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Research Article

Potential use of Anthropometric Parameters to Predict the Anemia Status of Adolescent Girls

Melda Oktaviana[1], Cesilia Meti Dwiriani[1*], Mira Dewi[1,2]
[1]Department of Community Nutrition, Faculty of Human Ecology, IPB University, Bogor 16680, Indonesia
[2]SEAFAST Center, IPB University, Bogor 16680, Indonesia

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***Corresponding Author:**
tel: +6285312881466
email: cmdwiriani@apps.ipb.ac.id

ABSTRACT

The study assesses the potential use of anthropometric parameters and their optimal cut-off value for predicting the anemia status of adolescent girls. This cross-sectional study analyzed data from 2,184 adolescent girls aged 15–19 years from West Bandung and Sumedang districts of Indonesia who participated in the Better Investment for Stunting Alleviation Program (BISA). Anemia is defined as a Haemoglobin (Hb) level <12 g/dL and was analyzed by HemoCue® 201+. Anthropometric parameters studied were Body Weight (BW), BMI-for-Age z-Score (BAZ), Waist Circumference (WC), Waist-to-Hip Ratio (WHR), and Waist-to-Height Ratio (WHtR) and all were measured according to WHO procedure. Receiver Operating Characteristics (ROC) was used to analyze the potential of anthropometric parameter to predict anemia status. Based on multivariate analysis, a significant correlation was found between age (OR=0.88; 95% CI:0.79–0.97) and WHtR (OR=0.12; 95% CI:0.02–0.63) with anemia status. The ROC analysis revealed that the WHtR parameter had the highest Area Under the Curve (AUC) for predicting anemia, although with a very low accuracy (AUC=0.529). The optimal cut-off with value of WHtR for adolescent girls was ≤0.44. This study suggests that WHtR is a potential parameter for early detection of anemia status among adolescent girls and needs to be confirmed with further studies.

INTRODUCTION

Globally, the number of reproductive women who experience anemia tends to increase from 2010 to 2019. According to World Health Organization (WHO), in 2019 three out of ten women of reproductive age in the world experience anemia. This number was equivalent to 500 million women aged 15–49 years (WHO 2021). The incidence of anemia in Indonesia was getting worse, anemia prevalence in women aged 15–49 years almost doubled from 2013 to 2018 (Ministry of Health Republic of Indonesia (MoH RI 2013; 2018)). According to 2018 Indonesia Basic Health Research, the prevalence of anemia among adolescents aged 5–15 and 15–24 years was 26.8% and 32%, respectively (MoH RI 2018). It made anemia in adolescents as a moderate public health problem in Indonesia (WHO 2010). Adolescent girls were considered to have a higher risk of anemia because their nutritional requirements increased along with rapid growth, menstruation, and future pregnancies (WHO 2011a; Teji *et al.* 2016). According to cross-sectional studies conducted in West Java, the prevalence of anemia among adolescent girls ranged from 14.3% to 45.5% (Sari *et al.* 2022; Agustina *et al.* 2021). As per WHO, anemia in adolescent girls was described by a Hemoglobin (Hb) level less than 12 g/dL (WHO 2011b).

Anemia was a condition caused by multideterminant, which were biological determinants such as malnutrition, growth, gender, physiological state, age, and ethnicity; infection and inflammation determinant; genetic Hb disorder; social and environmental determinants (WHO 2020). Iron deficiency remained a prominent cause of anemia worldwide (WHO 2021). Many studies have been conducted to analyze the interrelation between nutritional

status and anemia status or Hb level. Several studies reported positive correlation between obesity with anemia (Choma *et al.* 2015; Jeong *et al.* 2022), other studies reported the opposite result that obesity is a protective factor against anemia (Huang *et al.* 2015; Gokhale *et al.* 2022) and even no correlation (Crivelli *et al.* 2018; Mehdad *et al.* 2022). Although earlier studies reported a correlation between nutritional status and Hb levels in adolescent girls, most of these studies just focus on using Body Mass Index (BMI) as a parameter of antropometry.

Recent studies suggests that anthropometric measures such as Waist Circumference (WC), Waist-to-Hip Ratio (WHR), and Waist-to-Height Ratio (WHtR) can be used to predict Hb level (Dutta *et al.* 2021; Lee & Kim 2016). A cross-sectional study among Malaysian young adults showed that BMI was the best anthropometry parameter for predicting anemia than WC, WHR, and WHtR based on the ROC analysis (Dutta *et al.* 2021). Another study conducted on elderly Koreans showed that weight and BMI as the best predictor of Hb level (Lee & Kim 2016). Thus, previous studies provide the possibility of using anthropometric parameters for the early detection of anemia in a practical, inexpensive, and non-invasive way. To the best of the author's knowledge, this is the first study in Indonesia that uses anthropometric parameters to predict anemia in adolescents. Therefore, our study aims to analyze the accuracy of anthropometric parameters as predictors of anemia status as well as determine the optimal thresholds

METHODS

Design, location, and time

This cross-sectional study uses secondary data from the Nutrition International (NI) funded project, i.e., a baseline survey of the Better Investment for Stunting Alleviation (BISA) Program in West Bandung and Sumedang districts, West Java, Indonesia. The baseline survey was conducted from December 2019 to April 2020. The ethical clearance was obtained from the Research Ethics Committee of the Faculty of Medicine of Padjajaran University (Ethic number: 145/UN6.KEP/EC/2020).

Sampling

The BISA survey used a two-stage cluster sampling. Initially, 30 high schools from each district were selected with Probability Proportion-to-Size (PPS) methodology. The adolescent girls within every high school were selected with systematic random sampling from the list provided by the school, with minimum sample size of each school in West Bandung district of 63 and 61 for Sumedang district of West Java. From the 3,668 adolescent girls who participated in the baseline survey, we analyze a total of 2,184 adolescent girls who have met the inclusion criteria that were student from the high school in West Bandung and Sumedang district, aged 15-19 years, had complete data regarding weight, height, waist circumference, hip circumference, and hemoglobin measurement results.

Data collection

Body weight was measured twice using GEA digital weight scales, with adolescent girls being barefoot and in minimal clothing. The weight measurement was in kilograms (kg) to near 0.1 kg. Microtoise was used to measure height, with adolescent females' feet, heels, buttocks, and shoulder blades put against the stick and head positioned in the Frankfurt horizontal plane. The adolescent girls were measured twice for waist and hip circumference using anthropometric tape while standing straight and relaxed with arms at their sides and feet close together. Waist circumference was measured halfway between the bottom of the rib cage and the top of the iliac crest. The hip circumference was measured at its broadest point (WHO 1995). The measurements were taken in centimetres (cm) and were taken to the closest 0.1 cm.

The ratio of the waist-to-hip circumference was thcn calculated as WHR while the ratio of waist circumference to height as WHtR. BMI-for-Age Z-Score (BAZ) was calculated using WHO AnthroPlus after entrying age, sex, weight, and height data. The Hb levels was measured using capillary fingerpick blood by a HemoCue® 201+ portable device. The Hb value of <12 g/dL was classified as anemia according to the WHO criteria. The Hb value was also adjusted using the recommended altitude adjustment (WHO 2011b). Questions regarding age was collected with self-administrated questionnaire method

Data analysis

A 95% confidence level was used in the statistical analysis. We used SPSS version 22.0 dan MedCalc version 20.218 for data

analysis. A normality test was performed using Kolmogorov Smirnov. Frequency, median, minimal, and maximal were presented for not normally distributed data. The Mann-Whitney test was used to compare the median differences between the anemic and non-anemic groups in each variable. Spearman correlation was carried out to investigate the correlation between age and anthropometric parameters with Hb level. A multivariate binomial logistic regression model was performed to identify the variables that have a significant correlation with the anemia status, with the anemia code as 1 and the non-anemia code as 0.

Body weight, BAZ, WC, WHR, and WHtR data were used as continuous variables, and anemia status was used as a categorical variable in a Receiver Operator Characteristic (ROC) analysis. The ROC and Area Under the Curve (AUC) were calculated by plotting the true positive rate (sensitivity) in the false positive rate (100-specificity) for various parameter cut-off points. The Youden index (J) was used to determine optimal cut-off values for anthropometric measures for detecting anemia. The Youden index was defined as:

$$J = max_c \left(Sensitivity_c + Specificity_c - 1\right)$$

where c was a variable that could take any value (Kallner 2018). The $p<0.05$ was considered statistically significant for all evaluations.

RESULTS AND DISCUSSION

A total number of 2,184 adolescent girls from 35 high schools in West Bandung and Sumedang District were analyzed in this study. The range of an age was 15 to 19 years, and the average was 17±0.9 years old (Table 1). About 40% of adolescent girls aged 17 years old. Anemia was experienced by almost half (49.3%) of adolescent girls, which about 55% among them having mild anemia (Hb:10–10.9 g/dL), 42% having moderate anemia (Hb:8–10.9 g/dL), and 3% having severe anemia (Hb<8 g/dL). It makes anemia in adolescent girls in West Java and Sumedang districts a severe public health problem according to WHO criteria (WHO 2010). A previous study has shown the same results, where about 45.5% of adolescent girls who attended school in Cimahi, Purwakarta, and West Bandung districts in West Java Province had anemia (Agustina *et al.* 2021).

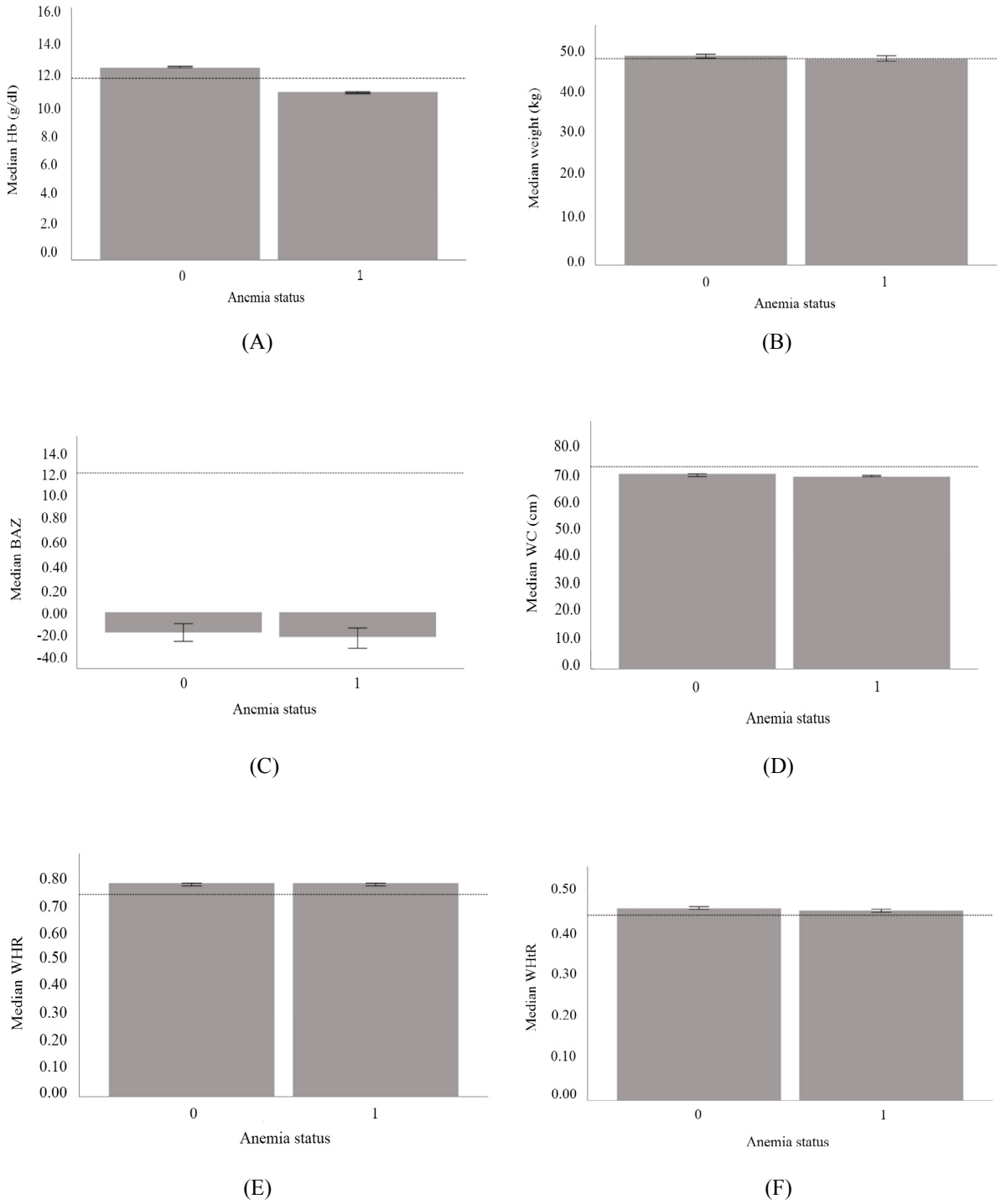
The Mann-Whitney test was used to examine the difference in the values of each variable between the anemic and non-anemic groups. The test was carried out at 95% confidence intervals, with significance considered when $p<0.05$. Among the 2,184 adolescent girls, it was divided into 1,077 (49.3%) of adolescent girls belonged to the anemia group and 1,107 (50.7%) belonging to the non-anemic group. Differences in Hb levels and anthropometric parameters between anemic and non-anemic groups are showed in Figure 1.

Figure 1 showed that the median of Hb levels in the anemia group was 11.1 g/dL (5.7–11.9 g/dL) while the non-anemic group was 12.7 g/dL (12.0–16.3 g/dL), and only WHtR parameter that significantly different between the anemic and non-anemic groups ($p=0.018$). Other anthropometric parameters, such as

Table 1. Age, hemoglobin, and anthropometric parameters of adolescent girls

Variables	Median	Minimum–Maximum
Age (years)	17.0	15.0–19.0
Hb (g/dl)	12.0	5.7–16.3
Body weight (kg)	48.0	27.2–104.6
Body height (cm)	153.1	131.0–197.5
Waist circumference (cm)	69.0	46.0–113.5
Waist-to-hip ratio	0.78	0.11–1.74
Waist-to-height ratio	0.45	0.32–0.75
BMI-for-age z-score	-0.21	-3.81–4.70

BMI: Body Mass Index; Hb: Haemoglobin



(A): Haemoglobin (Hb) level (g/dl); (B): Weight (kg); (C): BMI-for-Age z-Score (BAZ); (D): Waist Circumference (WC) (cm); E): Waist-to-Hip Ratio (WHR); (F): Waist-to-Height Ratio (WHtR); (0): Non-anemic group; (1): Anemic group; Statistically significant difference ($p<0.05$) was recorded for Hb level (A) and WHtR (F) using Mann-Whitney test; The dotted horizontal line indicating cut-off values; The cut-off for Hb level was 12 g/dl based on WHO reference (WHO 2011b); The cut-off for weight, BAZ, WC, WHR, and WHtR based on ROC analysis in Table 3

Figure 1. Comparison of haemoglobin levels and anthropometric parameters between adolescent girls with anemia and without anemia

BAZ (p=0.127), body weight (p=0.316), WC (p=0.075), and WHR (p=0.167), did not indicate a significant difference between the anemic and non-anemic groups in the Mann-Whitney tests. These results were different from studies in the adult group in Malaysia, which showed BMI, WC, WHR, and WHtR in the anemia group were significantly lower than in the non-anemic group (Dutta *et al.* 2021). The waist-to-height ratio was used as an indicator to measure excess fat in visceral adipose tissue, as well as to determine central obesity in adolescent girls (Browning *et al.* 2010). Research related to WHtR and Hb levels in adolescents is still limited. A study on adult women (>20 years) in China showed that women who are centrally obese tend to have higher Hb levels than those who are not centrally obese (Qin *et al.* 2013).

The bivariate analysis showed there was a positive correlation between age, WC, and WHtR with Hb level (p<0.05). Multivariate binomial logistic regression analysis showed that age (OR=0.88; 95% CI:0.79–0.97) and WHtR (OR=0.12; 95% CI:0.02–0.63) have a significant correlation with anemia (Table 2). It indicated that adolescent girls who were older and had higher WHtR were less likely to have anemia.

Younger adolescent girls tend to be anemic is in line with the study in South Ethiopia, which shows that in the early adolescent period (age 10–13 years), the risk of experiencing anemia was five times higher than in the late adolescent period (age 17–19 years) (Shaka & Wondimagegne 2018). Increasing Hb levels in older adolescent girls were probably influenced by the timing of the growth spurt in adolescents (Jorgensen *et al.* 2019). In addition, the increase in Hb levels along with increasing age may also be affected by an increase in the Mean Volume of Erythrocytes (MCV) and the Mean Mass of Hb in the one Erythrocyte (MCH) with the peak at age 18. Additionally, the Mean Concentration of Hb in the Erythrocyte (MCHC) tends to increase with age in adolescents (Gligoroska *et al.* 2019). Different findings were found in longitudinal studies of Malaysian adolescents, who indicated that the frequency of insufficient iron consumption increased twofold from 13 to 15 years old. This pattern continued until they were 17 years old. Followed by the anemia prevalence almost doubled in the same period (13 to 15 years old) (Krishnan *et al.* 2021)

Adolescent girls with higher WHtR tend not to experience anemia, possibly influenced

Table 2. Correlation between age, anthropometric parameters and haemoglobin level with anemia status

Correlation with Hb level[a]			Correlation with anemia status[b]				
Variables	r	*p*	Variables	B	*p*	OR	95% CI for OR
Age[c]	0.08	0.000*	Model 1:				
Weight[d]	0.02	0.456	Age	-0.14	0.007*	0.87	0.79–0.97
BAZ	0.02	0.258	Constant	3.27	0.003*	26.32	
WC[e]	0.05	0.012*	Model 2:				
WHR	0.04	0.090	Age	-0.13	0.007*	0.88	0.79–0.97
WHtR	0.07	0.002*	WHtR	-2.16	0.013*	0.12	0.02–0.63
			Constant	3.24	0.001*	25.48	

*Significant at p<0.05 based on Spearman Correlation test: [a]: Bivariate analysis using Spearman test; [b]: Multivariate analysis using Binomial Logistic Regression Stepwise method: [c]: Years; [d]: Kilogram (Kg); [e]: Centimeter (Cm): BAZ: BMI-for-Age z-Score; WC: Waist Circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio: OR: Odds Ratio; CI: Confidence Interval; Hb: Haemoglobin

by increased body fat. The WHtR was known to correlate with visceral fat (Browning 2010). A systematic review and meta-analysis of studies in children and adolescents (4.9–19 years) found that BMI and WHtR were strongly related to body fat evaluated using Dual-Energy X-Ray Absorptiometry (DEXA) (Martin-Calvo *et al.* 2016). Studies in adults using five anthropometric indicators, which include BMI, WC, WHR, WHtR, and Waist/Height Circumference 0.5 (WHT.5R), showed that WHtR was the best predictor for body and Visceral Fat Percent Adipose Tissue (VAT) as measured using DEXA (Swainson *et al.* 2017). This study supported the results of Ashwell *et al.* (2012), who suggested using the WHtR indicator instead of BMI and waist circumference in determining obesity when DEXA was unavailable. Studies on adolescents in Taiwan showed there was an increase in Hb levels in adolescents who were obese (Huang *et al.* 2015). Choma *et al.* (2015) also showed an increased Hb and CRP levels in the group with central obesity. An increase in Hb levels possibly due to increased erythropoiesis which occurs along with increasing the body size. However, inflammation in the central obesity, which was indicated by higher CRP levels, was known to be associated with iron deficiency characterized by decreased serum iron levels (Choma *et al.* 2015).

The ROC curves analysis in Table 3 showed that only the WHtR parameter could differentiate (p=0.018) between anemic and non-anemic adolescent girls based on their Hb levels. Although the WHtR could distinguish two groups, its accuracy was very low because the AUC value was 0.5–0.7 (Akobeng 2007) with an AUC (95% CI) value of 0.529. It indicated that WHtR had the potential as a predictor of anemia status for adolescent girls. Future research is needed to analyze the potential of WHtR as a predictor of anemia status in adolescents. The optimal cut-off of WHtR for predicting anemia based on the

Table 3. Comparison of receiver operating characteristics curves of anthropometric parameters in predicting anemia status of adolescent girls

Variables	AUC (95% CI)	*p*	Cut-off value	Se (%)	Sp (%)	Pairwise comparison of ROC curves		
						Variables	AUC difference	*p*
BAZ	0.519	0.127	≤1.23	91.7	12.6	BAZ~WC	0.003	0.744
						BAZ~WHR	0.003	0.856
BW[b]	0.512	0.316	≤47.7	50.7	53.8	BAZ~BW	0.006	0.283
						BAZ~WHtR	0.010	0.274
WC[c]	0.522	0.075	≤72.5	70.6	35.0	BW~WC	0.010	0.308
						BW~WHR	0.004	0.811
WHR	0.516	0.191	≤0.74	22.8	78.0	BW~WHtR	0.017	0.144
						WC~WHR	0.006	0.554
WHtR	0.529	0.018[a]	≤0.44	45.6	60.2	WC~WHtR	0.007	0.111
						WHR~WHtR	0.013	0.175

[a]p<0.05; [b]: Kilogram (Kg); [c]: Centimeter (Cm); BAZ: BMI-for-Age Z-Score; BW: Body Weight; WC: Waist Circumference; WHR: Waist-to-Hip Ratio; WHtR: Waist-to-Height Ratio; AUC: Area Under Curve; Se: Sensitivity; Sp: Specificity; AUC: Area Under the Curve; CI: Confidence Interval; ROC: Receiver Operating Characteristics

Youden index was ≤0.44 (Se=45.6%; Sp=60.2%). In predicting anemia, a paired assessment of all anthropometric measures revealed no significant differences (p >0.05). It indicated that the WHtR was not distinctly different from other parameters in detecting anemia in adolescent girls.

The results of this study indicated that the WHtR parameter as a potential predictor of anemia status in adolescent girls had the highest AUC value among other anthropometric parameters. As the authors' knowledge, this was the first study on Indonesian that uses the WHtR to predict anemia, so study related to WHtR and Hb levels in adolescent girls was still limited. Based on the ROC analysis, WHtR ≤0.44 was the optimal cut-off for predicting anemia in adolescent girls (Table 3). Previous studies in Malaysian young adults (Dutta *et al.* 2021) showed that BMI was the best predictor of anemia. The order of anthropometric parameters among Malaysian young adults from highest to lowest AUC value was BMI>BW>WC>WHtR>WHR. Although BMI was the best predictor of anemia, the WHtR parameter can be used as a predictor of anemia in young adult women with an optimal cut-off of 0.45 (AUC 95% CI:0.764; Se=83.6%; Sp= 59.1%) (Dutta *et al.* 2021). WHtR as a predictor of anemia was showed in a study conducted on school age children (ages 7, 9, 12, and 14 years) in Shandong, China. In school-age children, both boys and girls with a WHtR 0.30–0.34 and a WHtR≥0.60 had a higher prevalence of anemia than school-age children with other WHtR values (Zhang *et al.* 2021). A study on Korean elderly women showed that the AUC value for WHtR in predicting anemia was 0.52 (Lee & Kim 2016), like our study.

In contrast to previous studies, namely in young adults (Dutta *et al.* 2021) and the elderly (Lee & Kim 2016), BMI was not significantly related to Hb levels, nor was it a predictor of anemia in this study. WHtR has been reported as a parameter, that had potential for an alternative predictor of anemia in adolescent girls. It may be due to previous studies in adults and the elderly where there were significant differences in the parameters of body weight, BMI, WC, WHR, and WHtR (Dutta *et al.* 2021; Lee & Kim 2016). Meanwhile, our study reported significant differences were only found in WHtR parameters between the anemia and non-anemic groups. Some studies reported the WHtR as the best parameter to define obesity (Bacopoulou *et al.* 2015; Bojanic *et al.* 2020). Yan *et al.* (2007) also showed that WHtR had better accuracy than waist circumference-defined central obesity. It was due to the WHtR combining the advantages of BAZ and WHR parameters, which not only considered height in their measurements but also abdominal obesity into account (Yan *et al.* 2007). A study on adolescents in Central Java of Indonesia reported that WHtR had better accuracy than WC as a predictor of excess adiposity (Mulyasari & Pontang 2018). In addition, the almost balanced proportion between the anemia and non-anemic groups in this study might also have caused the accuracy of WHtR as a predictor of anemia in adolescent girls compared to WHtR's accuracy as a predictor in young adults, whose proportion of anemia is around 20% (Dutta *et al.* 2021).

Our study had various strengths, including similar studies not before conducted on Indonesian adolescent girls and a large sample of adolescent females from the West Bandung and Sumedang districts. However, some limitations need to be pointed out. First, Hb measurement in this study used the Hemocue method using capillary blood samples. The Cyanmethemoglobin method which was considered the gold standard might improve the accuracy. Second, the correlation between anthropometric parameters and Hb level was still unclear due to the design study was cross-sectional. Third, our study only involved adolescent girls who attended school in West Bandung and Sumedang districts. It may affect the generalization of the study results to all adolescent girls. However, this study could give insight that WHtR may be used as temporary early detection of anemia among adolescent girls aged 15–19 years in West Java

CONCLUSION

In summary, WHtR may has potential as a predictor of anemia status for adolescent girls with the optimal cut-off value being ≤0.44, although the results of the diagnostic test show low accuracy. This study also shows that adolescent girls of higher age and WHtR are less likely to experience anemia. This is the first study, and it is conducted on subjects who tend to be homogeneous, namely adolescent girls with Sundanese ethnicity. So further studies are needed on adolescent girls with different ethnic backgrounds to analyze the accuracy of the WHtR parameter in the early detection of anemia status.

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DECLARATION OF CONFLICT OF INTERESTS

The authors have no conflict of interest.

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