

Behavioral Factors and Household Food Security Associated with Anemia among Adolescent Girls in Padang City, Indonesia

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ABSTRACT

Anemia among adolescent girls is a multifactorial public health problem involving individual behavioral and household-level conditions. Objective: This study aimed to examine the associations between behavioral factors, household food security, and anemia among adolescent girls. Methods: A cross-sectional study was conducted from January to March 2026 among 320 adolescent girls aged 15–19 years in Padang City, West Sumatra, Indonesia, selected using multistage random sampling. Data were collected through structured interviews, anthropometric measurements, dietary assessment, household food-security assessment using the Household Food Insecurity Access Scale (HFIAS), and hemoglobin measurement using HemoCue® Hb 201+. Bivariate associations were assessed using the Chi-square test, followed by multivariable binary logistic regression. Results: Low household food security showed the strongest observed association with anemia (AOR = 3.56; 95% CI: 1.92–6.59; $p < 0.001$), followed by non-adherence to iron supplementation (AOR = 2.94; 95% CI: 1.61–5.35; $p < 0.001$), low consumption of iron-rich foods (AOR = 2.51; 95% CI: 1.38–4.56; $p = 0.002$), and low knowledge (AOR = 1.82; 95% CI: 1.03–3.24; $p = 0.041$). Irregular breakfast consumption and tea or coffee consumption after meals were not statistically significant after adjustment. The model showed adequate fit (Hosmer–Lemeshow $p = 0.681$), with a Nagelkerke R^2 of 0.418 and classification accuracy of 79.4%. Conclusion: Household food security and several behavioral factors were statistically associated with anemia among adolescent girls. Integrated interventions addressing household food access, iron supplementation adherence, dietary practices, and nutrition knowledge should be considered. Longitudinal studies are needed to clarify temporal relationships.



Keywords: Anemia, Adolescent Girls, Household Food Security, Iron Supplementation, Dietary Behavior, Nutritional Knowledge

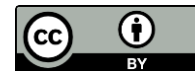
INTRODUCTION

Anemia is one of the most widespread nutritional problems globally, affecting more than half a billion women of reproductive age globally. According to the 2021 Global Burden of Disease Study, the prevalence of anemia among women aged 15–49 years reached 33.7%, significantly higher than the 11.3% among men in the same age range (GBD 2021 Anaemia Collaborators, 2023). This gender gap begins to widen significantly from adolescence, as iron requirements increase due to growth spurts and the onset of the menstrual cycle. For scientists outside the fields of nutrition and public health, it is crucial to understand that anemia is not simply an individual clinical condition, but rather an indicator of the quality of a society's food, education, and health systems, as well as a critical determinant of economic productivity and the achievement of the Sustainable Development Goals (SDGs) in health and poverty alleviation.

In Indonesia, this issue shows a similar pattern but with distinct local characteristics. The 2023 Indonesian Health Survey (SKI) recorded an anemia prevalence of 15.5% among adolescent girls aged 15–24, with a significant disparity between adolescent girls (18.0%) and adolescent boys (14.4%). While this national figure shows a downward trend compared to the 2018 Basic Health Research (Riskesdas), it still falls short of the WHO's target of eliminating anemia as a public health problem, and regional variation remains high some regions even reported prevalence rates above 40% among adolescent girls. This confirms that adolescent girls remain a priority at-risk group requiring special attention in national nutrition policies, while also demonstrating that aggregate national data do not fully reflect vulnerability at the household and community levels.

The biological vulnerability of adolescent girls to anemia is inextricably linked to two concurrent physiological phases: a growth spurt that sharply increases iron requirements, and regular monthly menstrual blood loss (Mangalik et al., 2023). This combination places adolescent girls at a significantly higher risk of iron deficiency than other age groups, making adolescence a critical window for intervention before entering reproductive age. If left untreated, anemia during this period has the potential to progress to anemia during pregnancy, increasing the risk of low birth weight, and contributing to an intergenerational cycle of stunting.

The impact of anemia on adolescent girls is multidimensional and goes beyond the purely clinical. Biologically, anemia reduces oxygen-carrying capacity and endurance; psychologically, it is associated with chronic fatigue and decreased concentration; and academically, anemia is associated with decreased attendance and academic achievement (Murthi et al., 2026). In the long term, untreated anemia during adolescence is a precursor to pregnancy complications and decreased economic productivity in adulthood. This complex series of impacts makes anemia in adolescent girls not simply a micronutrient issue, but a long-term investment in the quality of a nation's human resources.



Research over the past decade has increasingly confirmed that the etiology of anemia in adolescents is multifactorial and cannot be reduced to iron deficiency alone. A large-scale cross-sectional study by Knijff et al. (2021) of 2,150 adolescents in Klaten and West Lombok found that regular consumption of animal-based iron-rich foods was associated with a 35% reduced risk of anemia in adolescent girls, confirming the central role of dietary patterns in determining hemoglobin status (Knijff et al., 2021). Similarly, a systematic review by Wemakor et al. (2023) in Ghana showed that low dietary diversity was consistently associated with anemia in adolescent girls, alongside nutritional knowledge and household sociodemographic status. These findings reinforce the paradigm shift in anemia research from a purely biomedical approach to a more comprehensive health behavior approach (Wemakor et al., 2023).

Another widely studied behavioral determinant is adherence to iron supplementation (IBT), a national supplementation program that is the mainstay of anemia prevention in adolescent girls. However, 2023 Indonesian Health Survey (SKI) data revealed that 54.8% of adolescent girls had never received IBT, and among those who did, 51.4% did not consume it because they did not understand its benefits. This finding is supported by research by Siyami et al. (2023) in Central Java, which showed a significant relationship between knowledge and adherence to IBT and the incidence of anemia, as well as by a study by Nurjanah and Azinar (2023), which found that only 25.2% of adolescent girls were compliant with IBT, with support from parents, teachers, and health workers being the most influential factors. Compliance with iron supplementation in adolescent girls across countries also confirms that barriers to adherence are multilevel, encompassing individual, family, and healthcare system factors, making single education-based interventions often ineffective.

Beyond individual behavioral factors, recent literature increasingly highlights the role of household food security as a social determinant underlying consumption patterns and, ultimately, adolescent anemia status. A study by Hoteit et al. (2022) in Lebanon of 450 parent-adolescent pairs found that households with high levels of food insecurity had consistently lower dietary diversity, accompanied by an increased risk of malnutrition and anemia in adolescents, particularly amidst a prolonged economic crisis (Hoteit et al., 2022). Similar findings were reported by Wemakor et al. (2023) in Ghana, who showed that household food security scores were negatively correlated with anemia incidence after controlling for other sociodemographic variables. Both studies underscore that household food security is not simply a background variable but a causal pathway that directly shapes adolescent consumption behavior.

Stronger evidence for this association comes from two recent observational meta-analyses. Moosavian et al. (2025), in a meta-analysis of 25 observational studies with over 87,000 subjects, found that children and adolescents from food-insecure households had a significantly higher risk of anemia than those from food-secure households. Similarly, Li et al. (2025), in a separate systematic review and meta-analysis, found a positive correlation between inadequate dietary diversity and increased risk of anemia in the 6–18 age group, although both studies noted limited certainty of the evidence due to heterogeneity in the study designs reviewed. These two meta-analyses serve as important references, confirming that household food security deserves to be positioned as a social determinant of health that is as important as individual behavioral factors.



When these two groups of determinants adolescent behavior and household food security—are examined together, it becomes clear that they are not independent but rather influence each other within the framework of a socioecological model. Household food security shapes the availability and affordability of nutritious food, which in turn determines adolescents' consumption choices; family economic conditions also influence access to health services that provide iron supplementation; and adolescents' nutritional knowledge is often shaped by parenting patterns and health literacy within the household. This layered interaction between individual and structural determinants makes anemia in adolescent girls a complex and multifactorial public health phenomenon, so research and intervention approaches that focus solely on one area risk producing partial solutions.

Although empirical evidence regarding each of these determinants continues to grow, the literature review reveals several significant research gaps. First, in terms of empirical gaps, the majority of Indonesian studies, including those by Siyami et al. (2023) and Nurjanah and Azinar (2023), still focus on the variables of knowledge and adherence to iron tablets separately, without integrating household food security measurements as independent variables in the same analytical model (Nurjanah & Azinar, 2023; Siyami et al., 2023). Second, in terms of conceptual gaps, most domestic studies use an individual health behavior framework (health belief model or theory of knowledge, attitudes, and practices) without adopting a broader social determinants perspective, as demonstrated by international studies such as Hoteit et al. (2022) and Wemakor et al. (2023). Third, in terms of methodological gaps, the two most recent meta-analyses (Moosavian et al., 2025; Li et al., 2025) explicitly note the limited certainty of the evidence due to variations in food security measurement instruments and the limited number of studies that simultaneously assess the relative contributions of behavioral and household factors. Fourth, in terms of contextual gaps, research integrating these two perspectives in the Indonesian adolescent female population, with its unique socioeconomic characteristics and food access patterns, is still very limited, so findings from other countries may not be generalizable to the domestic population.

This gap underscores the urgency of conducting research that simultaneously integrates behavioral factors and household food security to explain the incidence of anemia in adolescent girls. Practically, identifying the relative contribution of each determinant will provide an empirical basis for strengthening iron supplementation programs, which currently face compliance challenges, while also supporting the design of family-based interventions that consider household food security. The findings of this study are also expected to enrich policy references for national anemia control programs and contribute to achieving the SDGs targets in health and food security.

The novelty of this study lies in its attempt to integrate the perspectives of individual health behavior and social determinants of household food security into a single model for analyzing anemia risk factors in adolescent girls an approach that, based on a recent literature review, has not been widely applied simultaneously in the Indonesian context. By combining individual and structural determinants, this study seeks to provide empirical evidence regarding the relative contribution of each factor, as a basis for developing more comprehensive and contextual anemia prevention strategies.

Based on the high prevalence of anemia in adolescent girls and the complexity of influencing factors, this study aims to analyze the relationship between behavioral factors and household food security with the incidence of anemia in adolescent girls. The results are expected to provide a basis for developing anemia prevention strategies that focus not only on individual behavioral changes but also consider household food security as a significant social determinant of health.

METHODS

This study employed a quantitative, observational, analytical cross-sectional design to examine the associations between behavioral factors, household food security, and anemia among adolescent girls. The independent and dependent variables were measured during the same study period; therefore, the analysis was intended to identify statistical associations rather than establish temporal or causal relationships.

The study was conducted from January to March 2026 in selected senior high schools (SMA), vocational high schools (SMK), and Islamic senior high schools (MA) in Padang City, West Sumatra, Indonesia. The study population comprised female adolescents aged 15–19 years enrolled in SMA, SMK, and MA in Padang City. The accessible population consisted of eligible female students enrolled in the selected schools during the data-collection period.

The minimum sample size was calculated using the single-proportion formula for a cross-sectional study:

$$n_0 = Z^2_{1-\alpha/2} P(1-P) / d^2$$

where n_0 represents the minimum required sample size, $Z = 1.96$ for a 95% confidence level, P represents the estimated proportion of anemia among adolescent girls based on the 2023 Indonesian Health Survey (SKI), and $d = 0.05$ represents the desired margin of error. The calculated minimum sample size was subsequently increased by 10% to account for potential non-response and incomplete observations:

$$n = n_0 + (10\% \times n_0)$$

Based on these assumptions and the sampling adjustment applied in this study, a total of 320 adolescent girls were included in the final analysis. All assumptions used in the sample-size calculation were determined before data collection.

Participants were selected using multistage random sampling. In the first stage, schools were selected using proportionate random sampling according to the administrative distribution of schools in Padang City. In the second stage, classes were selected randomly from the participating schools. Eligible female students were then selected using simple random sampling from the student lists until the required sample size was reached.

Participants were eligible if they were female adolescents aged 15–19 years, had experienced menstruation, were registered as active students in SMA, SMK, or MA in Padang City, and were willing to participate in the study with informed consent and parental or guardian consent where required. Students with a history of chronic diseases that could affect hemoglobin levels, including thalassemia, chronic kidney disease, or other hematological disorders; those experiencing acute



bleeding; those who had received therapeutic iron supplementation for a medical indication during the preceding month; and those who did not complete all study procedures were excluded.

The dependent variable was anemia status. Independent variables included knowledge of anemia, adherence to iron supplementation (TTD), dietary practices, breakfast habits, consumption of iron-rich foods, tea or coffee consumption after meals, physical activity, and household food security. Potential covariates included age, nutritional status based on body mass index-for-age (BMI-for-age), menstrual duration, maternal education, parental occupation, household income, and household size.

Data were collected using structured questionnaires, anthropometric measurements, dietary assessment, household food-security assessment, and hemoglobin testing. Knowledge, TTD adherence, breakfast habits, consumption of iron-rich foods, and tea or coffee consumption were assessed using structured interview questionnaires developed from relevant Ministry of Health guidance and the literature. Dietary intake was assessed using a Semi-Quantitative Food Frequency Questionnaire (SQ-FFQ). Household food security was assessed using the Household Food Insecurity Access Scale (HFIAS), consisting of nine questions that classify household food-access conditions into food secure, mildly food insecure, moderately food insecure, and severely food insecure categories. Nutritional status was assessed from measured body weight and height and classified according to BMI-for-age references. Hemoglobin concentration was measured using a calibrated HemoCue® Hb 201+ analyzer. Anemia was defined as a hemoglobin concentration below 12.0 g/dL.

Before the main survey, the questionnaire was pre-tested among 30 adolescent girls with characteristics comparable to the study population but who were not included in the study sites. Item validity was assessed using the Pearson Product Moment correlation, while internal consistency reliability was assessed using Cronbach's alpha. An item was considered valid when its correlation coefficient exceeded the critical r value at a 5% significance level, while a Cronbach's alpha value of ≥ 0.70 was considered acceptable.

Data were collected by trained enumerators who received standardized training in interviewing, questionnaire administration, anthropometric measurement, and hemoglobin testing. Prior to data collection, participants and their parents or guardians, where applicable, received information regarding the study objectives, procedures, potential benefits and risks, confidentiality, voluntary participation, and the right to withdraw without penalty. Each participant was assigned a unique identification code, and identifying information was separated from the analytical dataset. Data were analyzed using IBM SPSS Statistics. Descriptive statistics were presented as frequencies and percentages for categorical variables and as means with standard deviations or medians with interquartile ranges for numerical variables, depending on data distribution. Bivariate associations between independent variables and anemia status were examined using the Chi-square test. Variables with $p < 0.25$ in the bivariate analysis were considered for inclusion in the multivariable binary logistic regression model using the backward likelihood-ratio method. The strength of association was presented as odds ratios (ORs) or adjusted odds ratios (AORs) with 95% confidence intervals (CIs). Multicollinearity was assessed using the variance inflation factor (VIF). Model fit was

evaluated using the Hosmer–Lemeshow goodness-of-fit test. Statistical significance was determined at $p < 0.05$.

Ethical approval was obtained from the Health Research Ethics Committee of Abulyatama University before commencement of the study (Ethical Approval No.321/XX/2026). Written informed consent was obtained from participants and parental or guardian consent where required. Participation was voluntary, confidentiality was maintained through coded data, and participants were informed of their right to withdraw from the study at any time without consequences.

RESULTS

1. Respondent Characteristics

Table 1. Respondent Characteristics (n = 320)

Characteristics	n	%
Age (years)		
15–16	132	41.3
17–19	188	58.7
Nutritional status		
Thin	61	19.1
Normal	219	68.4
Overweight/Obesity	40	12.5
Food Security Status		
Food security	167	52.2
Food insecurity	153	47.8
Anemia Status		
No anemia	228	71.3
Anemia	92	28.7

Most respondents were in their late teens with normal nutritional status. Although more than half of households were classified as food secure, nearly half of respondents still lived in households experiencing food insecurity. This was accompanied by the continued presence of anemia in adolescent girls, indicating that anemia remains a public health problem requiring attention in the school-age group.

2. Bivariate Analysis

Table 2. Relationship between Behavioral Factors and Household Food Security with the Incidence of Anemia

Variables	Comparison	OR	95% CI	p-value
Knowledge	Low vs. adequate	2.18	1.29–3.67	0.003
TTD adherence	Non-adherent vs. adherent	3.42	1.98–5.91	<0.001
Iron-rich food consumption	Low vs. adequate	2.87	1.71–4.81	<0.001
Breakfast habit	Not regular vs. regular	1.76	1.05–2.96	0.031
Tea/coffee after meals	Yes vs. no	1.81	1.08–3.02	0.024



Physical activity	High vs. lower activity	1.29	0.77–2.18	0.312
Household food security	Low vs. adequate	3.71	2.18–6.30	<0.001

The bivariate analysis identified statistically significant associations between most behavioral variables, household food security, and anemia status. The strongest crude association was observed for low household food security (OR = 3.71; 95% CI: 2.18–6.30; $p < 0.001$), indicating that adolescent girls from households with low food security had higher odds of anemia than those from households with adequate food security. Non-adherence to TTD consumption also showed a substantial association with anemia (OR = 3.42; 95% CI: 1.98–5.91; $p < 0.001$).

Low consumption of iron-rich foods was similarly associated with higher odds of anemia (OR = 2.87; 95% CI: 1.71–4.81; $p < 0.001$). Low knowledge of anemia was associated with approximately twofold higher odds of anemia (OR = 2.18; 95% CI: 1.29–3.67; $p = 0.003$). Irregular breakfast consumption and tea or coffee consumption after meals were also statistically associated with anemia, although their crude associations were weaker than those observed for household food security, TTD adherence, and iron-rich food consumption.

In contrast, high physical activity was not statistically associated with anemia (OR = 1.29; 95% CI: 0.77–2.18; $p = 0.312$). Overall, the bivariate findings indicate that household food security and behaviors directly related to iron intake and supplementation showed the largest crude associations with anemia in this study population. These findings were subsequently examined in the multivariable model to account for potential confounding.

3. Multivariate Analysis

Table 3. Multivariable Logistic Regression of Factors Associated with Anemia Among Adolescent Girls

Variables	Comparison	AOR	95% CI	p-value
Low household food security	Low vs. adequate	3.56	1.92–6.59	<0.001
Non-adherence to TTD	Non-adherent vs. adherent	2.94	1.61–5.35	<0.001
Low iron-rich food consumption	Low vs. adequate	2.51	1.38–4.56	0.002
Low knowledge	Low vs. adequate	1.82	1.03–3.24	0.041
Irregular breakfast	Not regular vs. regular	1.47	0.82–2.65	0.187
Tea/coffee after meals	Yes vs. no	1.39	0.81–2.43	0.229

After adjustment for the variables included in the logistic regression model, low household food security had the largest observed association with anemia (AOR = 3.56; 95% CI: 1.92–6.59; $p < 0.001$). This means that the odds of anemia were higher among adolescent girls from households with low food security than among those from households with adequate food security, after adjustment for the other variables included in the model.

Non-adherence to TTD consumption was also independently associated with anemia (AOR = 2.94; 95% CI: 1.61–5.35; $p < 0.001$), followed by low consumption of iron-rich foods (AOR = 2.51; 95% CI: 1.38–4.56; $p = 0.002$) and low knowledge (AOR = 1.82; 95% CI: 1.03–3.24; $p = 0.041$). The confidence intervals for these four variables did not include 1.00, supporting statistically significant associations in the adjusted model.

In contrast, irregular breakfast consumption (AOR = 1.47; 95% CI: 0.82–2.65; $p=0.187$) and tea or coffee consumption after meals (AOR = 1.39; 95% CI: 0.81–2.43; $p=0.229$) were not statistically significant after adjustment. This indicates that their crude associations observed in the bivariate analysis were attenuated after accounting for the other variables in the model.

The Hosmer–Lemeshow test indicated no evidence of poor model fit ($p=0.681$). The Nagelkerke R^2 was 0.418, indicating that the variables included in the model accounted for approximately 41.8% of the model-based variation in the outcome. The classification accuracy was 79.4%. These diagnostic measures support the adequacy of the fitted model, although classification accuracy should not be interpreted as proof of causal or predictive validity beyond the study sample.

DISCUSSION

This study found that low household food security had the strongest observed association with anemia among adolescent girls after adjustment for other variables in the logistic regression model. Non-adherence to TTD consumption, low consumption of iron-rich foods, and low knowledge of anemia were also independently associated with anemia. In contrast, irregular breakfast consumption and tea or coffee consumption after meals were not statistically significant after adjustment. Because this study used a cross-sectional design, these findings should be interpreted as associations rather than evidence of causal relationships or temporal pathways.

The observed association between household food security and anemia is consistent with the social determinants of health framework, which emphasizes that access to adequate and nutritious food is shaped by conditions at the household and community levels. In households experiencing food insecurity, limitations in food availability, affordability, and access may be accompanied by lower dietary diversity and reduced consumption of nutrient-rich foods. These conditions may be particularly relevant to adolescent girls because iron requirements increase during growth and menstrual blood loss. The present finding is consistent with the meta-analysis by Moosavian et al. (2025), which reported a higher likelihood of anemia among children and adolescents experiencing household food insecurity. Nevertheless, because the present study measured food security and anemia during the same observation period, the result cannot establish that food insecurity preceded anemia.

The relationship between dietary diversity and anemia has also been reported in previous studies. Li et al. (2025) found that inadequate dietary diversity was associated with higher odds of anemia among children and adolescents. Similarly, Knijff et al. (2021) reported that more frequent consumption of micronutrient-rich foods was associated with a lower likelihood of anemia among Indonesian adolescents. These findings provide a plausible nutritional explanation for the association observed in the present study, in which low consumption of iron-rich foods remained statistically significant after adjustment. However, dietary intake was assessed using self-reported information, and the cross-sectional design does not allow the direction of the observed association to be established.

Non-adherence to TTD consumption was another variable that remained significantly associated with anemia in the adjusted model. This finding is consistent with previous Indonesian



studies reporting challenges in adherence to iron supplementation among adolescent girls. Nurjanah and Azinar (2023) reported relatively low compliance with TTD consumption and highlighted the importance of support from parents, teachers, and health workers. Similarly, Siyami et al. (2023) identified an association between knowledge, TTD adherence, and anemia. These findings suggest that improving adherence may require more than information provision alone. Individual knowledge, perceived benefits, family support, school-based implementation, and access to health services may interact in shaping supplementation behavior. Nevertheless, the present cross-sectional data cannot determine whether non-adherence preceded anemia or whether other unmeasured factors contributed to both conditions.

Low knowledge of anemia also remained statistically associated with anemia after adjustment. This finding supports the relevance of nutritional and health literacy in adolescent health behavior. Adolescents with limited knowledge may have less information about iron-rich foods, the importance of regular TTD consumption, or behaviors relevant to anemia prevention. However, knowledge should not be interpreted as a sufficient explanation for anemia because health behavior is also shaped by household resources, food availability, social support, and the accessibility of health services. The persistence of household food security as the strongest observed association in the adjusted model further indicates that behavioral characteristics should be interpreted within their broader socioeconomic context.

The loss of statistical significance for irregular breakfast consumption and tea or coffee consumption after adjustment provides an important distinction between crude and adjusted associations. Both variables were associated with anemia in the bivariate analysis but were no longer statistically significant in the multivariable model. This attenuation may indicate overlap with other dietary or household characteristics included in the model. Tea and coffee consumption after meals may theoretically reduce non-heme iron absorption because of their polyphenol content; however, the present analysis does not demonstrate an independent association after adjustment. Therefore, this finding should not be interpreted as evidence that tea or coffee consumption has no biological relevance, but rather that its statistical association with anemia was not independently demonstrated in this study.

The findings can be interpreted within a socioecological perspective. Individual characteristics such as knowledge, dietary practices, and supplementation adherence coexist with interpersonal and household conditions, including food access and socioeconomic resources. This perspective is consistent with previous evidence showing that anemia among adolescents is multifactorial. The current findings therefore support an integrated prevention approach involving school-based TTD programs, nutrition education, dietary improvement, and attention to household food-access conditions. Such an approach may be more appropriate than interventions that focus exclusively on individual knowledge or supplementation behavior.

The findings should nevertheless be interpreted in light of the study limitations. First, the cross-sectional design prevents determination of temporal order and limits causal inference. Second, several behavioral and dietary variables were obtained through self-report and may therefore be affected by recall or reporting bias. Third, the study was conducted in Padang City, limiting the

extent to which the findings can be generalized to adolescent girls living in areas with different socioeconomic and food-access conditions. Fourth, although HFIAS provides a structured assessment of household food-access conditions, household food security is multidimensional and may not capture all aspects of dietary quality and nutritional adequacy. Finally, residual confounding from unmeasured factors cannot be excluded.

Overall, the study demonstrates that household food security, TTD adherence, consumption of iron-rich foods, and knowledge were statistically associated with anemia among adolescent girls after adjustment for other variables. The results strengthen the rationale for integrating household-level food-security considerations with school- and individual-level anemia prevention programs. Longitudinal studies are warranted to establish temporal relationships and to further investigate how household food security, dietary behavior, supplementation adherence, and hemoglobin status interact over time.

CONCLUSIONS

This study aims to analyze the relationship between behavioral factors and household food security with the incidence of anemia in adolescent girls. The results of multivariate analysis showed that low household food security was the most dominant determinant (Adjusted OR 3.56; 95% CI 1.92–6.59), followed by non-compliance with iron supplement consumption (Adjusted OR 2.94; 95% CI 1.61–5.35), low consumption of iron-rich foods (Adjusted OR 2.51; 95% CI 1.38–4.56), and low knowledge (Adjusted OR 1.82; 95% CI 1.03–3.24). These findings confirm that anemia in adolescent girls is multifactorial and cannot be explained solely through individual behavioral approaches. Structural conditions in the form of household food security provide a greater contribution than behavioral factors after all confounding variables are controlled. The constructed regression model showed adequate predictive ability (classification accuracy 79.4%; Nagelkerke R^2 0.418) and good fit to the data (Hosmer–Lemeshow $p = 0.681$).

The implications of these findings emphasize the importance of shifting the paradigm of anemia management from approaches focused solely on individual supplementation and education to integrative strategies that strengthen household food security. School-based iron supplementation programs need to be complemented by family-based interventions that consider access to and availability of nutritious food, as well as the ongoing improvement of nutritional literacy. The results of this study can provide an empirical basis for the formulation of more comprehensive and contextual adolescent nutrition policies at the local and national levels, while also supporting the achievement of the Sustainable Development Goals in health and food security.

This study has several limitations that warrant consideration. The cross-sectional design limits the ability to draw causal conclusions between independent variables and anemia incidence. Measurement of several behavioral variables, including adherence to iron supplement consumption and food consumption patterns, relied on self-report data, potentially introducing recall bias. Furthermore, the study's location, limited to a single city in West Sumatra Province, limits the generalizability of the findings to adolescent girls with different socioeconomic characteristics and food access patterns. The household food security instrument used, although validated, may not



fully capture the dynamic dimensions of food availability and utilization in the Indonesian household context.

Based on these limitations, further research with longitudinal or cohort designs is urgently needed to clarify the temporal mechanisms between household food security, consumption behavior, and hemoglobin status. Studies that integrate more comprehensive iron biomarker measurements, mediation pathway analyses, and simultaneous evaluation of the effectiveness of family- and school-based interventions will provide stronger evidence. Expanding the geographic scope to areas with higher anemia prevalence and exploring the role of school environmental factors and social support are also recommended. Future research is expected to produce more accurate, contextualized, and sustainable anemia prediction models and prevention strategies for adolescent girls in Indonesia.

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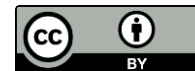
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