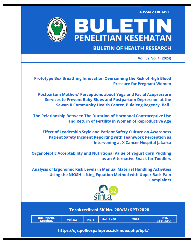

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Anemia Status of Girls Adolescent and It's Contributing Factors at Bekasi City, Indonesia

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ABSTRACT

Background: Anemia remains a significant public health issue, particularly among adolescent girls, due to its impact on cognitive development, productivity, and reproductive health. This study aims to investigate the association between anemia status and specific contributing factors—including nutritional status (underweight, overweight/obese), dietary intake (staple food and protein consumption), and socioeconomic status (parental education, pocket money)—among adolescent girls aged 12–18 years in Bekasi, Indonesia.
Methods: A cross-sectional study was conducted in 2018 across five high schools in Bekasi, involving 345 adolescent girls aged 12-18 years. Data were collected through food frequency questionnaires, anthropometric measurements, and hemoglobin level tests. Anemia was classified based on WHO guidelines. Statistical analysis included univariate, bivariate, and multivariate tests to identify significant predictors.
Results: The prevalence of anemia among participants was 30.7% (95% CI: 25.9%–35.8%), with mild anemia being the most common type, accounting for 48.1% of anemic cases. Overweight or obese participants were significantly more likely to be anemic (OR = 3.52, 95% CI: 1.65–7.51, p = 0.001). Staple food consumption frequency also showed a significant association with anemia risk (OR = 1.75, 95% CI: 0.95–3.21, p = 0.070). However, no significant association was found between socioeconomic status and anemia.
Conclusion: In conclusion, this study highlights the role of nutritional status and dietary patterns in anemia prevalence among adolescent girls. Public health interventions should focus on improving dietary quality and addressing both undernutrition and overnutrition. Future research should investigate the effectiveness of iron supplementation programs, the bioavailability of iron in staple diets, and the role of fortified school meals in reducing anemia risk in this population.

INTRODUCTION

Anemia is a significant national and global health issue, particularly affecting young children, menstruating adolescent girls and women, and pregnant and postpartum women. The Indonesian Health Survey (2023) found that the prevalence of anemia in Indonesia was 16.2%,

with 18% in women and 14.4% in men. Basic health research (Riskesdas) data in 2018 recorded that 26.8% of children aged 5-14 years suffered from anemia and 32% aged 15-24 years (Kemenkes, 2018). According to World Health Organization, 40% of children aged 6–59 months, 37% of pregnant women, and 30% of women aged 15–49 worldwide suffer from anemia. In 2019, the global prevalence of anemia was 29.9% among women of reproductive age. The prevalence was 29.6% in non-pregnant women of reproductive age and 36.5% in pregnant women. The reduction of anemia is one of the WHO Global Nutrition Targets for 2025 and is also a key objective within the Sustainable Development Goals (SDGs), alongside the reduction of stunting, wasting, and overweight (WHO, 2020). Basic health research (Riskesdas) data in 2018 recorded that 26.8% of children aged 5-14 years suffered from anemia and 32% aged 15-24 years (Kemenkes, 2018).

Anemia can lead to various non-specific symptoms, such as fatigue, weakness, dizziness, lightheadedness, drowsiness, and difficulty breathing, particularly during physical activity. Iron deficiency anaemia has also been shown to affect cognitive and physical development in children and reduce productivity in adults. It serves as a sign of both inadequate nutrition and poor health. Additionally, the impact of anemia on children's academic performance and adults' work efficiency can have further social and economic impacts for the individual and family. Anemic adolescent girls are at risk of becoming anemic women of reproductive age, and later becoming anemic mothers who may experience chronic energy deficiency during pregnancy. Chronic energy deficiency in pregnant women can increase the likelihood of giving birth to low birth weight babies and stunting. Key causes of and contributors to anemia is shown in conceptual model of anemia etiology. The micronutrient deficiencies and inflammation are immediate determinants of anemia, while the intermediate determinants consist of food insecurity (quality and quantity), inadequate material and child care, limited access to health/nutrition services and interventions, inadequate health/nutrition knowledge and education, and inadequate aceess to water, sanitation, and hygiene (World Health Organization, 2020).

Some research findings indicate that the most prevalent risk factors for anemia in low- and middle-income countries include nutritional deficiencies, infections/inflammation, and genetic hemoglobin disorders. The proportion of anemia due to iron deficiency varies depending on population groups, geographical conditions, infectious disease burden, and the prevalence of other anemia causes (Chaparro & Suchdev, 2019). Another study related to body image and eating disorder risk regarding the risk of anemia shows that body image can increase the risk of anemia in adolescent girls. Body image is closely related to the nutritional status of adolescent girls (Maryusman et al., 2020). Nutrient deficiencies and infections are the main key factors affect nutritional status. Socioeconomic status affects dietary intake, especially from the consumption of protein food. Further research is needed to explore nutritional status, socioeconomic status, and dietary intake as contributing factors to anemia. This study attempts to present aspects of nutritional status, socioeconomic status, and dietary intake as contributors to anemia. Nutritional status is seen from the categories of underweight, overweight, obesity, and stunting. Previous studies have not looked at the relationship between stunting and anemia. Socioeconomic status is measured by parental education. Meanwhile, for dietary intake, aspects of staple food, vegetables, and fruits consumption were also studied

METHODS

This study employed a cross-sectional design to assess the prevalence and determinants of anemia among adolescent girls in Bekasi, Indonesia. The research was conducted across five high schools in Bekasi, with data collection carried out in 2018. The study aimed to determine the prevalence of anemia, the nutritional status of participants, their food consumption patterns, and the factors contributing to anemia risk. A total of 345 adolescent girls aged 12-18 years were recruited using purposive sampling, selecting schools with a high proportion of female students. Purposive sampling was chosen over random or stratified sampling due to the specific aims of the study, which needed the inclusion of participants with characteristics, experiences, or ability relevant to the research topic. The rationale for this sampling method lies in its ability to align closely with the research goals, ensuring that data collected is meaningful and directly applicable.

To maintain transparency and reduce concerns about selection bias, clear inclusion criteria were established and consistently applied during participant selection. The sampling process involved collecting data from schools with a known high proportion of adolescent girls to ensure a representative sample. Inclusion criteria required participants to be healthy, within the specified age range, and willing to participate. Exclusion criteria included students who were fasting or menstruating at the time of data collection, as these factors could influence hemoglobin levels and lead to inaccurate assessments. The study involved several data collection methods, including food frequency questionnaires (FFQ) to assess dietary intake, anthropometric measurements to determine nutritional status, and hemoglobin (Hb) level tests to identify anemia cases. We identify the possible confounder factors affecting hemoglobin level in adolescent girls such as physical activity level, infection, supplement intake, menstrual history, socioeconomic status, and environmental factors. Due to the limited resources, we did not investigate these factors. The classification of anemia followed WHO guidelines, with anemia defined as Hb levels below 12 g/dL, further categorized into mild (11-11.9 g/dL), moderate (8-10.9 g/dL), and severe (<8 g/dL) anemia. Nutritional status was assessed using body mass index (BMI) classifications for underweight, normal weight, and overweight/obese categories. Data were analyzed using univariate, bivariate, and multivariate statistical methods to explore relationships between anemia and independent variables such as nutritional status, dietary intake, and socioeconomic factors. Statistical tests were conducted to determine significant associations and identify key predictors of anemia among adolescent girls. The findings provided insight into the predictors of anemia among adolescent girls, contributing to the formulation of targeted interventions for anemia prevention in this population.

RESULTS

This study employed a cross-sectional design to assess the prevalence and determinants of anemia among adolescent girls in Bekasi, Indonesia. The research was conducted across five high schools in Bekasi, with data collection spanning a defined period in 2018. The initial sample comprised 345 adolescent girls aged 12-18 years. Inclusion criteria required participants to be healthy, within the specified age range, and willing to participate. Exclusion criteria included those who were fasting or menstruating at the time of data collection, as these factors could influence hemoglobin levels.

Descriptive Statistics

Table 1 summarizes the baseline characteristics of the study participants. Mostly adolescent are above fifteen to eighteen years old. Regarding to parents last education, most of them has graduated from senior high school (>40%). Lastly, 62,3% adolescent receipt less than twenty thousand rupias pocket money every day.

Primary Outcome Measures

The primary outcome of the study was the prevalence of anemia among adolescent girls in Bekasi, with 30.7% of participants classified as anemic, the majority experiencing mild anemia (48.1%) (table 1). Furthermore, the significant correlation showed between nutritional status and stapel food consumption frequency with anemia status ($p < 0,05$) (table 2).

Secondary Outcome Measures

Secondary outcomes are the predictors of anemia in adolescent girls at Bekasi. Table 3 presents the results, indicating that mother education, staple food consumption, protein consumption, and nutritional status could be the predicting factor of anemia.

Table 1. Adolescent characteristic and anemia in adolescent in Bekasi City

Variables	n	%
Age		
12-15 years	90	26.9
15-18 years	255	73.1
Anemia status		
Anemic (Hb <12 gr/dl)	106	30.7
Non-anemic (Hb ≥ 12 gr/dl)	239	69.3
Category of anemia		
Mild	51	48.1
Moderate	48	45.3
Severe	7	6.6
Father's Education		
Didn't school	22	6.4
Elementary school	52	15.1
Junior High school	46	13.3
Senior High school	184	53.3
Diploma Degree	8	2.3
Bachelor/Master/Doctoral	33	9.6
Mother's Education		
Didn't school	20	5.8
Elementary school	70	20.3
Junior High school	69	20.0
Senior High school	159	46.1
Diploma Degree	14	4.1
Bachelor/Master/Doctoral	13	3.8
Pocket Money		
<Rp20.000	215	62.3
>=Rp20.000	130	37.7

Table 1 presents demographic, anemia status, and socioeconomic characteristics of a surveyed population, focusing on age, anemia status, parental education, and pocket money distribution. The majority of respondents (73.1%) are aged 15-18 years, while 26.9% are 12-15 years old. In terms of anemia status, 30.7% are anemic (Hb <12 g/dL), while 69.3% are non-anemic (Hb ≥12 g/dL). Among those with anemia, 48.1% have mild anemia, 45.3% have moderate anemia, and 6.6% have severe anemia. Regarding parental education, most fathers (53.3%) and mothers (46.1%) have completed Senior High School, while a smaller proportion hold a Bachelor/Master/Doctoral degree (9.6% for fathers and 3.8% for mothers), and some did not attend school (6.4% of fathers and 5.8% of mothers). Concerning financial allowance, 62.3% of respondents receive less than Rp20,000 in daily pocket money, while 37.7% receive Rp20,000 or more. This data provides insights into the respondents' age distribution, anemia prevalence, educational background of parents, and financial resources, which may influence their overall well-being and socioeconomic conditions.

Table 2. Cross-tabulation of Risk Factors for Anemia in Girls Adolescent in Bekasi City

Variables	Anemia Status				p-value
	Anemia		Non-anemia		
	n (106)	% (30.7)	n (239)	%(69.3)	
Father's Education Level					
Low	97	91.5	207	86.6	0.195
Moderate-High	9	8.5	32	13.4	
Mother's Education Level					
Low	102	96.2	216	90.4	0,062
Moderate-High	4	3.8	23	9.6	
Underweight Status					
Yes	2	2.1	16	8.7	0.030
Normal	95	97.9	167	91.3	

Variables	Anemia Status				p-value
	Anemia		Non-anemia		
	n (106)	% (30.7)	n (239)	%(69.3)	
Overweight & Obese Status					
Yes	9	8.7	56	25.1	0.001
Normal	95	91.3	167	75.9	
Stunting Status					
Yes	17	16.1	40	16.7	0.872
Normal	89	83.9	199	83.3	
Staple Food Consumption					
< 3 portion / day	19	17.9	66	27.6	0,050
≥ 3 portion / day	87	82.1	173	72.4	
Protein Source Consumption					
< 2 portion / day	40	37.7	66	27.6	0,060
≥ 2 portion / day	66	62.3	173	72.4	
Vegetables Consumption					
< 3 portion / day	93	87.7	194	81.2	0.130
≥ 3 portion / day	13	12.3	45	18.8	
Fruits Consumption					
< 2 portion / day	88	83.0	179	74.9	0.090
≥ 2 portion / day	18	17.0	60	25.1	

Table 2 presents the cross-tabulation of various risk factors for anemia in girls. Table shows that anemia prevalence was significantly associated with nutritional status, particularly among overweight and obese adolescents, where 56.1% of overweight/obese girls were anemic (p = 0.001). Additionally, anemia was more common among students who consumed staple foods less than twice daily (38.3%, p = 0.004), suggesting a possible link between meal frequency and anemia risk. Socioeconomic factors, such as pocket money and parental education, did not show a statistically significant relationship with anemia status. Parental education levels were generally low in both groups, with no significant difference between them. Although more non-anemic individuals consumed adequate portions of protein, vegetables, and fruits, these differences were not statistically significant (p-values of 0.060, 0.130, and 0.090, respectively). Overall, the findings suggest that nutritional status, particularly weight category, may have a stronger impact on anemia risk than dietary intake alone.

Table 3. Multivariate Analysis of Risk Factors for Anemia in Girls Adolescent in Bekasi City

Variables	Coefficient	p	OR	CI
Step 3				
Mother's Education (low)	-0.908	0.113	0.40	0.13-1.24
Staple food consumption (less)	0.602	0.053	1.82	0.99-3.36
Protein source consumption (less)	-0.509	0.055	0.60	0.35-1.01
Vegetables consumption (less)	-0.441	0.217	0.64	0.31-1.01
Underweight status	1,220	0,115	3.38	0.74-15.47
Overweight & Obese status	1.255	0.001	3.50	1.64-7.49
Constant	1.834	<0.05	6.26	
Step 4				
Mother's Education (low)	-0.921	0.107	0.39	0.13-1.22
Staple food consumption (less)	0.561	0.070	1.75	0.95-3.21
Protein source consumption (less)	-0.564	0.032	0.56	0.34-0.95
Underweight status	1.266	0.102	3.54	0.77-16.18
Overweight & Obese status	1.259	0.001	3.52	1.65-7.51
Constant	1.498	<0.05	4.47	

Table 3 presents the logistic regression analysis examines the relationship between various factors and the likelihood of a specific outcome, with results presented for Step 3 and Step 4 models. Overweight and obese status significantly increases the odds of the outcome (OR = 3.50,

p = 0.001 in Step 3; OR = 3.52, p = 0.001 in Step 4), while lower protein consumption significantly reduces the odds in Step 4 (OR = 0.56, p = 0.032). Lower maternal education and reduced staple food or vegetable consumption show trends toward association but are not statistically significant. The constant suggests a high baseline likelihood of the outcome. The refined Step 4 model maintains key predictors while improving significance for protein consumption.

DISCUSSION

The study on anemia among adolescent girls in Bekasi, Indonesia, found that 30.7% of the participants were anemic, with the majority (48.1%) exhibiting mild anemia (Hb 11-11.9 g/dl). These findings are consistent with previous research that highlights a significant prevalence of anemia in adolescent populations in both developing and developed countries. The high prevalence of anemia found in this study is in line with reported that iron deficiency anemia remains a major global health concern, particularly among adolescent girls (Wiafe et al., 2023). According to Global Report, the prevalence of anemia in adolescent girls globally can range from 20% to 50%, which aligns with the findings of this study. Similar rates have been observed in other Southeast Asian countries, including Bangladesh and India, where anemia rates in adolescents range from 25% to 40% (Kundu et al., 2023; Stevens et al., 2022; Sunuwar et al., 2023). The high prevalence of anemia in Indonesia aligns with a broader regional trend, as similar studies in other Asian countries, such as Bangladesh and India, also report high levels of anemia among adolescent girls (Rahman et al., 2024; Srivastava et al., 2022). These figures reflect the ongoing challenge of micronutrient deficiencies, particularly iron, in adolescent populations in low- and middle-income countries. Despite various public health efforts, such as fortification programs and supplementation initiatives, iron deficiency remains widespread in many areas, indicating that more targeted interventions are necessary (Wrottesley et al., 2023).

Nutritional Status and Anemia

The study found that overweight and obese adolescent girls had three times the risk of anemia, which is consistent with other studies indicating that obesity-related inflammation can affect iron absorption and contribute to anemia (Saad & Qutob, 2022). Specifically, the inflammatory markers associated with obesity, such as increased levels of hepcidin, are known to hinder iron absorption (Nemeth & Ganz, 2023). Hepcidin, a hormone involved in regulating iron homeostasis, is upregulated during inflammation, leading to reduced iron absorption and impaired iron release from stores. This supports the findings who reported a similar relationship between obesity and iron deficiency anemia in adolescents (Jeong et al., 2022; Syah, 2022). Conversely, underweight girls were also at a higher risk of anemia, likely due to inadequate dietary iron intake, research found that undernutrition, particularly iron deficiency, is prevalent in underweight populations (Tandoh et al., 2021). This is often due to insufficient intake of iron-rich foods or poor dietary diversity, which limits the availability of both heme and non-heme iron sources (Knijff et al., 2021). The relationship between nutritional status and anemia is complex, as it involves both the quantity and quality of the diet, as well as other factors such as absorption efficiency and iron bioavailability (Cohen & Powers, 2024; Piskin et al., 2022). In contrast, some studies, suggest that the relationship between body weight and anemia might not be as straightforward. They found that nutritional status could be a contributing factor to anemia but that other determinants, such as dietary habits, play a more significant role (Syah, 2022; Zhu et al., 2021). Therefore, while nutritional status is important, it is likely that a combination of dietary, metabolic, and inflammatory factors influences the development of anemia.

Socioeconomic Status and Anemia

An interesting finding of this study is the lack of a significant correlation between socioeconomic status (SES) and anemia among adolescent girls in Bekasi. One possible reason is the presence of national-level food fortification and school-based nutrition programs in Indonesia, which may have reduced disparities in dietary access across income groups. These initiatives could contribute to more uniform iron intake, regardless of economic background. This finding

contrasts with other studies that have consistently found a link between lower SES and a higher risk of anemia. Study highlighted that adolescents from lower-income households often face higher risks of iron deficiency and anemia due to limited access to nutritious food, poor living conditions, and limited healthcare (Taqwin et al., 2023). Additionally, SES in this study was assessed using limited proxies, such as parental education and pocket money, which may not adequately reflect broader aspects like household income, food security, or healthcare accessibility. Adolescents in these households may have limited access to animal-based proteins, fruits, and vegetables—key sources of bioavailable iron (Fairweather-Tait, 2023). However, the absence of this correlation in the Bekasi study could be due to the unique socio-economic context, such as the influence of food fortification programs in Indonesia. National fortification programs may have helped reduce the disparities typically seen between SES groups, providing a more uniform dietary intake of essential micronutrients. These programs have become an integral part of Indonesia's strategy to combat micronutrient deficiencies, including iron, and may have mitigated some of the socio-economic disparities typically observed in anemia prevalence (Dewi & Mahmudiono, 2021; Knijff et al., 2021). Another possibility is the school-based sampling methodology used in this study. By focusing on adolescents attending school, who may have more access to subsidized meals or fortified foods, the study's findings may not fully represent the broader socio-economic differences that would be seen in a more diverse sample. This is consistent with study, who noted that studies using school-based samples tend to show less variation in anemia rates across different SES groups (Gosdin et al., 2021). Thus, future studies may benefit from including more representative samples that account for rural versus urban disparities, as these are often linked to food security and nutritional outcomes.

Dietary Intake and Anemia

The study found that only the consumption of staple foods such as rice and bread was significantly correlated with anemia. Surprisingly, protein, fruit, and vegetable intake did not show a significant impact, contradicting previous research which suggested that a diet rich in fruits, vegetables, and protein could help prevent anemia (Restiana et al., 2022). In particular, a study suggest that fruits and vegetables, which are rich in vitamin C and non-heme iron, can enhance iron absorption and thereby reduce the risk of iron deficiency anemia (Kurniawan & Pibriyanti, 2023). The lack of association with protein intake in this study is puzzling. Protein sources, especially those rich in heme iron such as meat, poultry, and fish, are considered key elements in reducing anemia (Dixit et al., 2021). However, it is possible that other factors, such as the bioavailability of iron in the diet, may overshadow the effect of protein intake. The absorption of iron from plant-based sources is often hindered by the presence of inhibitors like phytates, which are found in staple foods like rice and bread. Phytates are known to bind to iron and reduce its bioavailability, making it less accessible to the body (Reddy et al., 2022). This could explain the stronger correlation with staple food intake as compared to more varied food groups, such as fruits, vegetables, and proteins. Moreover, the study's focus on staple foods as a main correlate may be since these foods constitute most of the diet for many adolescents in Indonesia. In fact, studies on iron deficiency often highlight the low bioavailability of iron from rice, a common staple, due to the high levels of phytates (Cheung et al., 2024; Ortenzi & Beal, 2021). This could explain the stronger correlation with staple food intake as compared to more varied food groups, such as fruits, vegetables, and proteins. It is also possible that other micronutrients, such as zinc and vitamin A, could have a stronger effect on anemia outcomes, as these are also involved in iron metabolism and immune function (Gernand et al., 2022; Jeng & Chen, 2022).

Predictors of Anemia

The study suggests that dietary patterns, malnutrition (both underweight and overweight), and the consumption of staple foods are the primary predictors of anemia risk. This finding is supported by other studies which emphasize the multifactorial nature of anemia in adolescents (Gupta et al., 2021). The role of inflammation in obesity and malnutrition, as well as dietary intake, is a critical determinant of anemia in adolescents, as outlined by previously study (Tiruneh & Ejigu, 2024). Furthermore, iron deficiency anemia is often seen as a consequence of both dietary

patterns and the body's impaired ability to absorb iron, which is why complex interactions between various factors must be considered in understanding anemia risk (Aksu & Ünal, 2023). Studies suggest that a more holistic approach, considering the interplay of diet, socioeconomic factors, and inflammation, is necessary for understanding and mitigating anemia in adolescents (Kumar et al., 2022). Nutritional interventions that address both dietary habits and other factors like obesity-related inflammation and micronutrient deficiencies will likely be more effective in reducing anemia prevalence (Loechl et al., 2023).

Implications for Public Health

The findings from this study have significant implications for public health, particularly in addressing anemia among adolescent girls. Given the high prevalence of anemia in Indonesia, targeted nutritional interventions are essential. Overweight and underweight adolescents are at increased risk of anemia, indicating that both obesity-related inflammation and inadequate iron intake contribute to the problem. Public health efforts should focus on improving the dietary quality of these groups, with particular emphasis on reducing obesity-related inflammation and increasing iron intake. Food fortification programs, such as those in Indonesia, play a crucial role in reducing anemia, as they help mitigate the nutritional disparities associated with socioeconomic status. Expanding such programs and ensuring the availability of iron-rich foods can address widespread micronutrient deficiencies (Nair et al., 2016). School-based interventions are also key. Implementing fortified meal programs or ensuring iron-rich meals in schools can help combat anemia at the community level. Education on proper nutrition and iron absorption should be integrated into school curriculums to promote healthier eating habits (De. A comprehensive, multisectoral approach involving health, education, and agriculture is essential for long-term anemia prevention. Early detection, iron supplementation, and addressing food insecurity are necessary to reduce anemia's burden on adolescent health and development (Mithra et al., 2021)

Limitations and Cautions

Despite the meaningful contributions, our study has several limitations that warrant acknowledgment. First, the cross-sectional design limits the ability to establish causality between anemia and the identified factors. Additionally, the study's reliance on school-based sampling may not fully represent the broader adolescent population, particularly those who are out of school or live in rural areas. The self-reported dietary intake data may also introduce recall bias, affecting the accuracy of the findings. Lastly, unmeasured confounding factors, such as genetic predisposition or undiagnosed health conditions, could influence the observed associations and should be addressed in future studies.

Recommendations for Future Research

Future research should adopt a longitudinal design to better understand causal relationships between anemia and factors such as nutritional status, dietary patterns, and inflammation. Expanding the sampling frame to include out-of-school adolescents, as well as populations in rural or underserved regions, would improve the generalizability of findings.. Additionally, randomized controlled trials (RCTs) should be conducted to evaluate the effectiveness of specific interventions, such as iron supplementation, dietary modification programs, or fortified school meal plans. More accurate methods for dietary assessment, such as food diaries or biomarkers, should be employed to reduce recall bias. Future studies should also employ more robust SES indicators, such as household income, food security scales, and access to health services, and utilize validated dietary assessment tools like 24-hour recalls or food diaries to improve data accuracy. Incorporating biomarkers of iron status and inflammation (e.g., serum ferritin, CRP, hepcidin) is also recommended to deepen understanding of the physiological mechanisms involved in anemia. Finally, evaluating the effectiveness of current anemia prevention programs, including food fortification and supplementation, is crucial for refining public health strategies.

CONCLUSION

In conclusion, this study provides valuable insights into the prevalence and predictors of anemia among adolescent girls in Bekasi, Indonesia. It underscores the importance of nutritional status, dietary intake, and local socioeconomic factors in shaping anemia outcomes. The findings highlight the complexity of anemia's etiology, emphasizing the need for comprehensive public health strategies that address not only iron deficiency but also the broader context of malnutrition, including both undernutrition and overnutrition. Despite the lack of a significant association with socioeconomic status, the study emphasizes the critical role of nutritional interventions, including food fortification and improved dietary patterns, in addressing anemia. Public health strategies must target both the undernourished and the overweight populations, ensuring equitable access to iron-rich foods and supplements. These strategies should be implemented through multi-sectoral collaborations involving the ministries of health, education, and agriculture. For example, the Ministry of Health can expand existing iron and folic acid supplementation programs in schools, while the Ministry of Education should integrate anemia prevention into the school curriculum through health literacy modules. School-based nutrition programs should provide fortified meals that include iron-rich and protein-rich food, and monitor their impact on student hemoglobin levels over time.. At the community level, nutrition outreach and counseling programs should target both adolescents and their caregivers to promote balanced diets and reduce stigma associated with body image and weight. In rural or low-income settings, government subsidies or vouchers could be used to improve access to diverse and iron-rich foods. These combined efforts would contribute to sustainable anemia reduction and improved adolescent health outcomes. This study is limited by its cross-sectional design, which prevents causal inference, and by reliance on self-reported dietary data that may be affected by recall bias. Additionally, the use of purposive school-based sampling and simplified socioeconomic indicators may limit the generalizability and depth of the findings. While the results contribute to our understanding of anemia risk factors, future research is needed to explore causal pathways, refine dietary assessments, and evaluate existing interventions. By addressing these gaps, more effective and sustainable approaches to anemia prevention can be developed for adolescent populations in Indonesia and beyond.

Author's Contribution Statement: Muhammad Nur Hasan Syah conceived and designed the study, developed the research framework, and supervised the overall project. He contributed to data collection, analysis, and interpretation. **Alfi Fairuz Asna** conducted literature reviews, assisted in data collection, and contributed to data analysis. She also played a key role in drafting and revising the manuscript. **Silvia Mawarti Perdana** provided methodological expertise, performed statistical analyses, and contributed to data visualization. She also reviewed and refined the manuscript for intellectual content. **Chioma Utah-Iheanyichukwu** contributed to assisted in manuscript preparation. She ensured accuracy and consistency in data presentation.

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