

RESEARCH STUDY

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The Relationship Between Iron Intake, Vitamin C, and Body Fat Percentage with the Incidence of Anemia in Adolescent Girls at Askhabul Kahfi Islamic Boarding School Semarang City

Hubungan Asupan Zat Besi, Vitamin C, dan Persen Lemak Tubuh dengan Kejadian Anemia pada Remaja Putri di Pondok Pesantren Askhabul Kahfi Kota Semarang

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ABSTRACT

Background: Anemia is a medical condition that arises from a deficiency of certain nutrients and is commonly observed in both developed and developing countries. Deficiencies in essential nutrients, such as iron, folic acid, protein, and vitamin C, are frequent causes of anemia in adolescents. Additionally, other factors, including body fat percentage, may also contribute to the condition.

Objectives: To analyze the relationship between iron intake, vitamin C intake, and body fat percentage among adolescent girls at Askhabul Kahfi Islamic Boarding School in Semarang City.

Methods: This cross-sectional study involved 65 adolescent girls selected using proportionate stratified sampling. Iron and vitamin C intake data were collected through interviews using the SQ-FFQ. Body fat percentage was measured using the Omron HBF-212 BIA device, and anemia was diagnosed based on hemoglobin levels using the EasyTouch GCHb device. Bivariate analysis was conducted with the Gamma correlation test, and multivariate analysis used ordinal logistic regression.

Results: Among the respondents, 33 (50.8%) had adequate iron intake, 35 (53.2%) had adequate vitamin C intake, 43 (66.2%) had normal body fat percentages, and 42 (64.6%) were not anemia. A significant relationship was found between iron intake (p-value = 0.010) and body fat percentage (p-value = 0.009) with anemia incidence. No significant relationship was found between vitamin C intake (p-value = 0.095) and anemia.

Conclusions: Iron intake and body fat percentage are significantly relationship with anemia in adolescent girls, with iron intake being the most influential factor.

INTRODUCTION

Anemia is a medical condition that arises due to deficiencies in certain nutrients and is commonly found in both developed and developing countries. Anemia is characterized by low hemoglobin levels in the blood compared to normal thresholds, which prevents the blood from carrying sufficient oxygen throughout the body, resulting in impaired oxygen distribution necessary to support optimal body functions¹. Compared to males, females are more likely to experience anemia due to the regular loss of blood during menstruation, which increases the likelihood of hemoglobin deficiency². In adolescent girls, hemoglobin levels are considered normal if they are ≥ 12 grams/dL³. At the national level, the 2018 Riskesdas survey reported that 32% of females aged 15 to 24 suffer from anemia⁴. In Central Java, the anemia screening results for adolescent girls by the Provincial Health Office up to December 2023 showed an

anemia prevalence rate of 30,45%, while in Semarang City, the figure reached 15,48%⁵.

Deficiencies in essential nutrients such as iron, folic acid, protein, and vitamin C are often factors contributing to adolescent anemia⁶. Iron deficiency anemia (IDA) is the most common type⁷. Iron plays a crucial role in the body for hemoglobin production⁸. If iron intake does not meet physiological needs or if iron absorption is impaired, it can lead to disruptions in iron homeostasis and contribute to the development of iron deficiency anemia⁹. A study by Herlinadiyaningsih and Susilo showed that iron deficiency anemia can occur due to insufficient iron intake in the body¹⁰.

Vitamin C plays a substantial role in increasing hemoglobin levels in the body. By reducing Fe³⁺ ions to Fe²⁺, vitamin C contributes to enhancing iron absorption in the small intestine, as Fe²⁺ is more bioavailable⁹. In a study conducted by Alfiah and Dainy, adolescents with

optimal vitamin C intake showed better tendencies towards anemia status compared to those who did not receive adequate intake. These findings emphasize that vitamin C sufficiency serves as an essential cofactor in the iron absorption process, contributing to the prevention of anemia caused by iron deficiency¹¹.

In addition to dietary intake, body fat percentage can also affect hemoglobin levels. This occurs because excess fat in the body can trigger the release of proinflammatory cytokines that increase hepcidin production¹². When hepcidin levels rise, it binds to the ferroportin protein, which functions as a channel for iron release into the bloodstream^{13,14}. As a result, ferroportin is internalized and degraded, thereby inhibiting the release of iron from storage cells. The decrease in plasma iron levels leads to a reduced availability of iron, which is crucial for hemoglobin synthesis¹⁵. A study by Acharya et al. showed a relationship between body fat percentage and the occurrence of anemia in adolescents¹⁶.

The incidence of anemia in adolescents remains relatively high, and its significant impact makes it an important health issue that requires special attention, particularly for adolescent girls who will become future mothers. Anemia has serious consequences for the health of adolescent girls, including a weakened immune system, physical growth disturbances, impaired intellectual development, decreased physical fitness, and reduced learning ability, as well as facing anemia during pregnancy in the future². Anemia during the pregnancy can increase the risk of complications, such as issues with fetal growth and development, preterm labor, and low birth weight¹⁷.

Unlike previous studies, this research focuses on the population of adolescent girls in Islamic boarding schools, which have unique characteristics in terms of diet, physical activity, and access to healthcare facilities. Islamic boarding schools, with their strict regulations on meal schedules and daily activities, offer a unique context that anemia research has not widely explored. A preliminary study at Askhabul Kahfi Islamic Boarding School in Semarang City revealed that several adolescent girls displayed symptoms of anemia, including weakness, fatigue, and dizziness, while engaging in daily activities. These symptoms suggest a possible deficiency in essential nutrients, particularly iron, which requires further attention in the context of dietary patterns and lifestyle habits within the boarding school environment.

In terms of dietary patterns, there are several issues indicating that many adolescent girls consume a diet that lacks essential nutrients, including inadequate intake of animal-based protein as a source of iron, particularly heme iron, as well as insufficient consumption of fruits and vegetables as sources of vitamin C. Although vegetables and fruits are available in the meal menu, many adolescent girls are reluctant to consume them. The provision of iron supplements initiated by the local health center for adolescent girls at the Islamic boarding school has not yielded the desired results, due to difficulties in monitoring and the unwillingness of the girls to take the supplements. Therefore, the researcher is motivated to further investigate the determinants of anemia, specifically exploring the relationship between iron intake, vitamin C

intake, and body fat percentage with the occurrence of anemia in adolescent girls at Askhabul Kahfi Islamic Boarding School in Semarang City.

METHODS

This study was designed with a quantitative descriptive approach and uses an analytical observational method to examine the relationships between variables. The design applied was cross-sectional, where data for both independent and dependent variables are collected simultaneously without remeasurement¹⁸. The study was scheduled to take place in July 2024, based on ethical approval from the Health Research Ethics Committee of the Faculty of Medicine, Semarang State University (UNNES), as stated in the approval number 258/KEPK/FK/KLE/2024, issued on June 21, 2024.

This study examined a population of adolescent girls aged 16-18 years at Askhabul Kahfi Islamic Boarding School in Semarang City, consisting of 290 individuals. Using the Lemeshow formula, the sample size was determined to be 65 participants, with a proportionate stratified sampling method. This method was used to ensure that each stratum or group is proportionally represented^{19,20}. In this study, the samples were grouped based on their grade levels.

This study used independent variables such as iron intake, vitamin C intake, and body fat percentage, with anemia in adolescent girls as the dependent variable. Iron and vitamin C intake data were obtained through interviews using the SQ-FFQ questionnaire, with intake categorized as inadequate if <77% of the Recommended Dietary Allowance (RDA) and adequate if ≥77% of the RDA²¹. Body fat percentage was measured using the BIA Omron HBF-212, with categories including low (5,0–19,9%), normal (20,0–29,9%), high (30,0–34,9%), and very high (35,0–50,0%)^{22,23}. Anemia status in this study was determined by measuring hemoglobin levels with the EasyTouch GChb device, chosen for its measurement accuracy, which closely aligns with the Cyanmethemoglobin method without significant differences^{24,25}. The anemia status categories used are severe anemia (<8,0 g/dL), moderate anemia (8,0–10,9 g/dL), mild anemia (11,0–11,9 g/dL), and no anemia (≥12,0 g/dL)³.

After the data was collected, the next step was to summarize the information using Microsoft Excel. Analysis was performed with the help of SPSS version 25, which included univariate analysis, bivariate analysis with the Gamma test, and multivariate analysis through ordinal logistic regression.

RESULTS AND DISCUSSIONS

Respondent Characteristics

In Table 1, the results of the univariate analysis showed that the XII grade group was the largest among the respondents, with 26 individuals (40,0%). Most of the respondents were 17 years old, with 25 individuals (38,5%). A total of 39 respondents (60,0%) did not consume iron supplements. Regarding nutritional intake, 33 respondents (50,8%) received adequate iron, and 35 respondents (53,8%) received adequate vitamin C. In terms of body fat percentage, most respondents, 43 individuals (66,2%), fall within the normal category. More

than half of the respondents, 42 individuals (64,6%), did not have anemia.

Table 1. Respondent Characteristics Data

Variable	Category	N	%
Class Level	Class X	22	33,8
	Class XI	17	26,2
	Class XII	26	40,0
	Total	65	100,0
Respondent Age	16 Years	22	33,8
	17 Years	25	38,5
	18 Years	18	27,7
	Total	65	100,0
Iron Supplement Intake	Yes	26	40,0
	No	39	60,0
	Total	65	100,0
Iron Intake	Inadequate	32	49,2
	Adequate	33	50,8
	Total	65	100,0
Vitamin C Intake	Inadequate	30	46,2
	Adequate	35	53,8
	Total	65	100,0
Body Fat Percentage	Low	3	4,6
	Normal	43	66,2
	High	14	21,5
	Very High	5	7,7
	Total	65	100,0
Anemia Status	Moderate Anemia	8	12,3
	Mild Anemia	15	23,1
	No Anemia	42	64,6
	Total	65	100,0

n: Number of respondents; %: Percentage of respondents

Data on iron intake were obtained through interviews using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ), supported by portion size booklets to assist respondents in providing accurate answers. The collected information was then analyzed using the Indonesian Food Composition Table (TKPI) from 2017. Based on the univariate analysis presented in Table 1, most respondents, totaling 33 individuals (50.8%), had adequate iron intake. This finding aligns with studies by Kusumawati et al. and Fitripancari et al., which also reported a high number of respondents with adequate iron intake in their respective populations^{26,27}. However, the results of this study contrast with findings by Emilia and Cia et al., who documented that many respondents had inadequate iron intake^{28,29}.

Iron intake among adolescent girls at Askhabul Kahfi Islamic Boarding School primarily stems from their habit of purchasing various types of food from the school canteen. Commonly purchased foods include chicken noodle soup, rice with chicken liver and gizzard, spicy fried chicken, fried eggs, and snacks such as grilled sausages and meatballs. Within the boarding school's menu, animal-based protein sources like fish stew, eggs, and chicken are served twice weekly, specifically on Wednesdays and Saturdays. Other sources of iron intake come from plant-based dishes, such as tempeh and tofu, which are served daily. Additionally, some parents living near the school bring animal-based dishes during their visits on Sundays, further supplementing the girls' iron intake. The boarding school also provides iron

supplementation in the form of iron tablets supplied by the local health center (Puskesmas). These are distributed in packs to each dorm room at specific intervals. However, not all respondents consume these supplements. Some reported experiencing side effects such as dizziness and nausea after taking them. This has contributed to inadequate iron intake among certain adolescent girls in the Islamic boarding school.

The vitamin C intake of the majority of respondents in this study was categorized as adequate, with 35 respondents (53.8%) falling into this category. These findings align with those reported by Sholihah et al. and Pradanti et al., where many respondents demonstrated adequate vitamin C intake^{30,31}. However, studies by Sholicha and Muniroh, as well as Permatasari et al., revealed contrasting results, indicating that the majority of their respondents had inadequate vitamin C intake^{32,33}.

Based on the dietary intake data collected using the SQ-FFQ, some adolescent girls at the Askhabul Kahfi Islamic Boarding School occasionally purchased packaged beverages containing vitamin C, such as Nutrisari and Sunkist, although the frequency was very low. Additionally, some respondents bought cut fruits like watermelon, melon, and papaya, which were occasionally available at the school canteen. However, their primary source of vitamin C came from vegetables served as daily side dishes at the boarding school. These vegetables often include chayote, water spinach, eggplant, mustard greens, and spinach, which were part

of the school's regular meal cycle. Furthermore, parents who visited the boarding school at certain times brought various fruits, such as oranges, for their children, contributing to an increase in their vitamin C intake. Despite these sources, many adolescent girls still failed to meet adequate vitamin C intake levels. Reasons for this included a general dislike for vegetables and fruits among some respondents and a tendency for others to be selective or picky about the types of vegetables they were willing to consume.

Body fat percentage refers to the proportion of fat in an individual's body compared to their total body weight. According to the data collected, most respondents at the Askhabul Kahfi Islamic Boarding School fell into the normal category for body fat percentage, with 43 respondents (66.2%). This finding aligns closely with studies conducted by Virginia and Fenty as well as Bagni et al., where the majority of respondents also exhibited normal body fat percentages^{34,35}. However, research by Sal et al. and Jordaan et al. presented contrasting results, with respondents in the normal body fat category being a minority^{14,36}.

The habit of consuming fried foods, which are rich in calories and fats, contributes to an increase in body fat percentage among adolescent girls at the Askhabul Kahfi Islamic Boarding School. During parent visits, many families bring additional fried dishes and snacks, further

increasing calorie and fat intake for these adolescents. Another factor contributing to elevated body fat percentages is the limited physical activity within the boarding school environment. Life at the boarding school tends to be sedentary, with minimal daily physical activity. Organized sports or physical exercises are practiced only biweekly due to alternating schedules with theoretical sports lessons. This lack of regular physical activity significantly impacts body fat accumulation.

Anemia conditions in adolescent girls can be identified through hemoglobin level measurements, performed using capillary blood samples analyzed with the EasyTouch GCHb digital device. The majority of adolescent girls at the Askhabul Kahfi Islamic Boarding School were found not to be anemia, with 42 respondents (64.6%) categorized as non anemia. These findings align with those of Hardiansyah et al. and Kusumawati et al., who reported that most respondents in their studies had normal hemoglobin levels, indicating the absence of anemia^{26,37}. This may be attributed to various factors, such as respondents not being in their menstrual periods during the measurement and consuming adequate nutrition, particularly iron. Additionally, some respondents were noted to regularly take iron supplements, which contributed to maintaining normal hemoglobin levels and reducing the risk of anemia.

Table 2. Bivariate Test Results of Iron Intake, Vitamin C, and Body Fat Percentage with Anemia Occurrence

Variable		Anemia			p-value	Correlation Coefficient
		Moderate Anemia	Mild Anemia	Non Anemia		
		n (%)	n (%)	n (%)		
Iron Intake	Inadequate	6 (18,8)	10 (31,3)	16 (50,0)	0,010*	0,543
	Adequate	2 (6,1)	5 (15,2)	26 (78,8)		
	Total	8 (12,3)	15 (23,1)	42 (64,6)		
Vitamin C Intake	Inadequate	7 (23,3)	6 (20,0)	17 (56,7)	0,095	0,376
	Adequate	1 (2,9)	9 (25,7)	25 (71,4)		
	Total	8 (12,3)	15 (23,1)	42 (64,6)		
Body Fat Percentage	Low	0 (0,0)	1 (33,3)	2 (66,7)	0,009*	-0,496
	Normal	4 (9,3)	6 (14,0)	33 (76,7)		
	High	3 (21,4)	6 (42,9)	5 (35,7)		
	Very High	1 (20,0)	2 (40,0)	2 (40,0)		
	Total	8 (12,3)	15 (23,1)	42 (64,6)		

*Statistically significant at p-value < 0.05

Relationship between Iron Intake and the Incidence of Anemia

Statistical analysis using the Gamma correlation test (γ) yielded a p-value of 0,010 (p-value < 0,05), indicating a statistically significant relationship between iron intake and anemia occurrence in adolescent girls at the Askhabul Kahfi Islamic Boarding School. Furthermore, the correlation coefficient of 0,543 suggested a moderate positive relationship. This indicates that an increase in iron intake can contribute to higher hemoglobin levels, thereby reducing the risk of anemia.

The findings by Kusumawati et al. and Salim et al. provide empirical support for this result, demonstrating a significant relationship between iron intake and anemia

occurrence^{26,38}. However, the study by Putri and Fauzia yielded different results, where no significant relationship between iron intake and anemia in adolescents was found (p-value 0,182 > 0,05)³⁹. Another study by Jausal et al. also reported no meaningful relationship between iron intake and anemia (p-value 0,630 > 0,05)⁴⁰. Additionally, the consumption of tea, which is high in tannins, can inhibit the bioavailability of iron by binding to iron ions in the digestive tract, thus reducing the availability of iron that is essential for various physiological functions².

As an essential component of hemoglobin, iron plays a crucial role in the oxygen-binding process, enabling the efficient transport of oxygen to peripheral

tissues and contributing to the regulation of oxygen homeostasis in the body⁹. Iron absorption occurs in the duodenum, the first part of the small intestine, where heme iron, found in red meat, is absorbed directly by the mucosal cells without requiring additional processes. In contrast, non-heme iron from vegetables and grains requires specific chemical processes to be absorbed by the body, with stomach acid and vitamin C playing a role in converting Fe³⁺ (ferric) to Fe²⁺ (ferrous)⁸.

When iron requirements increase or dietary intake is insufficient, the concentration of iron in the body decreases. This results in the production of smaller and hypochromic erythrocytes, leading to a reduced capacity of the blood to transport oxygen. Symptoms that arise from this condition include pale skin, weakness, and increased fatigue².

The Relationship between Vitamin C Intake and the Incidence of Anemia

The statistical analysis using the Gamma correlation test (γ) resulted in a p-value of 0,095 (p-value > 0,05), indicating that there was no statistically significant relationship between vitamin C intake and the incidence of anemia in adolescent girls at Askhabul Kahfi Islamic Boarding School in Semarang. Additionally, the correlation coefficient of 0,376 showed a weak positive relationship between anemia status and vitamin C intake. This suggests that adequate vitamin C intake may help reduce the risk of anemia, although its effect is not as strong as the relationship between iron intake and anemia.

Similar findings were reported by Habibie et al., who noted that, among female high school students, vitamin C intake was not significantly related to anemia incidence (p-value 1,00 > 0,05)⁴¹. Dewi et al. also found no significant correlation between anemia and vitamin C intake among adolescent girls in Bantul⁴². Research by Manikam et al. further supports these findings, stating that no relationship was found between anemia incidence and vitamin C intake among female students in Bekasi (p-value 1,00 > 0,05)⁴³. These findings emphasize that, while vitamin C intake may have other health benefits, its effect on preventing anemia appears limited, with factors such as iron intake likely playing a larger role in reducing anemia risk among adolescent girls.

This study revealed a different result from Farinendya et al., who identified a significant relationship between anemia and vitamin C intake in adolescent girls⁴⁴. Yuliani et al. also conducted a similar study and found a consistent relationship⁴⁵. Although there are indications of a relationship, most of the adolescent girls diagnosed with anemia in these studies had inadequate vitamin C intake, unlike those with sufficient intake. Based on the analysis, it can be concluded that other variables, including overall dietary patterns and health conditions related to nutritional status, have a more substantial impact on anemia than vitamin C intake itself.

At Askhabul Kahfi Islamic Boarding School, although iron and vitamin C intake among adolescent girls is generally adequate, this study did not find significant evidence of a relationship between vitamin C intake and anemia incidence. This suggests that other factors may play a larger role in influencing anemia status

among these adolescent girls. One possible factor influencing these results is the method of vegetable preparation at the boarding school. The vegetable dishes, which are the primary source of vitamin C for the adolescent girls, are always available during mealtimes. The most common cooking method is boiling vegetables until they become clear soup or broth. However, based on interviews and direct observations of several adolescent girls, vegetables are often served overcooked.

Overcooking vegetables can result in significant loss of vitamin C, as this compound is highly sensitive to high temperatures and prolonged cooking times. The presence of vitamin C is critical in maximizing the absorption of non-heme iron, typically found in plant-based foods. Vitamin C can convert non-heme iron from Fe³⁺ (ferric) to Fe²⁺ (ferrous), facilitating its absorption by the body, and can even increase its absorption rate by up to four times⁹. However, the role of vitamin C in preventing anemia is more supportive, as it aids in the absorption of iron but is not the primary factor in anemia prevention.

Furthermore, the habit of drinking tea at the boarding school also contributes to this issue. Tea contains polyphenols, such as tannins, which can interfere with the body's ability to absorb iron effectively. Tannins can bind to iron and reduce its availability for absorption, exacerbating iron deficiency among the adolescent girls. Therefore, although vitamin C from vegetables is adequately available, other factors, such as improper cooking methods and tea consumption habits, may contribute to its ineffectiveness in preventing anemia in adolescent girls at Askhabul Kahfi Islamic Boarding School.

Relationship Between Body Fat Percentage and the Incidence of Anemia

The statistical analysis conducted using the Gamma (γ) correlation test resulted in a p-value of 0,009 (p-value < 0,05), indicating a statistically significant relationship between body fat percentage and anemia incidence in adolescent girls at Askhabul Kahfi Islamic Boarding School, Semarang. Additionally, the obtained correlation coefficient of -0,496 indicates a moderate negative relationship. This means that the higher the body fat percentage, the greater the likelihood of individuals experiencing anemia.

The findings of this study align with the results reported by Acharya et al. and Mehdad et al., who highlighted the relationship between body fat percentage and anemia incidence^{16,46}. In this study, the majority of respondents, 33 individuals (76,7%), had a body fat percentage within the normal range and did not experience anemia. Conversely, studies by Virginia and Fenty and Hiremath et al. reported different results, where no significant relationship was found between body fat percentage and anemia incidence among adolescents, with recorded p-values greater than 0,0534^{34,47}.

Excess body fat can affect hemoglobin levels in the body through a complex mechanism. One of the mechanisms involved is the increased release of pro-inflammatory cytokines, which can stimulate the production of hepcidin¹². As the main regulator of iron

metabolism, hepcidin affects the body's iron balance. High levels of hepcidin result in reduced ability to absorb iron, through the mechanism of binding and decreasing the amount of ferroportin protein in intestinal epithelial cells¹⁴. Ferroportin is a protein that plays a vital role in exporting iron from intestinal cells into the bloodstream. If ferroportin levels decrease, iron absorption will be impaired.

Moreover, high levels of hepcidin can also affect the release of iron from the body's storage cells, such as macrophages and hepatocytes. Hepcidin works by binding to ferroportin on these storage cells, causing the degradation of ferroportin and inhibiting the release of iron into the blood. As a result, the availability of iron for vital processes in the body, such as erythropoiesis, is reduced¹⁵. Iron deficiency can lead to a decrease in hemoglobin levels, which ultimately increases the risk of anemia. Therefore, excess body fat, which triggers

increased hepcidin production, may play a role in disrupting iron metabolism, contributing to reduced hemoglobin levels and anemia.

Determinants of Anemia Incidence

The bivariate analysis revealed that iron intake and body fat percentage were associated with anemia incidence in this study, thus requiring multivariate analysis for a deeper investigation. Ordinal logistic regression was applied to analyze this relationship, which is suitable for variables with an ordinal scale. The anemia variable has several consecutive categories, while the independent variables are also ordinal⁴⁸. Ordinal logistic regression allows the researcher to observe how changes in the independent variables affect the likelihood of anemia, considering the levels present in the dependent variable.

Table 3. Ordinal Logistic Regression Model

Variable	Coefficient	S.E.	Wald	df	p-value	95% CI	
						Minimum	Maximum
Threshold							
Anemia = 2,00	-2,493	1,017	6,003	1	0,014	-4,487	-0,499
Anemia = 3,00	-0,789	0,964	0,670	1	0,413	-2,678	1,100
Location							
Iron intake (X ₁)	-1,713	0,624	7,542	1	0,006	-2,936	-0,491
Body fat percentage (X ₃)	-0,627	1,026	0,374	1	0,541	-2,638	1,383

Here are the results of the ordinal logistic regression model based on the table:

$$\text{Logit (Y1)} = 2,493 + 1,713 x_1 + 0,627 x_3$$

$$\text{Logit (Y2)} = 0,789 + 1,713 x_1 + 0,627 x_3$$

Thus, the analysis of the Odds Ratio (OR) can be expressed as follows:

- Odds ratio for the iron intake variable (X₁)= $e^{1,713} = 5,54$
- Odds ratio or the body fat percentage variable (X₃)= $e^{0,627} = 1,87$

Based on the results of the logistic regression analysis, iron intake showed a much more significant impact on anemia occurrence among adolescent girls, with an odds ratio (OR) of 5,54. In contrast, the effect of body fat percentage was only recorded at 1,87. These findings indicate that iron plays a more dominant role in influencing anemia compared to body fat percentage.

Iron is an integral component in the synthesis of hemoglobin, a protein required in the circulatory system to distribute oxygen throughout the body. When the body experiences iron deficiency, the hemoglobin synthesis process is disrupted, resulting in a decrease in red blood cell count. As a result, the blood's ability to distribute oxygen is reduced, increasing the risk of anemia. Adequate iron intake, particularly from animal-based food sources or supplements, is crucial to ensure the smooth formation of hemoglobin. Therefore, ensuring the body receives adequate iron can directly reduce the likelihood of anemia, making iron intake more important than other factors, such as body fat percentage.

Meanwhile, although body fat percentage plays a role in influencing anemia status, its impact is not as significant as iron intake. Excess body fat can increase the release of pro-inflammatory cytokines, which stimulate the production of hepcidin. Elevated hepcidin levels can inhibit the absorption of iron from the digestive tract and reduce the release of iron from body stores, such as in the

liver and macrophages. Nevertheless, the influence of body fat percentage on anemia is more indirect and complex, as this factor plays a larger role in affecting iron metabolism, while iron itself plays a more direct role in hemoglobin production.

Several additional factors were not covered in this study but may influence the occurrence of anemia in adolescent girls, such as digestive health disorders that reduce iron absorption, including celiac disease. Other medical conditions, such as blood production disorders, can also contribute to anemia. Additionally, genetic factors and ethnicity may affect iron metabolism and susceptibility to anemia. Overall nutrition intake, including vitamin B12, folate, and other nutrients that support red blood cell production, can also influence anemia status. This implies that the findings of this study may not fully reflect the complexity of factors that can impact the onset of anemia in adolescent girls. Therefore, while this study indicates that iron intake and body fat percentage influence the occurrence of anemia, there may be other elements not analyzed in this study that could make a significant contribution.

CONCLUSIONS

The majority of respondents had adequate iron and vitamin C intake, a normal body fat percentage, and were categorized as not anemic. The incidence of anemia among adolescent girls at the Askhabul Kahfi Islamic

Boarding School in Semarang is correlated with both iron intake and body fat percentage. However, no significant relationship was found between vitamin C intake and anemia. Iron intake is the most influential factor in the incidence of anemia among the adolescent girls at the Islamic boarding school. The researchers recommend expanding information about anemia for the adolescent girls and improving the quality of food processing, especially vegetables, to maintain their nutritional content and prevent nutrient loss due to overcooking. In addition, stricter monitoring of the students dietary patterns is important, including ensuring regular consumption of iron supplements. The Islamic boarding school can implement more intensive monitoring of the iron supplement program to ensure the local health center's program runs effectively.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

AH: methodology, project management, funding acquisition, supervision, validation, resource management, original draft writing, manuscript revision, and editing.; EPA: Conceptualization, data collection and curation, formal analysis, methodology, investigation, project management, resource allocation, original draft writing, manuscript revision, and editing; DS: Formal analysis, resource management, data visualization, validation, original draft writing, manuscript revision, and editing.

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