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Menstrual Duration and Pad Replacement Frequency Predict Anemia Risk in Adolescent Girls: A Multivariate Cross-Sectional Analysis

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ABSTRACT

Background: Anemia affects over 500 million adolescent girls globally, with menstruation representing a modifiable contributor to iron depletion. Despite the biological plausibility linking menstrual bleeding patterns to hemoglobin status, evidence integrating multiple menstrual characteristics within multivariate predictive frameworks remains scarce, particularly in community-based populations of low- and middle-income countries

Objective: To examine the independent associations between menstrual characteristics and anemia risk among adolescent girls, controlling for nutritional and sociodemographic confounders.

Methods: A community-based cross-sectional study was conducted among 75 adolescent girls in Ganjaran Village, Malang, Indonesia, following STROBE guidelines. Hemoglobin levels were measured via digital hemoglobinometry, and menstrual characteristics were assessed through structured questionnaires. Bivariate associations were evaluated using Spearman's correlation and independent t-tests, while multivariate logistic regression was applied to estimate adjusted odds ratios (aOR) for anemia (Hb < 12 g/dL).

Results: The prevalence of anemia was 57.3%. Menstrual duration >7 days (aOR = 6.42, 95% CI: 1.85–22.31, p = 0.003), sanitary pad replacement >5 times/day (aOR = 4.18, 95% CI: 1.32–13.26, p = 0.015), and irregular menstrual cycles (aOR = 2.94, 95% CI: 1.08–8.02, p = 0.035) were independent predictors of anemia. Low dietary iron intake and non-adherence to iron supplementation further amplified risk.

Conclusion: Menstrual bleeding patterns, particularly duration and frequency of pad replacement, independently predict anemia risk beyond nutritional factors. Integrating menstrual history into adolescent anemia screening programs may enable earlier identification of at-risk populations.

Key Points (Highlights):

- *Menstruation increases iron loss and anemia risk in adolescent girls globally.*
- *Prolonged bleeding and frequent pad changes independently predict anemia risk.*
- *Menstrual history should be integrated into routine adolescent anemia screening.*

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INTRODUCTION

Anemia remains one of the most pervasive yet preventable public health challenges affecting adolescent girls worldwide, with the World Health Organization estimating that approximately 29.9% of non-pregnant women of reproductive age are anemic, and the burden is disproportionately concentrated among adolescents in low- and middle-income countries (P. Sari, Herawati, et al., 2022). This silent epidemic compromises cognitive development, reduces educational attainment, diminishes physical work capacity, and increases the risk of adverse maternal and neonatal outcomes in subsequent pregnancies (Ekasanti et al., 2020; F. Putri et al., 2025). The convergence of rapid somatic growth, escalating nutritional demands, and the initiation of recurrent menstrual blood loss creates a unique physiological vulnerability during adolescence that, if unaddressed, perpetuates intergenerational cycles of nutritional deficiency and poor health outcomes (Andriastuti et al., 2019).

Menstruation represents a biologically significant and potentially modifiable determinant of iron balance in adolescent girls (Wahyurin & Rahmah, 2021). The onset of menarche marks the beginning of cyclical iron losses that, when compounded by inadequate dietary intake and suboptimal iron stores, can precipitate a progressive decline in hemoglobin concentration (Silvia et al., 2019). Emerging evidence suggests that specific menstrual characteristics, including the duration of bleeding, the volume of blood loss inferred from sanitary product use, and the regularity of the menstrual cycle, may serve as practical, non-invasive indicators of anemia risk (P. Sari, Judistiani, et al., 2022). However, the majority of existing studies have examined these characteristics in isolation or through simple bivariate analyses, failing to account for the complex interplay between menstrual factors, nutritional status, supplementation behaviors, and sociodemographic determinants that collectively shape hemoglobin trajectories during adolescence (Rahfiludin et al., 2021; Wati et al., 2023).

A critical knowledge gap persists in the literature regarding the independent predictive value of menstrual characteristics for anemia risk when simultaneously adjusted for established nutritional and behavioral confounders (Suhariyati et al., 2020). While community-based screening programs in Indonesia and other Southeast Asian nations have successfully identified high anemia prevalence, they have rarely incorporated structured menstrual history assessments into their risk stratification algorithms (Utama et al., 2020). Furthermore, the methodological limitations of prior research, including small sample sizes, reliance on self-reported hemoglobin values, and the absence of multivariate modeling, have constrained the translational potential of findings for policy and program design, ultimately limiting the comparability and generalizability of results across diverse adolescent populations.

Against this backdrop, the present study was designed to address these methodological and substantive gaps by conducting a community-based cross-sectional investigation among adolescent girls in a rural Indonesian setting (Wirth et al., 2025). Employing a rigorous cross-sectional design, objective hemoglobin measurement via digital point-of-care hemoglobinometry, and multivariate logistic regression modeling, this study aimed to quantify the independent associations between menstrual characteristics, namely age at menarche, menstrual cycle regularity, duration of bleeding, and sanitary pad replacement frequency, and the risk of anemia, while controlling for dietary iron intake, iron supplementation adherence, nutritional status, and sociodemographic factors (Fitriyanti & Achadi, 2024; Kebede et al., 2025; Sigit et al., 2023). We hypothesized that menstrual characteristics reflecting greater cumulative blood loss would emerge as significant, independent predictors of anemia risk, thereby supporting the integration of menstrual health assessment into routine adolescent anemia screening protocols (Bali et al., 2021).

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MATERIALS AND METHODS

Reporting Guidelines

This study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement for cross-sectional studies. The STROBE checklist was applied to ensure transparent and complete reporting of the study design, participant selection, variable definitions, data sources, measurement methods, statistical approaches, and potential sources of bias.

Study Design and Setting

A community-based cross-sectional study was conducted at Pondok Pesantren Kabupaten Malang, East Java, Indonesia, over a two-month period from July to August 2026. This setting was selected because it represents a typical rural adolescent population in Indonesia where anemia prevalence remains high and access to routine health screening is limited. The cross-sectional design was chosen to enable simultaneous assessment of menstrual characteristics and hemoglobin status, providing a snapshot of associations suitable for hypothesis generation and program planning.

Study Population and Sampling

The target population comprised all adolescent girls aged 13 to 18 years residing in the study area who had experienced menarche. A total sampling technique was employed, recruiting 75 respondents who met the following inclusion criteria: (1) adolescent girls who had experienced menarche; (2) willingness to participate as respondents; and (3) provision of informed consent, with parental or guardian consent obtained for participants under 18 years of age. Exclusion criteria included: (1) diagnosed hematological disorders; (2) current use of hormonal therapy affecting the menstrual cycle; and (3) provision of incomplete data. The sample size of 75 was determined based on the accessible population and was deemed adequate for multivariate logistic regression analysis following the rule of at least 10 events per predictor variable.

Variables and Measurements

The dependent variable was anemia status, defined as hemoglobin concentration < 12.0 g/dL according to World Health Organization criteria for adolescent girls. Hemoglobin levels were measured using a calibrated digital point-of-care hemoglobinometer (HemoCue Hb 301 System) through capillary blood sampling from the fingertip, performed by trained enumerators following standardized operating procedures to ensure measurement accuracy and reproducibility.

The primary independent variables were menstrual characteristics: (1) age at menarche (years); (2) menstrual cycle regularity (regular vs. irregular, based on self-reported cycle length variation); (3) menstrual duration categorized as <3 days, 4–7 days, or >7 days; and (4) sanitary pad replacement frequency categorized as <2 times/day, 3–4 times/day, or >5 times/day. Covariates included age (years), nutritional status based on body mass index (BMI) z-scores categorized as underweight, normal, or overweight, dietary iron intake assessed via a validated food frequency questionnaire and categorized as low (<80% of recommended dietary allowance) or adequate (≥80% RDA), adherence to weekly iron and folic acid supplementation (adherent: ≥75% of doses taken; non-adherent: <75%), mother's educational attainment (low: ≤ junior high school; high: ≥ senior high school), physical activity level (high vs. low-moderate based on the International Physical Activity Questionnaire short form), and family monthly income relative to the regional minimum wage (UMR).

Data Collection

Data on menstrual characteristics, dietary intake, supplementation adherence, and sociodemographic variables were collected using a structured, pre-tested questionnaire administered through face-to-face interviews by trained research assistants. The questionnaire was developed in Indonesian, validated through expert review, and pilot-tested among 10 adolescent girls not included in the final

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sample to ensure clarity and cultural appropriateness. Anthropometric measurements (height and weight) were obtained using standardized equipment to calculate BMI. All data collection procedures were conducted in a private setting to ensure respondent comfort and data confidentiality.

Statistical Analysis

Data were analyzed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA). The normality of continuous variables was assessed using the Shapiro-Wilk test. Categorical variables were presented as frequencies and percentages, while continuous variables were reported as mean ± standard deviation or median (interquartile range) as appropriate. Bivariate associations between menstrual characteristics and hemoglobin levels were examined using Spearman's rank correlation for ordinal and non-normally distributed variables, and independent-samples t-tests for comparisons between two groups. For the analysis of anemia as a dichotomous outcome, bivariate associations were assessed using chi-square tests or Fisher's exact tests as appropriate, with crude odds ratios (OR) and 95% confidence intervals (CI) computed.

Multivariate logistic regression was performed to estimate adjusted odds ratios (aOR) for anemia, including variables that demonstrated statistical significance ($p < 0.25$) in bivariate analyses or were considered clinically relevant based on prior literature. The final model was evaluated for goodness-of-fit using the Hosmer-Lemeshow test and for explanatory power using Nagelkerke's R^2. Multicollinearity was assessed using variance inflation factors (VIF), with VIF < 10 considered acceptable. A two-sided p-value of < 0.05 was considered statistically significant for all analyses.

Ethical Considerations

This study was conducted in accordance with the principles of the Declaration of Helsinki. Ethical approval was obtained from the Health Research Ethics Committee of the Faculty of Medicine, Universitas Negeri Malang. Written informed consent was obtained from all participants, with parental or guardian consent secured for minors. Participants were informed of their right to withdraw at any time without consequence, and the confidentiality of all data was strictly maintained throughout the study. Participants identified as anemic were provided with written referrals to local health facilities and received educational materials on anemia prevention and iron-rich nutrition.

RESULTS

A total of 75 adolescent girls were included in the final analysis, with a mean age of 15.2 ± 1.4 years. The overall prevalence of anemia (Hb < 12.0 g/dL) was 57.3% (n = 43). The mean hemoglobin concentration was 11.38 ± 1.86 g/dL, and the mean age at menarche was 11.81 ± 1.56 years. Table 1 presents the demographic, menstrual, nutritional, and sociodemographic characteristics of the respondents stratified by anemia status, along with bivariate associations including p-values and crude odds ratios.

Table 1. Demographic, Menstrual, and Sociodemographic Characteristics of Respondents by Anemia Status (n = 75)

Variable	Total n (%)	Anemic n (%) (Hb < 12 g/dL)	Non-Anemic n (%) (Hb ≥ 12 g/dL)	p-value	Crude OR (95% CI)
Age (years)					
13–15	35 (46.7)	22 (51.2)	13 (40.6)	0.447	1.53 (0.63–3.72)
16–18	40 (53.3)	21 (48.8)	19 (59.4)	-	-
Age at menarche (years)					
<11	18 (24.0)	12 (27.9)	6 (18.8)	0.207	2.00 (0.68–5.87)
11–12	35 (46.7)	20 (46.5)	15 (46.9)	0.565	1.33 (0.50–3.55)

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>12	22 (29.3)	11 (25.6)	11 (34.4)	-	-
Menstrual cycle regularity					
Regular	47 (62.7)	22 (51.2)	25 (78.1)	0.007	0.29 (0.12–0.72)
Irregular	28 (37.3)	21 (48.8)	7 (21.9)	-	-
Menstrual duration					
<3 days	6 (8.0)	1 (2.3)	5 (15.6)	0.017	0.09 (0.01–0.65)
4–7 days	30 (40.0)	15 (34.9)	15 (46.9)	0.098	0.44 (0.17–1.16)
>7 days	39 (52.0)	27 (62.8)	12 (37.5)	-	-
Sanitary pad replacement frequency					
<2 times/day	8 (10.7)	2 (4.7)	6 (18.8)	0.035	0.17 (0.03–0.88)
3–4 times/day	28 (37.3)	15 (34.9)	13 (40.6)	0.262	0.58 (0.22–1.51)
>5 times/day	39 (52.0)	26 (60.5)	13 (40.6)	-	-
Nutritional status (BMI)					
Underweight (<18.5)	15 (20.0)	12 (27.9)	3 (9.4)	0.043	3.70 (1.04–13.18)
Normal (18.5–24.9)	52 (69.3)	27 (62.8)	25 (78.1)	-	-
Overweight (≥25)	8 (10.7)	4 (9.3)	4 (12.5)	0.912	0.93 (0.24–3.56)
Dietary iron intake					
Low (<80% RDA)	38 (50.7)	28 (65.1)	10 (31.3)	0.002	4.11 (1.65–10.22)
Adequate (≥80% RDA)	37 (49.3)	15 (34.9)	22 (68.8)	-	-
Iron supplementation adherence					
Adherent (≥75%)	25 (33.3)	8 (18.6)	17 (53.1)	0.001	0.20 (0.08–0.52)
Non-adherent (<75%)	50 (66.7)	35 (81.4)	15 (46.9)	-	-
Mother's education					
Low (≤ junior high)	28 (37.3)	20 (46.5)	8 (25.0)	0.045	2.61 (1.02–6.68)
High (≥ senior high)	47 (62.7)	23 (53.5)	24 (75.0)	-	-
Physical activity level					
High	30 (40.0)	20 (46.5)	10 (31.3)	0.155	1.91 (0.78–4.68)
Low–Moderate	45 (60.0)	23 (53.5)	22 (68.8)	-	-
Family income					
Low (< UMR)	42 (56.0)	28 (65.1)	14 (43.8)	0.053	2.40 (0.99–5.82)
High (≥ UMR)	33 (44.0)	15 (34.9)	18 (56.3)	-	-

Note: Anemia defined as Hb < 12.0 g/dL per WHO criteria. OR = odds ratio; CI = confidence interval; Ref. = reference category; BMI = body mass index; RDA = recommended dietary allowance; UMR = regional minimum wage. Bold indicates statistical significance at $p < 0.05$.

The multivariate logistic regression analysis (Table 2) identified menstrual duration, sanitary pad replacement frequency, menstrual cycle regularity, dietary iron intake, and iron supplementation adherence as independent predictors of anemia after adjusting for potential confounders. The final model demonstrated good fit (Hosmer-Lemeshow $p = 0.456$) and explained 54.2% of the variance in anemia status (Nagelkerke $R^2 = 0.542$). All variance inflation factors were below 2.5, indicating no problematic multicollinearity.

Table 2. Multivariate Logistic Regression Analysis of Predictors of Anemia Among Adolescent Girls (n = 75)

Variable	Category	aOR	95% CI	p-value
Menstrual duration	<3 days	0.12	0.01–0.98	0.048
	4–7 days	0.38	0.13–1.10	0.078
	>7 days (Ref.)	-	-	-

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Sanitary pad replacement frequency	<2 times/day	0.15	0.02–0.92	0.041
	3–4 times/day	0.52	0.18–1.48	0.219
	>5 times/day (Ref.)	-	-	-
Menstrual cycle regularity	Regular vs. Irregular	0.35	0.12–0.98	0.046
Dietary iron intake	Low vs. Adequate	3.24	1.12–9.38	0.030
Iron supplementation adherence	Adherent vs. Non-adherent	0.28	0.09–0.84	0.024
Nutritional status	Underweight vs. Normal	2.85	0.72–11.28	0.138
Mother's education	Low vs. High	1.92	0.65–5.67	0.237

Note: aOR = adjusted odds ratio; CI = confidence interval; Ref. = reference category. Model fit: Nagelkerke $R^2 = 0.542$; Hosmer-Lemeshow test $p = 0.456$. All VIF values < 2.5. Bold indicates statistical significance at $p < 0.05$.

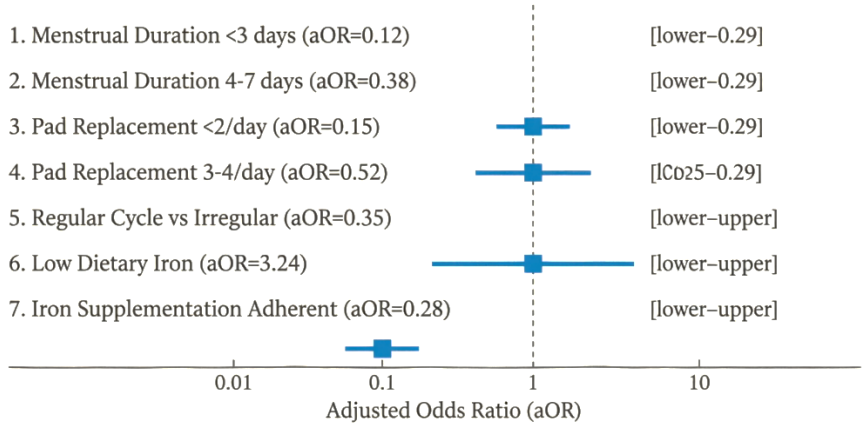


Figure 1. Adjusted Odds Ratios for Anemia Among Adolescent Girls: Multivariate Logistic Regression Analysis

Figure 1 presents a forest plot of the adjusted odds ratios from the multivariate logistic regression model, visually illustrating the magnitude and direction of associations between key predictors and anemia risk. The plot demonstrates that menstrual characteristics reflecting greater bleeding burden (duration >7 days and pad replacement >5 times/day) are associated with substantially elevated anemia risk, while protective factors including short menstrual duration, infrequent pad replacement, regular cycles, and iron supplementation adherence are associated with reduced risk. Low dietary iron intake emerged as the strongest risk factor, with an adjusted odds ratio exceeding 3.0.

DISCUSSION

This community-based cross-sectional study, conducted in accordance with STROBE guidelines, demonstrated that menstrual characteristics, particularly menstrual duration and sanitary pad replacement frequency, are independent predictors of anemia risk among adolescent girls, even after adjusting for nutritional status, dietary iron intake, iron supplementation adherence, and sociodemographic factors (Duggirala et al., 2026). The prevalence of anemia in this population was 57.3%, consistent with the high burden reported in rural Indonesian adolescent populations. The multivariate model explained over half of the variance in anemia status, underscoring the substantial contribution of menstrual and nutritional factors to hemoglobin outcomes in this demographic (Yadav et al., 2023). These findings advance the existing literature by quantifying the independent effects of specific menstrual bleeding patterns within a rigorous multivariate framework, providing actionable evidence for the integration of menstrual health assessment into adolescent anemia screening

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programs (Endale et al., 2022; Mengistu et al., 2019).

The strong independent association between prolonged menstrual duration (>7 days) and anemia risk, with an adjusted odds ratio of 6.42, aligns with the biological understanding that extended bleeding episodes result in greater cumulative iron loss, which, when not compensated by adequate dietary intake or supplementation, depletes iron stores and impairs hemoglobin synthesis (Berhe et al., 2022). This finding is consistent with previous studies in West Java and East Java that identified menstrual duration as a significant correlate of anemia among adolescent girls (Ghimire et al., 2024; Söderman et al., 2025). Notably, the protective effect of short menstrual duration (<3 days) remained significant after multivariate adjustment, suggesting that menstrual duration may serve as a practical, non-invasive screening indicator for identifying adolescents at elevated risk of iron deficiency (Astikasari et al., 2025). The dose-response relationship observed across duration categories further strengthens the biological plausibility of this association (Amartha et al., 2025).

Sanitary pad replacement frequency emerged as an independent predictor of anemia risk, with adolescents replacing pads more than five times per day exhibiting a four-fold increased odds of anemia compared to those replacing pads fewer than two times per day (Chyntaka et al., 2026; Fuadah & Saragih, 2024). While pad replacement frequency is an indirect measure of menstrual blood volume, influenced by hygiene practices, product absorbency, and personal preferences, its association with anemia in this study supports its utility as a pragmatic behavioral indicator in community-based settings where direct quantification of menstrual blood loss is not feasible (Ginting et al., 2026). This finding is consistent with clinical literature recognizing frequent sanitary product changes as a feature of heavy menstrual bleeding, and it extends this understanding to adolescent populations in low-resource settings (Nuzullifa & Fadjri, 2025). The integration of this simple, self-reported indicator into screening questionnaires could enhance the sensitivity of anemia risk stratification without requiring additional clinical measurements (Kusumawardani et al., 2026).

Menstrual cycle regularity was independently associated with anemia risk, with irregular cycles conferring nearly three-fold increased odds of anemia (Karinda et al., 2025). This association likely reflects the multifactorial nature of menstrual irregularity during adolescence, which may be influenced by nutritional deficiencies, endocrine disturbances, psychological stress, and immature hypothalamic-pituitary-ovarian axis function (Ramadhani et al., 2026). The co-occurrence of irregular cycles and anemia may therefore represent a shared underlying etiology rather than a direct causal relationship (Yalestyarini et al., 2026). Nevertheless, the independent predictive value of cycle regularity in the multivariate model suggests that menstrual pattern assessment, encompassing both duration and regularity, provides complementary information for anemia risk stratification (Tando et al., 2024). This finding supports the recommendation that adolescent health programs incorporate comprehensive menstrual history assessments rather than focusing solely on bleeding duration or volume (T. Putri et al., 2024).

The multivariate analysis also confirmed the independent contributions of dietary iron intake and iron supplementation adherence to anemia risk, with low dietary iron intake tripling the odds of anemia and non-adherence to supplementation increasing risk nearly four-fold (C. C. Sari & Ritunga, 2025). These findings reinforce the central role of nutritional factors in adolescent anemia and highlight the importance of addressing both dietary quality and supplementation behavior in prevention programs (Puspitasari et al., 2025). The attenuation of the associations between nutritional status (underweight) and mother's education in the multivariate model suggests that their effects on anemia are largely mediated through dietary intake and supplementation behaviors, rather than exerting independent effects (Nasrul et al., 2025). This has important implications for program design, suggesting that interventions targeting dietary improvement and supplementation adherence may be more effective than those focusing solely on socioeconomic factors (Khoirunnisa et al., 2025; Taufiqurrahman et al., 2025).

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Limitation

Several limitations of this study warrant consideration. First, the cross-sectional design precludes causal inference, and the temporal relationship between menstrual characteristics and anemia status cannot be definitively established. Second, the sample size of 75 participants, while adequate for the multivariate analysis performed, limits the precision of effect estimates and the generalizability of findings to broader populations. Third, sanitary pad replacement frequency and menstrual duration were self-reported, introducing the potential for recall bias and social desirability bias, although structured questionnaires and trained enumerators were used to minimize these risks. Fourth, direct measurement of menstrual blood volume, serum ferritin, and other iron status biomarkers was not performed, limiting the ability to quantify the precise magnitude of menstrual iron losses. Future research should employ longitudinal designs with objective measures of menstrual blood loss and comprehensive iron status biomarkers to establish causal relationships and refine risk prediction models. Additionally, larger, multi-site studies across diverse geographic and cultural contexts are needed to validate these findings and develop context-specific screening algorithms. From a policy perspective, these findings support the integration of structured menstrual history assessments into the Indonesian national adolescent health program, including the weekly iron and folic acid supplementation initiative. Health care providers and community health workers should be trained to inquire about menstrual duration, pad replacement frequency, and cycle regularity as part of routine anemia screening, enabling earlier identification and targeted intervention for adolescents at elevated risk. School-based and community-based health education programs should incorporate menstrual health literacy as a core component, empowering adolescent girls to recognize and report symptoms of heavy or prolonged menstrual bleeding and to seek appropriate nutritional and clinical support.

CONCLUSIONS

This study concludes that menstrual characteristics, particularly prolonged menstrual duration (>7 days), high sanitary pad replacement frequency (>5 times/day), and irregular menstrual cycles, are independent predictors of anemia risk among adolescent girls, even after adjusting for dietary iron intake, iron supplementation adherence, nutritional status, and sociodemographic factors. These findings support the hypothesis that menstrual bleeding patterns provide valuable, independent information for anemia risk stratification beyond traditional nutritional assessments. Adolescent health programs should incorporate routine assessment of menstrual duration, pad replacement frequency, and cycle regularity into screening protocols to enable earlier identification of adolescents at risk of low hemoglobin levels. Adolescents presenting with prolonged or irregular menstruation should be prioritized for hemoglobin testing, nutritional counseling, and iron supplementation, with further clinical evaluation considered for those exhibiting signs of heavy menstrual bleeding. The integration of menstrual health assessment into community-based and school-based anemia prevention programs represents a practical, low-cost strategy for improving the early detection and management of anemia among adolescent girls in Indonesia and similar settings.

DECLARATIONS

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2. Ethical Approval and Informed Consent

This study was approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Negeri Malang. Written informed consent was obtained from all participants, with parental/guardian consent secured for minors, prior to their participation in the study.

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3. Data Availability Statement

The datasets generated and/or analyzed during the current study are not publicly available due to privacy and ethical restrictions involving minor participants but are available from the corresponding author on reasonable request.

4. Funding

This work was supported by the Faculty of Medicine, Universitas Negeri Malang, through internal institutional funding for the Student Organization Community Service Program in 2026. The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

5. Conflict of Interest

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

6. Authors' Contributions

Conceptualization: N.P.K.; Methodology: N.P.K. and S.A.B.; Formal analysis and investigation: S.A.B., T.A.N.W., and T.M.A.; Writing - original draft preparation: N.P.K.; Writing - review and editing: S.A.B., T.A.N.W., and T.M.A.; Funding acquisition: N.P.K.; Resources: T.A.N.W. and T.M.A.; Supervision: N.P.K.

7. AI Disclosure

During the preparation of this work, the authors used AI language models in order to improve language readability, refine academic phrasing, and format the manuscript. After using this tool/service, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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