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ASSOCIATION BETWEEN MID-UPPER ARM CIRCUMFERENCE AND HEMOGLOBIN CONCENTRATION IN ADOLESCENT GIRLS: A CROSS-SECTIONAL STUDY

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Abstract

Background: Anemia remains a relevant nutritional concern among adolescent girls. Mid-upper arm circumference (MUAC) is a practical anthropometric measurement that may be associated with hemoglobin concentration and may help identify adolescents with limited nutritional reserves.

Objective: This study aimed to examine the association between MUAC length and hemoglobin concentration in adolescent girls at SMA N 1 Tegalalang, Gianyar Regency.

Methods: This analytical observational study used a cross-sectional design. A total of 147 female students were recruited using consecutive sampling. MUAC was the independent variable, and hemoglobin concentration was the dependent variable. Hemoglobin was measured using a point-of-care testing device. Data were analyzed using ANCOVA in IBM SPSS Statistics version 27, with the control of age and menstrual duration.

Results: Most participants had a MUAC of ≥23.5 cm (50.34%) and normal hemoglobin concentration (≥12 g/dL; 93.9%). After adjustment for age and menstrual duration, MUAC was significantly associated with hemoglobin concentration ($F = 5.257$, $p = 0.024$, partial $\eta^2 = 0.047$).

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Conclusions: A significant association was observed between MUAC and hemoglobin concentration among female adolescents. MUAC may be considered a practical anthropometric measure for identifying adolescents who could benefit from further nutritional assessment and hemoglobin testing.

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INTRODUCTION

Anemia is a condition characterized by hemoglobin levels below the normal reference range (1,2). The global prevalence of anemia among adolescent girls ranges from 40% to 88% (1). One of the major risk factors for anemia is nutritional status. Adolescent girls are particularly vulnerable to anemia (especially iron deficiency anemia) because of rapid growth, increased iron requirements, dietary inadequacy, and menstrual blood loss (3). Nutritional problems among adolescent girls, particularly prolonged inadequate nutrient intake, may lead to chronic energy deficiency (CED), which in females can be identified by a mid-upper arm circumference (MUAC) of less than 23.5 cm (4). Chronic energy deficiency can adversely affect various metabolic processes in the body. A study conducted by Farahdiba (2021) reported a significant association between CED and the occurrence of anemia (5). In addition to nutritional status, dietary practices, menstruation, parasitic infections, and socioeconomic factors may contribute to iron deficiency anemia among adolescents (6). Anemia during adolescence may impair physical growth and development. Moreover, anemia during adolescence may extend into later life and is associated with adverse reproductive outcomes, including maternal death, preterm delivery, and low-birth-weight infants. (7). In Indonesia, anemia remains a major public health concern, with its prevalence increasing from 37.1% in 2013 to 48.9% in 2018. The highest proportion of anemia cases was reported among individuals aged 15–34 years (8). Studies in rural Indonesia have also reported that inadequate nutritional intake and other modifiable factors contribute to iron deficiency anemia among adolescent girls and women (9).

Bali Province has a relatively high prevalence of anemia, reaching 27.1% (8). Gianyar Regency recorded the second-highest prevalence of anemia in Bali in 2020, accounting for 9.7% of cases (10). Gianyar Regency consists of several districts, including Tegalalang District. According to the Gianyar District Health Office (2023), access to healthcare services among the working-age population (15–59 years) in Tegalalang remains limited. Among women of reproductive age, healthcare service coverage was reported to be 48.3% at Tegalalang I Primary Healthcare Center and only 17.9% at Tegalalang II Primary Healthcare Center. This limited access to healthcare services may contribute to the occurrence of health problems among women of productive age, including anemia (11).

Anemia screening is commonly performed through visual assessment of conjunctival pallor. However, this method has limited accuracy because it depends heavily on the observer's experience and judgment. Therefore, alternative methods are needed to support the early detection of anemia (12). Since anemia is closely associated with nutritional deficiencies that result in low hemoglobin levels, nutritional status may serve as an initial indicator for anemia screening. One method that can be used to assess the risk of chronic energy deficiency is the measurement of mid-upper arm circumference. This measurement is important for identifying individuals at risk of CED, which is defined as a long-term deficiency in energy and protein intake. According to the Indonesian Ministry of Health guidelines, a MUAC of ≥23.5 cm is considered normal, whereas a MUAC of <23.5 cm indicates a risk of chronic energy deficiency (13). Mutmainnah et al. in 2021 reported a significant association between chronic energy deficiency and anemia among adolescent girls (14).

In Gianyar Regency, particularly in Tegalalang District, hemoglobin screening among adolescent girls is still rarely performed. Therefore, MUAC measurement may serve as an alternative screening method for identifying individuals at risk of anemia. A study by Ina et al. (2018) supported this concept, demonstrating a significant association between MUAC and anemia among female students residing in the dormitory of Tribhuwana Tunggadewi University, Malang (15). However, Laghari et al. (2017) reported that although MUAC was positively correlated with hemoglobin levels among females, no significant correlation was observed among males (16).

Despite these findings, the relationship between MUAC and hemoglobin levels remains inconclusive. Furthermore, access to healthcare services in Tegalalang District remains limited, and studies investigating hemoglobin levels in this area are still scarce. These circumstances provided the rationale for the present study, which aimed to examine the association between mid-upper arm circumference and hemoglobin levels among adolescent girls in Gianyar Regency, particularly in Tegalalang District.

MATERIALS AND METHODS

The study protocol received ethical approval from the Health Research Ethics Committee, Faculty of Medicine and Health Sciences, Universitas Warmadewa (Approval No. 454/Unwar/FKIK/EC-KEPK/VII/2024). This analytical cross-sectional study was carried out among female students enrolled in grades 10, 11, and 12 at SMAN 1 Tegalalang, Gianyar, during the 2022/2023 academic year.

Participants were enrolled consecutively. Although the estimated minimum sample size was 113 students, 147 students were included in the final analysis. MUAC was treated as the independent variable, and hemoglobin concentration was the dependent variable. MUAC was obtained using a non-stretchable measuring tape. Capillary hemoglobin concentration was determined using the EasyTouch GCHb point-of-care testing device. Primary information was collected directly from the participants, whereas school enrollment data were obtained as secondary data.

Data analysis was performed using IBM SPSS Statistics version 27. Descriptive statistics were used to summarize participant characteristics, MUAC, and hemoglobin concentration. ANCOVA was performed to examine differences in hemoglobin concentration between MUAC categories while adjusting for age and menstrual duration. Statistical significance was defined as $p < 0.05$.

RESULTS AND DISCUSSIONS

A total of 147 female adolescents were included in this study. Based on Table 1, most participants were 17 years old (n = 71; 48.30%), followed by those aged ≤16 years (n = 46; 31.29%) and >18 years (n = 30; 20.41%). Based on BMI classification, normal BMI was observed in more than half of the participants (n = 78; 53.06%). The remaining participants were classified as overweight (n = 34; 23.13%), underweight (n = 19; 12.93%), and obese class I (n = 16; 10.88%); no participants were classified as obese class II. With respect to menstrual duration, most participants reported menstruation lasting more than 5 days (n = 78; 52.06%), followed by 5 days (n = 55; 37.41%) and fewer than 5 days (n = 14; 9.52%).

Table 1. Participant Characteristics (N = 147)

Characteristic	n	%
Age		
≤ 16 years	46	31.29
17 years	71	48.30
≥ 18 years	30	20.41
BMI		
Underweight (<18.5)	19	12.93
Normal (18.5 – 22.9)	78	53.06
Overweight (23.0 – 24.9)	34	23.13
Obesity I (25.0 – 29.9)	16	10.88
Obesity II (≥30)	0	0
Menstrual Duration		
< 5 day	14	9.52
5 day	55	37.41
>5 day	78	52.06

Most participants were 17 years old, had normal BMI, and reported a menstrual duration of more than 5 days. Adolescence is a period of rapid growth and increased nutritional requirements; therefore, adequate intake of energy, protein, iron, folate, and vitamin B12 is important to support erythropoiesis and maintain hemoglobin levels (17).

More than half of the participants had normal BMI, suggesting that the overall nutritional status of the study population was generally adequate. However, underweight, overweight, and obesity were also observed. Both low and excessive body weight may be relevant to hemoglobin status. Low body mass may reflect insufficient macro- and micronutrient reserves, whereas overweight and obesity may be associated with inflammation-related alterations in iron metabolism (17).

Most participants reported menstrual duration of more than 5 days. Menstrual blood loss may contribute to iron depletion and anemia, especially when iron intake is inadequate. However, menstrual duration alone does not necessarily reflect menstrual blood volume; cycle regularity, bleeding intensity, dietary iron intake, and iron supplementation should also be considered when evaluating anemia risk (18).

Based on Table 2, the mean MUAC of the participants was 24.0 ± 2.4 cm. The distribution of MUAC categories was nearly equal, with 49.66% of students classified as being at risk of CED and 50.34% classified as not being at risk. The mean hemoglobin concentration was 13.5 ± 1.4 g/dL, and most participants had hemoglobin concentrations of at least 12 g/dL. ANCOVA showed a significant association between MUAC category and hemoglobin level after adjustment for age and menstrual duration ($F = 5.257$, $p = 0.024$).

Table 2. Mid-Upper Arm Circumference and Hemoglobin Characteristics (N = 147)

Variable	Mean ± SD	Category	n	%	F	p
MUAC (cm)	24.0 ± 2.4	At Risk CED (<23.5 cm)	73	49.66	5.257	0.024
		Not at risk CED (≥23.5 cm)	74	50.34		
Hemoglobin (g/dL)	13.5 ± 1.4	<12 g/dL	9	6.1		
		≥12 g/dL	138	93.9		

The association between MUAC and hemoglobin level may be explained by the role of nutritional reserves in erythropoiesis. MUAC reflects peripheral muscle mass and subcutaneous fat reserves; therefore, a lower MUAC may indicate prolonged inadequacy of energy and protein intake (19). This condition may coexist with insufficient intake or bioavailability of iron, folate, vitamin B12, vitamin A, and other nutrients required for hemoglobin synthesis. Thus, MUAC may reflect a broader nutritional context relevant to hemoglobin status rather than serving as a direct marker of iron deficiency alone.

In the present study, ANCOVA demonstrated that hemoglobin levels differed significantly across MUAC categories after adjustment for age and menstrual duration (F = 5.257, p = 0.024). This finding suggests that the association between MUAC and hemoglobin level remained statistically significant after accounting for potential differences related to age and menstrual duration. Age was included because nutritional requirements and physiological changes may vary throughout adolescence, whereas menstrual duration was included because menstrual blood loss may affect iron balance and hemoglobin concentration.

The present finding is consistent with evidence from rural India, where anthropometric indicators, including MUAC, were associated with hemoglobin concentrations among adolescent girls. Ahankari et al. reported that lower anthropometric measures were associated with lower hemoglobin levels, supporting the potential value of simple anthropometric measurements in settings where laboratory testing is not readily available (20). Similarly, research among adolescent girls in East Java found that MUAC was significantly associated with hemoglobin level after multivariable analysis (21). These findings support the potential role of MUAC as a simple and low-cost preliminary screening tool in school-based health programs, particularly where routine hemoglobin testing is limited. Recent evidence from Indonesia has also shown that low MUAC was independently associated with anemia among adolescent girls after adjustment for other nutritional and behavioral factors, further supporting the potential value of MUAC in school-based nutritional risk screening (22). Another evidence from Indonesia also supports the relevance of MUAC as a nutritional indicator associated with anemia among non-pregnant women of reproductive age, although the age group differs from that of the present study (23).

Nevertheless, the relationship between nutritional status and anemia may vary between populations. A cross-sectional study in Kupang, Indonesia did not find a

statistically significant association between BMI-defined nutritional status and anemia, despite a high anemia prevalence (24). This inconsistency may be related to differences in the anthropometric indicator used, dietary iron intake, iron bioavailability, infectious burden, menstrual blood loss, and the prevalence of micronutrient deficiencies or hemoglobin disorders.

Importantly, the ANCOVA result indicates that hemoglobin levels differed significantly across MUAC categories after adjustment for age and menstrual duration; it does not establish that increasing MUAC causes an increase in hemoglobin concentration. As most participants had hemoglobin levels within the normal range, the observed association may reflect variation in hemoglobin concentration both within the non-anemic range and among the relatively small subgroup with anemia. Future studies should include dietary assessment, serum ferritin, inflammatory markers, menstrual blood volume, and hemoglobinopathy screening to determine whether MUAC independently predicts iron deficiency or anemia.

CLINICAL IMPLICATION

The association observed between MUAC category and hemoglobin concentration indicates that MUAC measurement may be useful as an initial nutritional risk assessment in school-based health programs. In settings where access to laboratory testing is limited, students with MUAC values below 23.5 cm may be prioritized for dietary assessment, nutritional counseling, and hemoglobin testing.

Nutritional interventions for students with low MUAC may include counseling on adequate energy and protein intake, consumption of iron-rich foods, and dietary practices that improve iron absorption. When anemia is suspected or confirmed, further clinical evaluation and management should follow applicable local guidelines.

MUAC should not be used as a replacement for hemoglobin testing. It does not establish the presence, severity, or etiology of anemia. Instead, MUAC can be incorporated into a broader adolescent health assessment that includes clinical history, hemoglobin measurement, dietary evaluation, and follow-up of abnormal findings.

LIMITATIONS

This study used a cross-sectional design; therefore, the observed association between mid-upper arm circumference (MUAC) and hemoglobin levels cannot establish causality. The study was conducted in a single school, which may limit the generalizability of the findings. In addition, dietary intake, iron status biomarkers, menstrual blood volume, infection, and hemoglobin disorders were not assessed. Therefore, iron deficiency could not be confirmed, as hemoglobin measurement alone cannot distinguish iron deficiency anemia from other causes of anemia (25). Although age and menstrual duration were adjusted for in the analysis, residual confounding may still be present.

CONCLUSIONS

Mid-upper arm circumference (MUAC) was significantly associated with hemoglobin levels among female adolescents at SMAN 1 Tegalalang after adjustment for age and menstrual duration. This finding suggests that MUAC may serve as a simple and low-cost preliminary indicator for identifying adolescent girls who may require further

nutritional assessment and hemoglobin testing. However, MUAC should not replace direct hemoglobin measurement for the diagnosis of anemia. Future studies involving larger and more diverse populations should include dietary assessment, iron status biomarkers, menstrual blood volume, and other potential confounding factors to better determine the role of MUAC in anemia risk assessment among adolescent girls.

CONFLICT OF INTEREST

The authors declare there is no conflict of interest.

AUTOR CONTRIBUTIONS

LPW contributed to the study conceptualization, data collection, data curation, formal analysis, and preparation of the original draft. SRD contributed to the study conceptualization, methodology, supervision, data interpretation, and manuscript review and editing. NWA, DPOL, KAK and DAAASA contributed to the methodology, data interpretation, manuscript review, and editing. PIBA contributed to the statistical analysis, data interpretation, and manuscript review and editing. All authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

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DECLARATION OF ARTIFICIAL INTELLIGENCE USE

Grammarly was used solely to support language editing and grammatical refinement of the manuscript. All content was reviewed, verified, and approved by the authors, who retain full responsibility for the accuracy, integrity, authorship, and compliance of the manuscript with the journal's publication requirements.

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