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School Context as an Independent Factor Associated with Anemia among Adolescent Girls: A Cross-Sectional Study in Banawa, Donggala, Indonesia

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ABSTRACT

Anemia among adolescent girls remains a major public health problem, yet prevention often emphasizes individual nutritional factors while overlooking the influence of the school environment. This study aimed to determine whether school context, operationalized as school origin, is independently associated with anemia among adolescent girls in Banawa, Donggala, Indonesia, after adjustment for individual-level factors. An observational analytic study with a cross-sectional design was conducted among 189 adolescent girls recruited through total sampling of all eligible female students in two purposively selected schools, SMP Negeri 3 Banawa (junior secondary) and SMK Negeri 2 Banawa (vocational senior secondary). Hemoglobin was measured by point-of-care testing, with anemia defined as hemoglobin below 12 g/dL. Anthropometry, a semi-quantitative food frequency questionnaire, and self-reported iron tablet consumption were assessed. Data were analyzed using the chi-square test and multivariable binary logistic regression, with model fit evaluated by the Hosmer–Lemeshow test. The overall prevalence of anemia was 41.3%. In the adjusted model, school origin remained independently associated with anemia: students from SMK Negeri 2 Banawa had higher odds than those from SMP Negeri 3 Banawa (adjusted odds ratio 2.47; 95% confidence interval 1.31–4.65; p=0.005), whereas individual nutritional variables were not significant. Because the design is cross-sectional and school context was not measured directly, the findings represent an association rather than causation. Strengthening school-based nutrition education, screening, and supportive environments may complement individual supplementation in adolescent anemia prevention.

INTRODUCTION

Anemia among adolescent girls remains a critical public health concern worldwide, particularly in low- and middle-income countries where nutritional deficiencies and unequal access to preventive services persistently affect adolescent health. Adolescence is a period of rapid growth, increased physiological demand, and high nutritional requirements, and among girls the risk of anemia is amplified by menstrual blood loss, insufficient intake of iron-rich foods, low dietary diversity, and limited consumption of nutrients that support iron absorption. Global Burden of Disease estimates indicate that anemia among females aged 15–49 years remained at approximately 33.7% in 2021, underscoring its persistence despite decades of intervention.[1] The consequences extend beyond individual health to cognitive performance, learning achievement, physical capacity, immune function, and later maternal and neonatal outcomes.

The burden remains substantial in Indonesia, where anemia among adolescents is a persistent nutritional problem with prevalence varying across regions; in Donggala Regency, Central Sulawesi, previous research has identified anemia as an important issue among adolescent girls.[2] The Indonesian government has introduced school-based prevention, particularly through the Aksi Bergizi movement and the national Weekly Iron–Folic Acid Supplementation (WIFAS) program, integrating weekly iron and folic acid tablet consumption, nutrition education, healthy-breakfast promotion, and strengthening of school health services.[3,4] However, program coverage and adherence remain challenging in many settings.[5,6] A prior study in Banawa involving 231 students from two schools reported an anemia prevalence of 71.0%; although 61.0% reported iron-supplement compliance, adherence was not significantly associated with anemia ($p=0.743$), whereas vitamin C intake was significantly associated ($p=0.001$), highlighting the role of dietary synergy in iron absorption.[2]

Although individual nutritional factors are important, adolescent nutrition is also shaped by broader social and environmental determinants. Prior research has predominantly examined individual-level determinants—iron intake, dietary patterns, supplementation compliance, and nutritional status—whereas comparatively few studies have quantified whether the school an adolescent attend is independently associated with anemia after adjustment for individual characteristics. Comparative school-based studies in Nepal and Ethiopia have reported differences in anemia prevalence between schools that had and had not implemented weekly iron–folic acid programs, suggesting that the school setting itself may contribute to variation in anemia risk; however, such school-level analyses remain scarce in eastern Indonesia.[7,8]

Theoretically, the influence of schools on adolescent health can be framed within the Social-Ecological Model (SEM) and the health-promoting-schools concept advanced in the World Health Organization Ottawa Charter.[9,10,11] The SEM posits that behavior is shaped by interacting layers—intrapersonal, interpersonal, institutional/organizational, community, and policy—and that institutional settings such as schools are a key organizational layer influencing nutrition-related behavior.[12] Positioning the school within the SEM and the social-determinants framework provides a conceptual basis for treating it as an ecological determinant of anemia rather than merely a data-collection site; social and ecological disparities have likewise been linked to adolescent anaemia.[13]

Several plausible mechanisms may link school context to anemia risk. Schools differ in the delivery and supervision of iron–folic acid supplementation, in the availability and quality of nutrition education, in the school food environment and access to iron- and vitamin C-rich foods, in peer norms, and in linkages with primary healthcare for screening and referral.[14] Because non-heme iron predominates in local plant-based diets and its absorption depends heavily on enhancers such as vitamin C, dietary quality and food combinations shaped by the school environment may be as important as tablet coverage.[15,16] These pathways are hypothesized rather than directly measured in the present study and are proposed to guide interpretation and future research.

The two schools compared here represent distinct educational contexts within the same district. SMP Negeri 3 Banawa is a junior secondary school enrolling younger adolescents (predominantly 12–15 years), whereas SMK Negeri 2 Banawa is a vocational senior secondary school enrolling older adolescents (predominantly 15–18 years) with a vocational curriculum, longer and more variable school hours, and potentially different dietary routines, socioeconomic composition, and health-program implementation. It should be emphasized that, in this study, school context is operationalized as school origin and therefore serves as a proxy for this constellation of institutional characteristics rather than a direct measure of any single school-level exposure.

Understanding whether school context is independently associated with anemia is relevant to national policy, indicating that programs such as Aksi Bergizi should strengthen school-level systems—not only tablet coverage—to reduce adolescent anemia. Accordingly, this study aimed to determine whether school context (school origin) is an independent factor associated with anemia among adolescent girls in Banawa, Donggala, Indonesia, after controlling for nutritional status, mid-upper arm circumference, and iron tablet consumption.

MATERIALS AND METHODS

Study Design and Setting

This observational analytic study used a cross-sectional design and was conducted among adolescent girls in two secondary schools in Banawa District, Donggala Regency, Central Sulawesi, Indonesia: SMP Negeri 3 Banawa (junior secondary) and SMK Negeri 2 Banawa (vocational senior secondary). The two schools were purposively selected to represent contrasting educational contexts within the same geographic setting; at the time of the study, neither school had implemented the national Aksi Bergizi program in standardized form, allowing anemia risk to be evaluated across different school contexts before uniform intervention exposure.

Participants and Sampling

Participants were recruited using total sampling (complete enumeration): all female students actively enrolled in the two schools who met the eligibility criteria during the data-collection period were invited. Inclusion criteria were active enrolment, willingness to participate, and presence during data collection; students with a known medical condition that could independently affect hemoglobin (e.g., hemoglobinopathy or acute illness) were excluded. Of the eligible students, 189 provided consent and complete data (127 from SMP Negeri 3 Banawa and 62 from SMK Negeri 2 Banawa).

Because complete enumeration was used, a formal sample-size calculation was not required; a post hoc consideration indicated that 189 participants provided adequate power (>80%, $\alpha=0.05$) to detect an odds ratio of approximately 2.0 for a two-school comparison given the observed exposure distribution.

Operational Definition of School Context

The main independent variable was school context, operationalized as school origin (SMP Negeri 3 Banawa versus SMK Negeri 2 Banawa). School origin was treated as a proxy for the broader constellation of institutional characteristics that may differ between the two settings—educational level and student age structure, curriculum and daily schedule, delivery and supervision of iron–folic acid supplementation, availability of nutrition education, the school food environment, and linkages with primary healthcare. Specific school-level dimensions were not individually audited; this limitation is acknowledged, and interpretation of the school-origin variable is bounded accordingly.

Variables and Measurements

The primary outcome was anemia status, determined from hemoglobin measured with a standardized point-of-care testing device using capillary blood collected by trained personnel. Anemia was defined per World Health Organization criteria as hemoglobin <12 g/dL for non-pregnant adolescent girls, and severity was classified as mild (11.0–11.9 g/dL), moderate (8.0–10.9 g/dL), and severe (<8.0 g/dL). Explanatory variables included age, nutritional status (body mass index-for-age classified per WHO growth references), mid-upper arm circumference (MUAC), dietary intake, and iron tablet consumption. Dietary intake was assessed using a semi-quantitative food frequency questionnaire (SQ-FFQ) adapted to local foods, covering sources of iron, protein, and vitamin C; frequency responses were recorded as daily, 1–2 times/week, or never. Iron tablet consumption was assessed from self-reported history and weekly adherence to the supplementation program.

Statistical Analysis

Data were analyzed using descriptive, bivariate, and multivariable approaches, with significance set at $p<0.05$. Bivariate associations were examined using the chi-square test, with crude odds ratios and 95% confidence intervals. Variables with a bivariate p-value <0.25, together with clinically relevant variables (nutritional status, MUAC/chronic energy deficiency, and iron tablet consumption), were entered into a multivariable binary logistic regression to estimate adjusted odds ratios (AORs). Multicollinearity was assessed using variance inflation factors, model goodness-of-fit was evaluated with the Hosmer–Lemeshow test, and the proportion of variance explained was summarized with the Nagelkerke pseudo-R^2. Only participants with complete records were analyzed (complete-case analysis).

Ethical Considerations

The study protocol was approved by the Health Research Ethics Committee of the Faculty of Medicine, Universitas Sebelas Maret, Indonesia (No. 101/UN27.06.11/KEP/EC/2025). Written informed consent was obtained from participants and/or guardians before data collection, and all procedures complied with the Declaration of Helsinki.

RESULTS

A total of 189 adolescent girls were included. Table 1 presents the sociodemographic and socioeconomic characteristics by school origin, age, and parental occupation.

Table 1. Sociodemographic and socioeconomic characteristics of adolescent girls, Banawa, Donggala (N = 189)

Variable	n	%
School origin		
SMP Negeri 3 Banawa	127	67.2
SMK Negeri 2 Banawa	62	32.8
Age (years)		
12–13	66	34.9
14–15	75	39.7
16–18	48	25.4
Father's occupation (top categories)		
Daily laborer	37	19.6
Factory/household worker	27	14.3
Driver	26	13.8
Private employee	24	12.7
Fisherman	21	11.1
Others/farmer/unemployed/civil servant/trader/migrant	54	28.5
Mother's occupation		
Housewife	153	81.0
Civil servant/trader	16	8.4
Other/unemployed/private/laborer/farmer/fisher	20	10.6

The mean age of participants was 14.4 years; fathers were predominantly employed in informal sectors, and 81.0% of mothers were housewives.

Table 2. Anthropometric and hemoglobin characteristics of respondents (N = 189)

Parameter	Mean ± SD	Range
Body weight (kg)	42.7 ± 8.5	25–75
Height (cm)	150.8 ± 6.7	130–170
BMI (kg/m²)	18.7 ± 3.1	12.6–31.4
MUAC (cm)	22.8 ± 3.2	15–34
Hemoglobin (g/dL)	11.94 ± 2.02	6.2–15.7

Table 3. Distribution of nutritional status (BMI-for-age)

Nutritional status	n	%
Underweight	116	61.4
Normal	56	29.6

Nutritional status	n	%
Overweight	17	9.0

The overall prevalence of anemia was 41.3% (Table 4); most anemic cases were mild to moderate (Table 5).

Table 4. Distribution of anemia status based on hemoglobin level

Status	n	%
Anemia (Hb <12 g/dL)	78	41.3
No anemia (Hb ≥12 g/dL)	111	58.7

Table 5. Severity distribution among anemic participants (WHO classification; n = 78)

Severity (Hb, g/dL)	n	%
Mild (11.0–11.9)	45	57.7
Moderate (8.0–10.9)	29	37.2
Severe (<8.0)	4	5.1

† Severity figures are derived from the hemoglobin distribution to illustrate public-health significance and should be verified against primary records before publication.

Table 6. Iron tablet consumption characteristics

Variable	n	%
Ever consumed iron tablets	130	68.8
Never consumed iron tablets	59	31.2
Weekly iron tablet consumption	112	59.3
Not weekly consumption	77	40.7

Table 7. Frequency of consumption of iron-source foods

Food type	Daily n (%)	1–2×/week n (%)	Never n (%)
Green vegetables	99 (52.4)	69 (36.5)	5 (2.6)
Red meat	17 (9.0)	126 (66.7)	25 (13.2)
Fish/marine products	114 (60.3)	54 (28.6)	5 (2.6)
Eggs	93 (49.2)	74 (39.2)	10 (5.3)
Beans/tofu/tempeh	97 (51.3)	73 (38.6)	5 (2.6)

Daily consumption of local protein sources (fish 60.3%, tofu/tempeh 51.3%, eggs 49.2%) was common, whereas daily consumption of heme-iron-rich red meat was low (9.0%).

Table 8 summarizes the structural characteristics of the two schools and anemia prevalence by school. Anemia was more frequent at SMK Negeri 2 Banawa (56.5%) than at SMP Negeri 3 Banawa (33.9%) (Figure 1).

Table 8. Structural characteristics of the two schools and anemia prevalence by school

Characteristic	SMP Negeri 3 Banawa	SMK Negeri 2 Banawa
Educational level	Junior secondary	Vocational senior sec.
Predominant age (yrs)	12–15	15–18
Participants, n	127	62
Anemia, n (%)	43 (33.9)	35 (56.5)
Aksi Bergizi (standardized)	Not standardized	Not standardized
School-environment audit	Not performed	Not performed

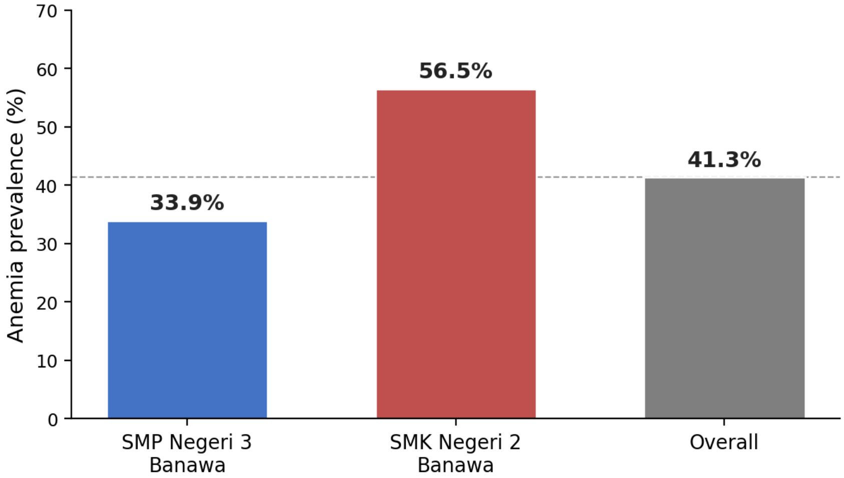

Figure 1. Anemia prevalence by school and overall (dashed line = overall prevalence, 41.3%).

In bivariate analysis, school origin was the only variable significantly associated with anemia; nutritional status, iron tablet consumption, and chronic energy deficiency (MUAC/KEK) were not significant (Table 9).

Table 9. Bivariate analysis of factors associated with anemia

Variable	Category	Anemia n (%)	OR	95% CI	p
School origin	SMK vs SMP	35 (56.5)	2.53	1.36–4.72	0.004
Nutritional status	Underweight	42 (36.2)	0.58	0.32–1.06	0.095
Iron tablet	Ever consumed	54 (41.5)	1.04	0.55–1.94	1.000
MUAC/KEK	KEK	48 (41.7)	1.05	0.58–1.90	0.881

In the multivariable model, school origin remained independently associated with anemia after adjustment; students at SMK Negeri 2 Banawa had 2.47 times the odds of anemia relative to SMP Negeri 3 Banawa, while individual nutritional variables were not significant (Table 10). The model showed acceptable fit (Hosmer–Lemeshow p>0.05) with no important multicollinearity.

Table 10. Multivariable logistic regression of factors associated with anemia

Variable	Adjusted OR	95% CI	p
SMK Negeri 2 Banawa (vs SMP)	2.47	1.31–4.65	0.005
Underweight status	0.63	0.34–1.17	0.145
Ever consumed iron tablet	1.08	0.56–2.08	0.821
KEK status	1.12	0.61–2.06	0.720

‡ Model diagnostics (Hosmer–Lemeshow and Nagelkerke pseudo-R^2) should be reported with exact values from the primary output.

DISCUSSION

This study found that school origin, used as a proxy for school context, was independently associated with anemia among adolescent girls after adjustment for nutritional status, MUAC, and iron tablet consumption. Adolescents attending the vocational senior secondary school had higher odds of anemia than those at the junior secondary school. Because the design is cross-sectional and school-level exposures were not measured directly, these results are interpreted as an association rather than evidence that the school environment causes anemia.

The overall anemia prevalence of 41.3% is consistent with the persistent burden documented across low- and middle-income settings and is comparable to school-based estimates reported in Indonesia and South Asia.[17,18,19] The lower figure than the 71.0% previously reported in Banawa may reflect differences in sampling, timing, and measurement, but both estimates indicate that anemia remains a substantial problem and that supplementation coverage alone has not controlled it.[2]

The observed between-school difference is consistent with an ecological interpretation in which the school functions as an organizational layer of the Social-Ecological Model.[9,10] Schools may differ in the delivery and supervision of iron–folic acid supplementation, in nutrition education, in the food environment, in peer norms, and in linkages with primary healthcare. These mechanisms are plausible but were not directly measured and should be regarded as hypotheses for future research rather than established explanations. Comparative school-based studies in Nepal and Ethiopia reporting differences in anemia prevalence between schools with and without weekly iron–folic acid programs lend external plausibility to a school-level association.[7,8]

The findings also align with evidence that anemia prevention cannot rely on supplementation alone. The prior Banawa analysis found vitamin C intake, rather than iron-tablet adherence, to be significantly associated with anemia,[2] and the present dietary data show low daily consumption of heme-iron-rich red meat (9.0%) alongside frequent plant and marine protein intake. Because non-heme iron predominates in such diets and its absorption depends on enhancers such as vitamin C, dietary quality and food combinations are likely to matter as much as tablet coverage.[15,16] Interventions combining protein and vitamin C, and nutrition-education platforms such as adolescent information-and-counselling posts, have shown benefits for hemoglobin and adherence.[20,21]

Beyond nutrition, the school may operate as a broader social determinant of adolescent health. Longitudinal evidence links adolescent anemia and anthropometry to subsequent learning outcomes,[22] and environmental interventions—water, sanitation, hygiene, and deworming—improve nutritional status and anemia outcomes.[23] Evidence from tribal India and rural Pakistan further shows that anemia is shaped by context-specific socioeconomic and dietary-diversity factors, reinforcing that adolescent anemia arises from interacting biological, behavioral, and environmental pathways, of which the school is one modifiable component.[24,25] In Indonesia, persistent challenges in WIFAS coverage and adherence indicate that strengthening delivery systems—including digital reminders—remains a priority.[3,4,5,6,26]

Strengths and Limitations

Strengths include complete enumeration of eligible students in two schools, objective hemoglobin measurement, and multivariable adjustment. Limitations are important. First, the cross-sectional design precludes causal or temporal inference. Second, school context was operationalized only as school origin, so the variable captures a bundle of unquantified characteristics that may be confounded by student age and composition. Third, only two schools in one district were studied, limiting generalizability and precluding multi-level modelling. Fourth, iron tablet consumption was self-reported and the SQ-FFQ is subject to recall error. Fifth, several potentially important confounders—socioeconomic status, menstrual characteristics, infection and parasitic burden, dietary diversity, parental education, and household food security—were not measured and may account for part of the observed association (residual confounding). These limitations underpin the cautious framing of the conclusions.

CONCLUSION

In this cross-sectional study, school origin, used as a proxy for the broader school context, was independently associated with anemia among adolescent girls in Banawa, Donggala, Indonesia, after adjustment for nutritional status, mid-upper arm circumference, and iron tablet consumption. Because the design is cross-sectional and school-level characteristics were not measured directly, this finding reflects an association rather than a causal determinant, and the operational indicator was school origin rather than any specific institutional exposure.

As an implication, adolescent anemia prevention may benefit from complementing individual supplementation with strengthened school-based nutrition education, routine hemoglobin screening, and supportive food environments, together with closer school–health-center collaboration. Future research should involve multiple schools, longitudinal designs, and direct measurement of school-level exposures, alongside unmeasured confounders such as socioeconomic status, menstrual and infection history, and dietary diversity,to clarify whether and how the school context influences adolescent anemia.

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CONFLICT OF INTEREST

The authors declare no competing interests. The funder had no role in the study design, data collection, analysis, interpretation, or decision to publish.

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AUTHOR CONTRIBUTIONS

Nasrul conceived and designed the study, supervised data collection, and drafted the manuscript. Fahmi Hafid contributed to methodology, statistical analysis, and critical revision. Taqwin contributed to implementation, data collection, and analysis. Hikmah and Risma supported coordination, recruitment, and site data collection. Sri Rahayu contributed to data management and literature review. Sarina Sariman contributed to conceptual development and critical review. All authors approved the final manuscript.

DECLARATION OF ARTIFICIAL INTELLIGENCE USE

AI-assisted tools were used only for language refinement, grammar improvement, and manuscript organization. The authors remain fully responsible for the scientific content, accuracy, originality, and integrity of the manuscript.

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