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BODY MASS INDEX AND WAIST CIRCUMFERENCE ARE ASSOCIATED WITH VISCERAL FAT MEASURED BY BIOELECTRICAL IMPEDANCE ANALYSIS IN ADOLESCENTS

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ABSTRACT
Background: Overweight and obesity are two health conditions that contribute to the impaired quality of life. Two parameters of obesity also indicating body composition, body mass index (BMI) and waist circumference (WC), have been used as simple tools to assess visceral fat. Studies on bioelectrical impedance analysis (BIA) for anthropometric measurements involving Indonesian population and adolescent age group are limited. **Objective:** The study aims at demonstrating that body mass index and waist circumference are related to visceral fat using bioelectrical impedance analysis in adolescents. **Methods:** First-year students of the Faculty of Medicine Diponegoro University participated in the study. This cross-sectional study measured BMI, WC, mid-arm circumference (MAC), and visceral fat (VF) of 130 participants. BMI, WC, MAC, and VF were assessed using *Omron* digital scale, measuring tape, and body impedance analysis, respectively. Spearman test was used for the bivariate analysis while multiple regression and ROC curve were employed to perform multivariate analysis. Significant results were determined if p value <0.05 for the bivariates. **Results:** The correlation between body mass index and mid-arm circumference and visceral fat showed a strong value with r: 0.794 and p-value=<0.001 and r= 0.713 and p value=<0.001, respectively. Meanwhile the correlation between waist circumference and visceral fat showed r= 0.655 and p value=<0.001. BMI and WC showed the greatest correlation to VF. The comparison between genders showed that women have lower strength in all variables compared to men. Using an ROC curve, cut-off values to identify visceral fat was 18.99 kg/m2 for BMI; and 69.5 cm for WC. **Conclusion:** BMI and waist circumference are strongly related to visceral fat based on BIA in medical students.
Keywords*: body mass index, waist circumference, visceral fat, bioimpedance, adolescents*

INTRODUCTION

Obesity has become a major public health problem worldwide affecting adults and adolescents.[1]–[4]. High visceral fat as one of the indicators for obesity correlates to morbidities such as metabolic syndrome and cardiovascular diseases [5]–[7]. The measurement of abdominal visceral fat is important for public health outcomes because of the association between obesity and its metabolic complications. Abdominal visceral fat can be measured directly using computed tomography (CT) and magnetic resonance imaging (MRI) but they are costly.

Instead of being an indicator for fatness, body mass index (BMI) indicates heaviness and is unable to distinguish body fat from fat-free mass. However, it is commonly used as one of the measurements which are linked to chronic diseases and metabolic disorders.

Recent studies have been done on a few anthropometric measurements to represent visceral fat [2], [10], [11]. Waist circumference is a suggested measurement in clinical settings since it is a simple method and can be associated with indicators for visceral fat in the abdomen. Dual-energy X-ray absorptiometry (DXA) is another method to measure obesity or an excess of body fat, other than MRI and CT.

Measurement using bioelectrical impedance analysis (BIA) is increasingly popular but not enough studies are available particularly involving the Indonesian population and adolescent age group. [2] Mid-arm circumference is a widely used parameter in Asian countries to determine thinness in a population. [8][9]

BIA works by calculating the ions on the surface of the body and using magnetic sensitivity. The electrical impedance of the body is determined using BIA, the opposite to the flow of an electrical current through body tissues. [12]–[14] Correlations between BIA and anthropometric masurements such as WC comparing both sexes are limited.

The utilization of BMI and WC to describe obesity is emphasized by the strong correlation

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between both methods and visceral fat or other direct fat measurements. The difference between both sexes may also be observed but previous studies showed mixed results regarding the influence of sex difference on anthropometric measurements. The novelty of the study is in the population where adolescents play a big role in Indonesia's social pyramid. The study aims at demonstrating that body mass index and waist circumference may reflect visceral fat in adolescents.

METHODS

This study was an observational analysis using a cross-sectional design conducted from September to October 2020 at the Faculty of Medicine, Diponegoro University. This study measures body mass index, waist circumference, mid-arm circumference, and visceral fat of 130 first-year medical students of Diponegoro University.

Study subjects were recruited and they had consented by filling out a *Google Form*. Body mass index and visceral fat were assessed using *Omron* digital scale with a multifrequency bioelectrical impedance analysis Omron Karada Scan HBF-375, and waist and mid-arm circumference were assessed using a measuring tape. Subjects with obesity were ruled out from the sample set. Waist circumference was measured by asking the subjects to remove clothing around the abdomen beforehand. The abdominal perimeter from the center point between the lowest ribs and highest arch of sciatic bone was measured using a measuring tape. The MAC was measured on the right upper arm at the median of the distance between shoulder and elbow.

All of the data were numerical. The normality of data distribution is determined using the Kolmogorov-Smirnov test. The Spearman test is used if the data do not show normal distribution. The results are considered significant with $p<0.05$ for bivariate analyses. Cutoff values for BMI and WC as indicators of visceral fat were determined using a receiver operating characteristic (ROC) curve and area under the curve (AUC) for ROC. To determine optimal cut-off values of BMI and WC for identification of visceral fat, the formula $(1-\text{sensitivity})^2 + (1-\text{specificity})^2$ was used.

The ethics number was 89/EC/KEPK/FK-UNDIP/VI/2020 obtained from the ethical comittee of Faculty of Medicine Diponegoro University Semarang Indonesia. Data analysis was done using SPSS 26.0 and the hypothesis was tested using correlation studies.

RESULTS

Table 1 showed values measured using standardized methods. Among 130 respondents, there were more female respondents, 87 (66.92%), compared to male, 43 (33.08%). None of them was obese, yet some showed waist circumference above the normal range.

The participants' largest proportion (45.0%) were 19 years old. The samples who were normoweight were 76.2%. There were only 10.8% of the samples who were overweight while the remaining of them were underweight. Almost three-fourths of the subjects (71.6%) had normal WC. The mean VF was 4.24 with a median of 3.5.

Table 1. Characteristic and anthropometry of subjects

Variable	Mean (SD)	Median (range)
Age (year)	18.8 (0.74)	19 (18-21)
Body height(cm)	161.9 (7.61)	160(145-180)
Body weight (Kg)	56.9 (9.8)	55(40-90)
BMI (Kg/m2)	21.6 (2.65)	21.4(15.8-28.4)
WC (cm)	76.8 (8.74)	75 (62-102)
MAC (cm)	26.9(3.19)	26.5 (20-34)
Visceral fat (VF)	4.24 (2.71)	3.5 (0.5-12)

BMI: body mass index, WC: waist circumference, MAC: mid-arm circumference

Table 2. Gender differences in correlations between visceral fat (VF) and variables

Variables	Female n=87	Male n=43	Total n=130
	r	*r*	*r*
BMI	0.852*	0.893*	0.794*
WC	0.519*	0.777*	0.713*
MAC	0.569*	0.693*	0.655*

*p-value <0.005
Spearman correlation test

Table 3. Area under curve (AUC) of the receiver operating characteristic curve for BMI and WC as indicators for visceral fat

Variables	AUC	Cut-off
BMI	0.916	18.99 kg/m2
WC	0.832	69.5 cm

Kolmogorov-Smirnov normality test for all BMI, WC, MAC, and VF did not show normal data distributions. Thus, Spearman test was used to find out their intervariable correlations.

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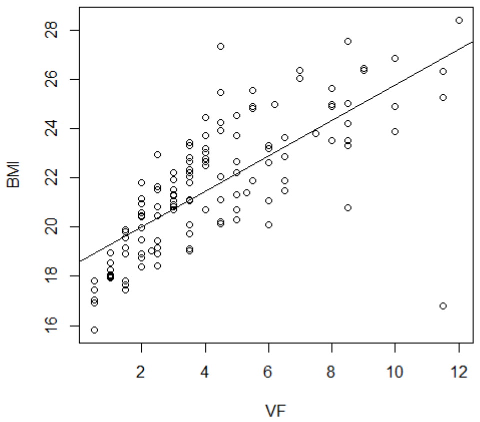
The correlation coefficients among VF and other variables were shown in table 2. BMI demonstrates a significant positive Spearman's correlation (*p*<0.001) with a strong degree (*r*=0.794) towards VF (Fig. 1). As for BMI, MAC also demonstrates a significant positive correlation (*p*<0.001) showing a strong correlation (*r*=0.713) towards VF (Fig. 2). WC showed a significant positive correlation (*p*<0.001) with a moderate strength (*r*=0.655) towards VF (Fig. 3).

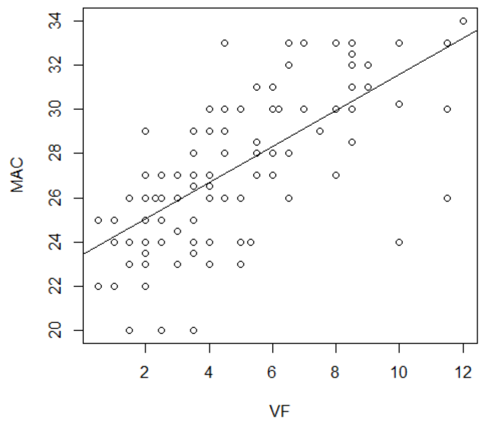
The comparison between genders was highlighted in Table 2. Women had lower strength in all variables when the relationship between the two variables was measured. Figure 1, 2, and 3, showed all samples' correlations varying from moderate to strong relationships. The probability that the anthropometric measurements represented visceral fat was high as the p value was lower than 0.001. The BMI and VF showed greater strength compared to the correlation between WC and VF.

Table 3 showed AUC of more than 0.5 for BMI (0.916) and 0.816 for WC. Figure 4 shows the ROC curve for BMI, WC as indicators of visceral fat. Optimal cut-off values of BMI and WC for identification of visceral fat are shown in Table 4. The cut-off values to identify visceral fat was 18.99 kg/m2 for BMI; and 69.5 cm for WC.



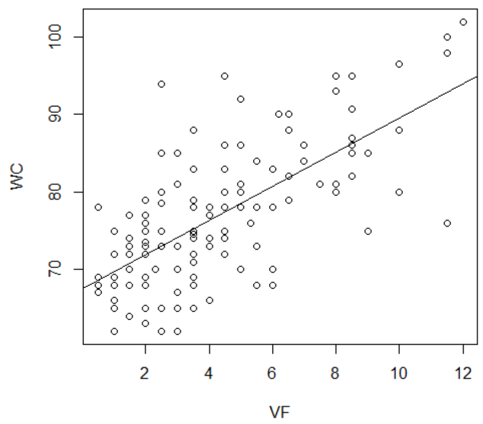
r= 0.794 p-value=<0.001

Fig. 1 Scattered plot for the correlation between body mass index and visceral fat



r= 0.713 p-value=<0.001

Fig. 2 Scattered plot for the correlation between mid-arm circumference and visceral fat



r= 0.655 p-value=<0.001

Fig. 3 Scattered plot for the correlation between waist circumference and visceral fat

BMI and WC showed the greatest correlation to VF. This demonstrated that these two methods are valid to screen for obesity.

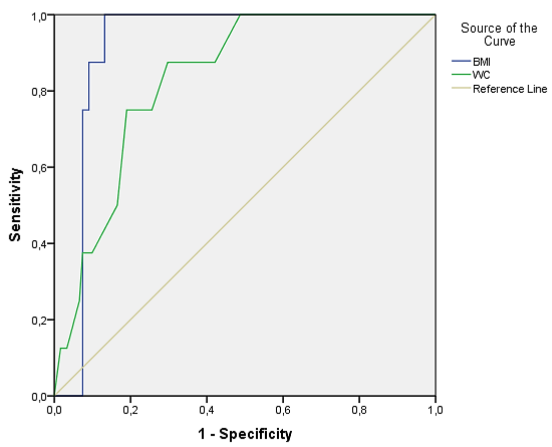


Fig. 4 Receiver operating characteristic (ROC) curve for BMI and WC as indicators of visceral fat.

DISCUSSION

The variables in the study with the strongest correlations with VF are BMI and WC. The p values showing statistically significant results emphasized that these anthropometric measurements can be used to estimate abdominal fat. VF is not an uncommon parameter in the last decade since the first BIA scale was introduced and widely used. Previous studies showed that BMI and VF were correlated and since then, numerous studies on comparison of both methods have also demonstrated reliable results.

WC and VF were recently correlated since WC represents the abdominal fat including the major omentum in the body. Excess fats are stored in visceral organs and also subcutaneous space.[4] But the visceral parts especially around the abdomen have been proven to be the first place to store fats. MAC and VF may not represent anything since MAC is commonly used to measure thinness instead of obesity or overweight. [8], [9]

BMI and WC on VF showed the strongest correlations. This finding is similar to previous studies. Visceral fat contribute to the presence of low-grade chronic inflammation leading to future metabolic syndrome.[17] Other biomarkers are obtained from the blood such as lipid profiles but non-invasive methods are imperative in community settings and for screening. [15], [16]

Body mass index is useful and has long been used although it may not reflect true fat percentage.[11] As for BMI, this study also showed that WC had a positive significant correlation with VF which differs from previous studies. Rai showed a negative correlation between WC and VF in men.[15]

The ROC curve showed considerably low cut-off values for both BMI (>18.9 kg/m2) and WC (> 69.5 cm). Based on the WHO criteria for BMI, most of the samples were underweight and normoweight (13.1% and 76.2% respectively), only 10.8% were overweight and none was obese. This may explain the relatively low cut-off values for both variables.

Women showed correlations with lower strength in all variables compared to men. The higher the BMI and WC in men, the higher the VF in them. This is contrary to a recent study which showed that WC in women plays as the best predictor for abdominal VF level. Furthermore, the difference in both genders is diminished with age so a more significant difference is observed in younger age groups.[18]

The use of anthropometry especially BMI and WC may still be useful in adolescents. These are appropriate alternatives to the more elaborate CT scan to measure visceral fat. This study showed a significant positive correlation between each BMI and WC towards VF. These results are similar to previous studies which showed that an increase in VF may be reflected by BMI and WC.

There were a few limitations in the study. Subjects are not told to diet or not diet before the measurement. Subjects were not told to not be dehydrated during the measurement. However, data are cleaned up so these conditions did not disturb the validity of the result.

The study was held during the coronavirus disease 2019 global pandemic, where activities inside the faculty were heavily restricted. Therefore, some measurements such as WC and body height for calculating BMI were done by the subjects themselves without direct supervision. Although the procedure had been provided online, errors were still possible and may affect the final result of this study. Subjects' height, body weight, mid-arm circumference visceral fat were measured on the spot. Besides the aforementioned technical and procedural problems, and even sample distribution for each of the BMI or WC categories is needed to enhance the validity of the data.

This is the first study comparing anthropometric parameters with visceral fat using a bioelectrical impedance analysis scale in Indonesia. BMI and WC can be reliable tools to screen for risks of metabolic syndrome in adolescents.

CONCLUSION AND SUGGESTION

BMI and waist circumference are strongly related to visceral fat based on BIA in medical students. These values may be used as predictors for the extent of visceral fat in adolescents. Further studies are imperative to compare other tools in measuring visceral fat.

Conflicts of Interest

The authors declare no conflict of interest.

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Author Contributions

Conceptualization, DAI, HU, DW, BP, EB; methodology, DAI, TJ, SB, LH; software, DAI, HU, SB; validation, BP, EB, LH, formal analysis, DAI, DW, SB; investigation, DAI, HU, DW, TJ; writing—original draft preparation, DAI, LH; writing—review and editing, TJ, BP, EB; visualization, SB; supervision, BP, EB; project administration, HU; funding acquisition, DAI, HU, DW.

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