMK Muhammadiyah 1 Purwokerto, with the strength of association measured using Prevalence Ratios (PR).

Methods

This analytical observational study employed a cross-sectional design to examine the relationship between the frequency and timing of iron enhancer and inhibitor consumption and the occurrence of iron-deficiency anemia. The study was conducted at SMK Muhammadiyah 1 Purwokerto between August and September 2025.

The total population included all 132 female tenth-grade students. Participants were selected using proportional purposive sampling based on specific inclusion criteria: aged 14–17 years and willingness to participate in the study. The exclusion criteria included girls who were menstruating during data collection to avoid the confounding effects of menstrual blood loss on hemoglobin levels and those who did not complete all the study procedures. Sample size

calculation using the Lemeshow formula indicated that a minimum of 71 participants was required for the study. Accounting for a 10% potential dropout rate, the final sample size was 78 participants.

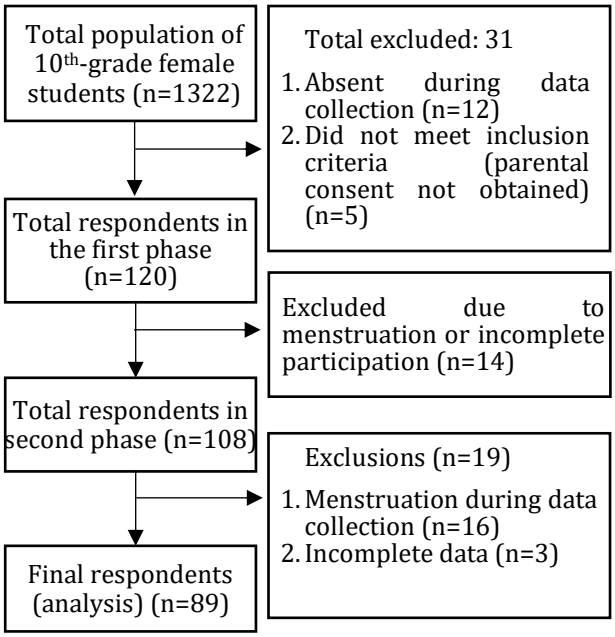


Figure 1. Participant flow diagram

The study assessed both the frequency and meal-timing patterns of consuming iron absorption enhancers (e.g., vitamin C-rich foods, vitamin A-rich foods, and certain animal proteins) and inhibitors (e.g., tea, coffee, milk, chocolate, and certain legumes) using a Food Frequency Questionnaire (FFQ) and 24-hour dietary recalls. Hemoglobin levels were measured from capillary fingertip blood using a calibrated BeneCheck Hemoglobin Meter, with anemia defined as Hb <12 g/dL according to the World Health Organization (WHO) reference standard.

Data were collected in two sessions. The first session included hemoglobin measurement, assessment of participant characteristics, and a weekday 24-hour dietary recall interview. The second session consisted of a 24-hour dietary recall on a weekend and the FFQ covering the previous month. Primary data sources included hemoglobin measurements, anthropometric assessments, and dietary interviews, while secondary data were obtained from school profiles and records of female students in the tenth grade.

Univariate analysis was used to describe the distribution of participant characteristics. Bivariate analysis examined the crude association between each independent variable and anemia using the chi-square test or Fisher's exact test (for expected cell counts <5). The strength of associations was expressed as Prevalence Ratios (PR) with 95% confidence intervals to identify variables acting as risk or protective factors.

This study was approved by the Health Research Ethics Committee of the Faculty of Health Sciences, Universitas Jenderal Soedirman (No. 1905/EC/KEPK/VIII/2025). This study adhered to ethical principles for health research involving human participants, including respect for autonomy, beneficence, non-maleficence, and justice. All participants provided informed consent prior to their participation in the study.

Result and Discussion

Table 1 shows that most respondents were aged 14–15 years (79.8%), and nearly all lived with their parents or family (97.8%). More than half of the participants had a monthly allowance of ≥ IDR 360,000 (52.8%). The majority reported no history of weekly iron-folic acid (IFA) consumption (93.3%) or daily IFA intake during menstruation (94.4%). Most respondents had a normal nutritional status (79.8%), while 4.5% were underweight and 15.7% were classified as overweight or obese. The prevalence of anemia was 39.3% (Hb <12 g/dL).

Regarding dietary patterns, 52.8% of the participants frequently consumed iron enhancers, and 52.8% frequently consumed iron inhibitors. Most respondents consumed enhancers during meals (77.5%) and inhibitors less than one hour after meals (85.5%).

Table 1. Characteristics of Respondents

Variable	n	%
Age		
14-15 years	71	79.8
16-17 years	18	20.2
Living Arrangement		
Boarding/independent living	2	2.2
Living with parents/family	87	97.8
Monthly Allowance		
< IDR 360,000	42	47.2
≥ IDR 360,000	47	52.8
History of Weekly Iron-Folic Acid (IFA) Consumption		
No	83	93.3

Yes	6	6.7
History of Daily IFA Consumption During Menstruation		
No	84	94.4
Yes	5	5.6
Nutritional Status		
Underweight (-3 SD to < -2 SD)	4	4.5
Normal (-2 SD to +1 SD)	71	79.8
Overweight (+1 SD to +2 SD)	10	11.2
Obesity (> +2 SD)	4	4.5
Anemia Status		
Anemia (Hb <12 g/dL)	35	39.3
Not anemic (Hb ≥12 g/dL)	54	60.7
Iron Enhancer Intake (Frequency)		
Rarely (score < 2.1)	42	47.2
Frequently (score ≥ 2.1)	47	52.8
Timing of Iron Enhancer Intake		
During meals	69	77.5
<1 hour after meals	20	22.5
Timing of Iron Inhibitor Intake		
<1 hour after meals	77	85.5
>1 hour after meals	12	13.5

As shown in Table 2, the frequency of iron enhancer consumption was significantly associated with iron-deficiency anemia (p = 0.016). Respondents who frequently consumed enhancers had a higher prevalence of anemia (51.1%) than those who rarely consumed them (26.2%). This finding aligns with previous studies by Wahyurin and Rahmah (2021), which demonstrated a significant relationship between the consumption of iron enhancers and anemia among adolescent girls in the Banyumas Regency. Similarly, Skolmowska and Głąbska (2022) reported that vitamin C intake was associated with anemia, further supporting our results of the present study.

Analysis of the one-month Food Frequency Questionnaire (FFQ) revealed that a substantial proportion of respondents regularly consumed chicken (39.3%), oranges (25.8%), and watermelon (24.7%) at a frequency of 1–2 times per week, and eggs (38.2%) at 3–6 times per week. Repeated consumption of these foods likely contributes to the increased bioavailability of non-heme iron through enhancer components such as vitamin C and animal protein (Ruelas et al., 2025).

The prevalence ratio (PR = 0.153) indicated a protective effect; specifically, respondents who rarely consumed iron enhancers had an 84.7% lower risk of developing iron-deficiency anemia than those who frequently consumed enhancers. This underscores the critical role of dietary iron enhancers in modulating the risk of anemia in adolescent girls.

Table 2. Bivariate analysis of enhancer and inhibitor intake in relation to anemia

Variable	Iron Deficiency Anemia		Total	P-value	PR
	Anemia	Not Anemic			
	n (%)	n (%)	n (%)		
Frequency of Iron Enhancer Consumption					
Rare (<2.1)	11 (26.2)	31 (73.9)	42 (100)	0.016	0.153
Frequent (≥2.1)	24 (51.1)	23 (48.9)	47 (100)		
Frequency of Iron Inhibitor Consumption					
Frequent	25 (52.1)	23 (47.9)	48 (100)	0.008	2.315
Rare	10 (24.4)	31 (75.9)	41 (100)		
Timing of Iron Enhancer Consumption					
<1 hour after meals	7 (35)	13 (65)	20 (100)	0.653	-*
During meals	28 (40.6)	41 (59.4)	69 (100)		
Timing of Iron Inhibitor Consumption					
<1 hour after meals	30 (39)	47 (61)	77 (100)	1.00	-*
>1 hour after meals	5 (41.7)	7 (58.3)	12 (100)		

*Timing of consumption: Not significant (p > 0.05); PR not calculated

The frequency of iron inhibitor consumption was significantly associated with anemia (p = 0.008). Respondents who frequently consumed inhibitors had a higher prevalence of

anemia (52.1%) than those who rarely consumed them (24.4%). This finding can be explained by the presence of compounds such as tannins in tea and coffee, calcium in milk, and polyphenols and phytates in plant-based foods, which form complexes with dietary iron and reduce its absorption. These interactions decrease the bioavailability of iron, leading to lower hemoglobin levels and contributing to iron deficiency anemia (Piskin et al., 2022). Observational and interview data indicated that 39.4% of the respondents consumed tea, milk, or coffee daily, typically obtained from school canteens or nearby vendors. FFQ data further showed that tea (37.1%), cow's milk (31.5%), and coffee (15.7%) were consumed 1–2 times per week, whereas long beans (18%) and chocolate (14.6%) were consumed 1–2 times per month.

Table 2 indicates that the timing of iron-enhancer consumption was not significantly associated with anemia ($p = 0.653$). Respondents consuming enhancers during meals and those consuming them within one hour after meals exhibited similar anemia prevalence (40.6% vs. 35%). This lack of association may be related to eating habits. Two rounds of 24-hour food recalls showed that most respondents consumed enhancers with main meals, but in relatively small amounts. For example, a balanced *Program Makan Bergizi Gratis (MBG)* includes one serving of fruit (100 g); however, respondents consumed only half a serving of oranges, providing insufficient vitamin C to optimize iron absorption (Kemenkes, 2014). This suggests that although the timing was appropriate, the small quantity of enhancers limited their effectiveness in improving the iron status.

Consuming enhancers with main meals can enhance the bioavailability of non-heme iron via multiple mechanisms. For instance, vitamin C-rich foods, such as guava, when consumed with mung beans, can significantly increase hemoglobin levels and reduce the prevalence of anemia (Rani et al., 2024). Vitamin C facilitates the reduction of ferric iron to the more soluble ferrous form, stabilizing it in the intestinal environment and enhancing its availability for hemoglobin synthesis, thereby preventing iron deficiency anemia (Piskin et al., 2022b).

Similarly, the timing of iron inhibitor consumption was not significantly associated with anemia ($p = 1.000$). Anemia prevalence was comparable among respondents consuming inhibitors less than one hour (39%) and more than one hour (41.7%) after meals. This can be attributed to the respondents' patterns of inhibitor consumption throughout the day rather than at specific meal times. Both weekday and weekend 24-hour recalls revealed that tea, coffee, and milk were consumed before meals, during school breaks, and outside the main meals. For example, one participant consumed chocolate and cheese for more than three hours before the main meal (11:00 AM), drank tea during a school break (11:00 AM), and consumed chocolate milk for more than one hour after the main meal (3:00 PM). This overlapping consumption reduced the differentiation between timing categories, making meal timing insufficient as a distinguishing factor for the risk of anemia.

Findings from Lee (2023) suggest that the consumption of coffee and green tea is not consistently associated with hemoglobin levels but may influence iron stores, particularly ferritin. Similarly, Nyakundi et al. (2024) and Yani et al. (2023) was reported that high tea consumption patterns are associated with an increased risk of iron deficiency in women of reproductive age. These effects are attributed to the polyphenols in tea, which can inhibit iron absorption, especially when consumed close to main meals.

This study has several limitations. The cross-sectional design restricted the ability to infer causal relationships between dietary factors and anemia. Dietary intake data collected through FFQ and repeated 24-hour recalls are susceptible to recall bias and measurement errors. Iron deficiency assessment was based solely on hemoglobin levels without confirmation using specific biochemical markers such as serum ferritin. Additionally, analyses were limited to bivariate associations and did not adjust for potential confounders, including nutritional status, IFA supplementation history, or menstrual characteristics using multivariate techniques. Therefore, these results should be interpreted with caution and require validation through longitudinal or interventional studies to establish causality and provide more robust evidence.

Conclusion

This study found that the frequency of iron enhancer and inhibitor consumption was

significantly associated with iron-deficiency anemia, whereas the timing of inhibitor intake and the timing of enhancer consumption showed no significant association.

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