Body Mass Index, Waist Circumference, and Body Fat Percentage as Predictors of Hemoglobin Status in Adolescents Girl

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Abstract. Adolescence is a critical period of rapid growth and development, requiring adequate iron stores for optimal haemoglobin production. This study looked at the relationship between teenage girls' hemoglobin levels and their body mass index (BMI), waist circumference (WC), upper arm circumference (UAC), and body fat percentage (BFP). This study used a cross-sectional design with fifty adolescent girls at SMA Negeri 12 Bandar Lampung. The statistical analysis used in this study was the Spearman Rank test. The results showed that the prevalence of anemia in adolescent girls was 38%. There were a significant association ($p<0.05$) between BMI, WC, and BFP with haemoglobin levels. In contrast, the UAC showed no significant association ($p>0.05$) with haemoglobin levels. These findings suggest that body composition, particularly central adiposity as reflected in waist circumference and body fat percentage associated with haemoglobin status in adolescent girls. Further investigation is needed to elucidate the underlying mechanisms and explore possible interventions to manage the high prevalence of anemia in this population.

Keywords : body mass index, haemoglobin, waist circumference, body fat percentage, adolescent girls

INTRODUCTION

Adolescent health is a critical concern globally, as this life stage represents a period of rapid growth and development, making adequate nutrition essential for physical and cognitive development [1]. One of the significant nutritional issues in adolescence is anemia, commonly caused by iron deficiency [2]. Anemia affects millions of adolescents worldwide, with an estimated 29.9% prevalence among women of reproductive age include adolescence globally [3]. Body composition indicators like body mass index (BMI), waist circumference, and body fat percentage have been found to be possible factors influencing hemoglobin status in addition to nutritional inadequacies. The correlation between these

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variables and hemoglobin levels is crucial to understanding how body fat distribution and nutritional status may contribute to anemia risk [4].

In Indonesia, anemia remains a public health concern, particularly among adolescent girls. According to the Indonesia Basic Health Survey 2018, the prevalence of anemia in adolescents has remained persistently high, with nearly 27% of girls aged 15-19 affected [5]. Iron deficiency anemia in this population is primarily associated with insufficient dietary intake of iron-rich foods, but recent studies suggest that body composition may also play a role [6], [7]. The association between BMI, waist circumference, and percent body fat with hemoglobin levels in female adolescents requires further exploration, particularly in the context of Indonesia, where dietary patterns, socioeconomic factors, and nutritional deficiencies vary across regions.

In Lampung, a province in Indonesia, adolescent health statistics reflect a similar trend. Data from the local health offices indicate that anemia in adolescent girls is a rising issue, with around 30% of adolescents affected. This figure suggests the need for targeted interventions to address both nutritional and lifestyle factors that may contribute to the high prevalence of anemia in the region. Research specific to Lampung highlights that the nutritional status of adolescents is influenced not only by diet but also by socioeconomic status and cultural practices, which could affect body composition and, subsequently, hemoglobin levels [8].

Body composition markers such as BMI, waist circumference, and percent body fat are frequently used to assess overall health and nutritional status. BMI is a widely accepted measure of general body fat based on height and weight, while waist circumference is a more specific indicator of central fat distribution, which has been linked to various metabolic conditions. Percent body fat provides a more direct measure of adiposity and may offer insights into how body fat distribution impacts hemoglobin levels. Several studies suggest that increased adiposity, particularly in the abdominal region, may be associated with inflammation, which could impair iron metabolism and contribute to anemia [9].

Existing research has explored the correlation between body composition and hemoglobin levels in various populations, though findings have been inconsistent. Some studies have reported a negative association between increased adiposity and hemoglobin status, while others found no significant correlation [10]. This discrepancy may be due to differences in study populations, methods of measuring body composition, or regional variations in dietary patterns. As such, there is a need for further research, particularly in the Indonesian context, to clarify these associations and develop appropriate public health strategies for reducing anemia among adolescents [11].

The purpose of this study is to examine the relationship between hemoglobin status in female adolescents and BMI, waist circumference, and body fat percentage. By examining these variables, we aim to contribute to the growing body of literature on how body composition influences anemia risk in this vulnerable population, with particular attention to regional factors in Indonesia and Lampung. Understanding these correlations may inform

more effective interventions and policies to improve adolescent health outcomes, particularly concerning anemia prevention.

SUBJECT AND METHOD

This study employed a cross-sectional design to investigate the correlation between body composition indicators and hemoglobin status among female adolescents. Fifty adolescent girls from SMA Negeri 12 Bandar Lampung participated in the study. Inclusion criteria required participants to be female students aged 12 to 18 years who provided informed consent, while exclusion criteria included individuals with known chronic diseases or those taking iron supplementation within the last three months.

Data collection involved measuring various anthropometric parameters and assessing hemoglobin levels. Anthropometric measurements included Body Mass Index (BMI), waist circumference (WC), upper arm circumference (UAC), and percent body fat (BFP). BMI was calculated using height measured with a microtoise and weight recorded with a calibrated weighing scale. Waist circumference and upper arm circumference were measured using a flexible measuring tape. Percent body fat was assessed using bioimpedance analysis (BIA). Hemoglobin levels were measured with a portable hemoglobinometer using capillary blood samples obtained via finger prick.

Data analysis involved descriptive statistics to calculate means and standard deviations for the anthropometric measurements and hemoglobin levels. The Spearman Rank test was used to examine the relationship between hemoglobin levels and anthropometric markers because the data might not have been distributed normally. To determine statistical significance, a significance level of $p < 0.05$ was established, and analyses were carried out with the proper software tools to guarantee the accuracy of the findings.

RESULTS

The univariate analysis provides a preliminary overview of the physical characteristics and health status of the adolescent girls in the study. The mean BMI of 21.28 suggests that the participants, on average, fall within a healthy weight range. However, the standard deviation indicates a notable degree of variability in BMI among the subjects. Additionally, the average waist circumference of 60.51 cm, while within normal limits for many, underscores the importance of considering regional fat distribution in assessing health risks. The mean upper arm circumference and hemoglobin levels provide insights into muscle mass and iron status, respectively. While these findings offer a basic understanding of the sample population, further statistical analyses are required to explore the correlations between these variables and hemoglobin status. The results of the univariate analysis are presented in Figure 1.

Table 1. Univariate analysis of BMI, UAC, WC, and Hb

No	Variabel	Mean ± stdev
1	BMI	21.28 ± 4.99
2	UAC	25.37 ± 4.36
3	WC	60.51 ± 9.61
4	Hb	12.91 ± 2.38

A statistically significant negative correlation was identified between BMI and hemoglobin levels ($r = -0.300$, $p = 0.034$), indicating that an increase in BMI corresponds with a decrease in hemoglobin levels. Thus, higher BMI is linked to lower hemoglobin levels among the adolescent girls in the study. Although a negative correlation was also observed between upper arm circumference (UAC) and hemoglobin levels ($r = -0.243$), this relationship was not statistically significant ($p = 0.090$), suggesting that there may be no strong or consistent association between UAC and hemoglobin levels in this sample. Similarly, a significant negative correlation was found between waist circumference and hemoglobin levels ($r = -0.315$, $p = 0.026$), signifying that as waist circumference increases, hemoglobin levels tend to decrease. Hence, higher waist circumference is also associated with lower hemoglobin levels in the adolescent girls studied.

A significant negative correlation was also observed between body fat percentage and hemoglobin levels ($r = -0.507$, $p = 0.030$). This suggests a stronger negative association compared to BMI and waist circumference, indicating that higher body fat percentage is more strongly associated with lower hemoglobin levels in the adolescent girls studied.

The findings of the bivariate analysis suggest that there is a significant negative association between measures of adiposity (BMI, waist circumference, and body fat percentage) and hemoglobin levels in adolescent girls. This implies that higher levels of adiposity, as indicated by higher BMI, larger waist circumference, and greater body fat percentage, are associated with lower hemoglobin levels. These results align with previous research suggesting a link between obesity and anemia.

Table 2. The correlation analysis of BMI, UAC, WC, BFP, and Hb concentration

No	Variabel	r	p
1	BMI	-0.300	0.034
2	UAC	-0.243	0.090
3	WC	-0.315	0.026
4	BFP	-0.507	0.030

DISCUSSION

The results of this study demonstrate significant negative correlations between adiposity indicators, including Body Mass Index (BMI), waist circumference, and body fat percentage, and hemoglobin levels in female adolescents. The observed negative association between BMI and hemoglobin levels ($r = -0.300$, $p = 0.034$) aligns with previous research indicating that higher body fat, particularly in the context of obesity, may contribute to anemia in adolescents. This could be explained by the potential for chronic low-grade inflammation caused by excess adipose tissue, which interferes with iron metabolism and reduces the bioavailability of iron for hemoglobin synthesis. The significant negative correlation between waist circumference and hemoglobin levels ($r= -0.315$, $p = 0.026$) also suggests that central adiposity might play a role in the risk of developing anemia. Studies have shown that abdominal fat accumulation is particularly associated with pro-inflammatory cytokines, which could further impair iron homeostasis [12], [13].

The finding of a stronger negative correlation between body fat percentage and hemoglobin levels ($r = -0.507$, $p = 0.030$) compared to BMI and waist circumference provides a deeper understanding of how overall adiposity may influence hemoglobin status. Body fat percentage is considered a more accurate measure of total adiposity than BMI, which does not differentiate between fat mass and lean mass. The significant association found in this study supports previous research, which highlights that increased adiposity, especially visceral fat, is a key factor linked to higher inflammatory responses, contributing to iron dysregulation and anemia in adolescents. This finding underscores the importance of body composition assessment beyond BMI to fully capture the health risks associated with excessive body fat, particularly in relation to iron deficiency and anemia [14], [15].

Interestingly, while a negative correlation was found between upper arm circumference (UAC) and hemoglobin levels ($r = -0.243$, $p = 0.090$), this correlation was not statistically significant. UAC is often used as a proxy for muscle mass, and the lack of a strong association with hemoglobin in this study may suggest that muscle mass alone does not significantly influence hemoglobin levels in this population [16]. This is consistent with research indicating that adiposity, rather than muscle mass, may be the primary driver of inflammation-related iron metabolism disorders in adolescents [12]. However, future research may explore the potential role of lean mass in modulating iron status in different populations, as other studies have indicated that lean mass could have a protective effect against anemia, particularly in populations with varying levels of physical activity [17].

The significant associations between adiposity measures and hemoglobin levels in this study suggest that obesity prevention and management could play a critical role in reducing anemia risk among adolescents [18]. The link between increased adiposity and lower hemoglobin levels has important public health implications, particularly in regions where both obesity and anemia coexist. As excess body fat appears to exacerbate iron deficiency,

interventions focused on improving dietary quality and promoting physical activity in adolescents may help address both obesity and anemia simultaneously [19]. Furthermore, this study's findings highlight the need for healthcare providers to consider body composition when assessing anemia risk, as traditional markers such as BMI may not fully capture the complexity of the correlation between obesity and hemoglobin levels.

CONCLUSION

In conclusion, this study adds to the expanding literature of research that highlights the negative implications of obesity on hemoglobin levels in adolescent girls. The findings support the hypothesis that higher levels of body fat are associated with lower hemoglobin levels, potentially due to the pro-inflammatory effects of excess adipose tissue on iron metabolism. These results highlight the importance of early intervention strategies aimed at preventing both obesity and anemia in adolescents. Further research is required to investigate the mechanisms underlying this correlation and to identify the most effective interventions for addressing this issue to reduce the dual burden of obesity and anemia in this vulnerable population.

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