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Research Paper

Body Fat Percentage Prediction Model of Female Republic of Indonesia Defense University Cadet

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Abstract

The incidence of obesity among female adolescents and adults continues to rise in Indonesia, posing significant health risks, such as cardiovascular diseases. Female cadets at the Republic of Indonesia Defense University (RIDU) are reserve members in national defense, and their performance is correlated with their nutritional status; therefore, their nutritional status should be closely monitored. Anthropometric examination is a method for nutritional assessment that incorporates body fat percentage (BFP) as part of body composition analysis. Predictive models for BFP can help identify obesity rates within a population. In Indonesia, no research has focused on BFP prediction models specifically for female RIDU cadets. This study aimed to develop a model to estimate BFP in this group. Conducted in August 2021, the research employed a quantitative cross-sectional approach involving 108 female students aged 18 to 20 from RIDU who met the inclusion and exclusion criteria. The study analyzed the relationship between BFP (measured by bioelectrical impedance analysis, or BIA) and independent variables such as age, body mass index (BMI), and waist circumference (WC). Pearson correlation tests and multivariate linear regression were used to create the prediction model. Findings showed an average BFP of 28.303% ± 6.37%. BMI had the strongest correlation with BFP (r = 0.722). The resulting predictive model is BFP = -94.055 + 39.064*WC + 1.073*age + 1.420*BMI, with an adjusted R square value of 0.535, indicating the model's explanatory power. This study showed the first to predict BFP in female RIDU cadets. Age, BMI, and WC were predictors of BFP among female RIDU cadets.

Keywords: *Anthropometry, body fat percentage, cadet, female, predictive model*

INTRODUCTION

The incidence of obesity among adolescents and adults in Indonesia continues to rise (Septia et al., 2022). The prevalence of obesity in women at the age of 16-18 years and adults (>18 years) in Indonesia were 4.5% and 29,3%, respectively, based on Body Mass Index (BMI) per age (Kementerian Kesehatan RI, 2018). Several factors can contribute to obesity. Lack of physical activity in conjunction with excessive food intake results in a positive energy imbalance. Individual factors such as genetics, race, and gender may also be related to obesity (Ludwig et al., 2022; Sartorius et al., 2015; Thamrin et al., 2022). Obesity can have several health consequences. Obesity is related to anxiety disorder. A previous study showed that individuals with obesity are more likely to experience anxiety disorders than those without obesity. Potential mechanisms that may explain the correlation between obesity and anxiety disorder were physiological factors, such as chronic inflammation, hormonal imbalances, dysregulated neurotransmitter systems, and psychosocial

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factors, including body image dissatisfaction and societal stigma (Gariepy et al., 2010). Obesity may cause musculoskeletal disease. Visceral adipose tissue secretes pro-inflammatory molecules called adipokine that can promote systemic inflammation and contribute to the pathogenesis of musculoskeletal diseases, including the loss of muscle integrity (Collins et al., 2018). A study showed that there was a U-shaped association between BMI and cardiovascular disease (CVD) mortality in East and South Asians. This indicates that both lower and higher BMI levels were linked to an increased risk of CVD mortality compared with the reference BMI range (Chen et al., 2013). Obesity as well as overweight may cause metabolic syndromes (Agrawal et al., 2023; González-Muniesa, 2017; SB et al., 2023).

The nutritional status of young female Republic of Indonesia Defense University (RIDU) bachelor program cadets needs to be observed because they are reserve components in the national defense (Savitri & Prabandari, 2020; Unhan RI, 2023). In addition, research has shown that body size and composition are related to army physical performance (Friedl, 2012; Mikkola et al., 2012; Pletcher et al., 2023).

The nutritional status can be determined in various ways, including anthropometric examination through the calculation of BMI or the composition of body fat percentage (BFP) (Gavriilidou et al., 2015; Marra et al., 2019). Several methods are available for assessing body composition such as: Dual-Energy X-ray Absorptiometry (DXA), Bioelectrical impedance analysis (BIA), and Air Displacement Plethysmography (ADP). The gold standard for determining body composition is DXA. X-ray technology is used to measure the distribution of lean mass, fat mass, and bone mineral density in the body. DXA scans provide detailed information about different body compartments and their respective proportions, permitting a comprehensive examination of body composition. DXA works by passing two X-ray beams with different energy levels through the body. Because the body's various tissues and materials absorb these X-rays, it is possible to estimate the lean mass and fat mass as well as the bone mineral density. DXA scans are typically performed on specialized machines and involve lying on a table while the scanning device moves over the body. DXA has high-precision specification, but there was still radiation exposure to the patient (Alammar et al., 2020; Cherian et al., 2021; Heymsfield et al., 2014; Lee et al., 2018). In a BIA examination, a harmless current is generated and passed through the individual being measured. The electric current mainly passes through the fat-free mass body compartment with a large amount of water containing electrolytes, which means it has the lowest resistance. The greatest impedance to electric current was observed in fat tissue (water content is only 14-22%). The electrical impedance of bodily tissue is measured by BIA. BIA can be used to assess fluid volume, total body water, fat-free body mass, and body fat percentage (through estimation) (Toomey et al., 2015). The ADP, or Bod Pod, was used to determine body composition by measuring changes in air pressure within a sealed chamber. The ADP principle is based on the whole-body densitometric principle. ADP provides accurate results, but its availability is limited because of the need for specialized equipment and the need for specific population-specific equations and assumptions regarding fat density and fat-free mass (Fields et al., 2005; Toomey et al., 2015).

BFP from the BIA analysis was one of the parameters used to determine obesity in the community. Based on the National Institutes of Health (NIH) classification, a woman can be classified as obese if her BFP level is ≥ 30%. However, the cutoff level of BFP in men for obesity is ≥ 25% (National Institutes of Health, 1998). Body fat percentage is a body composition indicator. The two components of body composition are fat mass and fat-free mass (Tomlinson et al., 2019). Based on these theories, body composition can be divided into three or four components. In the three-component division theory, fat-free mass is subdivided into fat-free tissue mass and bone mineral content. In the four-component classification, body composition is divided into fat mass, minerals, proteins, and fluids (Toomey et al., 2015). The advantage of examining body composition using BIA

is that it can determine body composition based on fat mass, which is more accurate and specific than BMI or waist circumference (Khairani & Sudiarti, 2021; Trang et al., 2019). A person's body composition can change with age from embryonic to adulthood (Ponti et al., 2020). There are changes in the composition of water, fat, mineral protein with age. Body composition can also change due to changes in energy intake, physical activity, aging, and pathological conditions associated with certain diseases (Holmes & Racette, 2021). The fat mass content can change depending on the fat deposits in the body. Fat mass in women tends to be higher than fat mass in men, which is around 8-19%, fat in men and 21-33% fat in women (Kupusinac et al., 2017; Schorr et al., 2018). The BFP prediction model can be utilized to ascertain the prevalence of obesity within a community (Khairani & Sudiarti, 2021; Molina-Luque et al., 2019).

Several studies have shown that variables such as BMI, waist circumference (WC), and age were predictors of BFP model prediction (Junior et al., 2017; Khairani & Sudiarti, 2021; Sartorius et al., 2015). No studies have used the BFP prediction model in Indonesian female RIDU cadets. The purpose of this study was to develop a prediction model for assessing the BFP of female RIDU cadets.

RESEARCH METHOD

This quantitative study was conducted using a cross-sectional method (Adaki et al., 2023). The minimum sample of this study was 104 subjects based on the G-power calculation for correlation (the biggest minimum sample size from variables in this study). We used the total sampling and analyzed 108 female students from the Indonesia Defense University who met the inclusion and exclusion criteria. The inclusion criteria were female aged 18-20 years old and enrolled as the first batch in the bachelor's program at RIDU. The exclusion criteria were dropout and a health-related emergency condition. Informed consent was obtained from the subjects prior to their participation in the study. Data collection was conducted from August 20–27, 2021. The total number of female RIDU students in batch 1 was 113. As 3 subjects refused to join the research and 2 subjects were under 18 years old. A total of 108 subjects met the inclusion and exclusion criteria and were analyzed in this study. Ethical approval has been granted by the Commission of Health Research Ethics at the Faculty of Medicine and Health, University of Muhammadiyah Jakarta (Ethical No. 152/PE/KE/FKK/-UMJ/VIII/2021). A letter of permission was obtained from the RIDU. The location of the study is the RIDU area, Indonesia Peace and Security Center, Sentul Bogor. The study was conducted in August 2021. To examine BIA, In Body type 201 was used. We measured the height of the subjects using a body weight scale GEA ZT-120 (Purnamasari et al., 2021). Waist circumference was determined using non-elastic measuring tape.

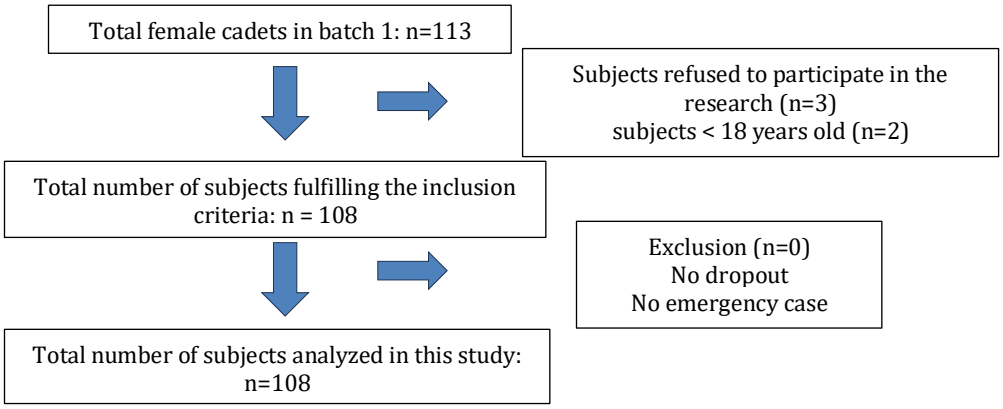

Figure 1. Flow diagram of participant recruitment

To obtain BFP from BIA, we ensured that the InBody 201 device was properly calibrated and functioning. Any metal objects, such as jewelry, watches, and clothing containing metal components, were removed. The subject was in a relaxed state. Subject's height was submitted to the InBody 201 device using a touch screen. Subject stood barefoot on the foot electrodes of the BIA InBody 201, with both feet positioned correctly on the designated footprints. Subjects maintained a stable stance with their feet shoulder-width apart. Arms raised in front of the subject as height as subject's chest. After pressing the command on the InBody 201, the device began sending a low-intensity electrical current through the subject's body. The device then analyzed the electrical impedance data and generated a BFP for the subject. Weight (in kg) also obtained from BIA. To measure height, subjects stood straight with their back against the wall and their feet placed together. The measuring device was aligned with the subject's head to ensure it was parallel to the ground. We gently placed the measuring device on the subject's head, read, and recorded the height measurement at the point where the measuring device aligned with the subject's head. The height was recorded to the nearest centimeter. To obtain waist circumference data, we ensured that the subjects stood upright with their feet shoulder-width apart. We used non-elastic tape that could easily wrap around the subject's waist. The measurement location was the midpoint between the top of the hip bone and the bottom of the lowest rib cage. We ensured that the tape was parallel to the floor and was not twisted, and we maintained a consistent level of tension while avoiding compression of the subject's skin. We took the measurement at the end of a normal breath without sucking in or pushing out the subject's abdomen. The measurement was recorded to the nearest centimeter. Age was determined by subtracting the patient's date of birth from the date of data collection. In cases in which the subject's birthdate fell after the data collection date, age was calculated as the closest preceding birthday

In this study, the independent variables were age, BMI, and waist circumference, and the dependent variable was body fat percentage. Statistical analysis was performed using the Statistical Package for the Social Sciences (SPSS) version 16. Descriptive statistics, such as mean and range, were analyzed along with the analytical data through bivariate and multivariate analyses. The data distribution was assessed using the Kolmogorov-Smirnov test. For bivariate analysis, the Pearson correlation test was used for normally distributed data, and the Spearman's correlation test was applied to non-normally distributed data. A multivariate linear regression test was then conducted (including independent variables with a P value of <0.25) to develop a predictive model for body fat percentage. A result was considered statistically significant when the P value was less than 0.05.

FINDINGS AND DISCUSSION

A total of 108 female cadets were analyzed in this study. Mean age, body weight, and other anthropometric data for subjects are presented in Table 1. The mean of BMI was 21,46±2,56, while the mean of WC was 68,5±5,48. The mean body fat percentage was 28,3± 6,37%. The mean ages, weights, and heights in this study were 18,84±0,61, 54,49±6,51, 169,34±4,45 respectively. The minimum age in this study was 18 years, and the maximum age was 20 years.

Table 1. Baseline characteristics of subjects

	Variable	Value
1.	Age (year)	
	Mean	18,84
	Range	18-20
	IQR	18; 19
2.	Waist Circumference (cm)	
	Mean	68,5
	Range	56-82,5
	IQR	64,3; 71,9
3.	Body Mass Index (kg/m^2)	
	Mean	21,46
	Range	15,4-29
	IQR	19,8; 22,87
4.	Weight (kg)	
	Mean	54,49
	Range	37,9-71,4
	IQR	49,8; 58,6
5.	Height (cm)	
	Mean	169,34
	Range	147,7-172
	IQR	156,12; 162,5
6.	Body Fat Percentage (%)	
	Mean	28,3
	Range	15,6-49,7
	IQR	24; 32,67

The average of subjects in this study had normo-weight BMI (between range 18,5-22,9 kg/m2) based on Asia-Pacific classification (World Health Organization Western Pacific Region, 2000). This result aligns with other findings. The average BMI of a high school student in West Java Indonesia was also in the normo-weight category (Khairani & Sudiarti, 2021). The average of military personnel subjects in a study by Pierce in USA also has normal nutritional status (normo-weight category) based on Center for Disease Control (CDC) BMI guidelines (normo-weight BMI 18,5-24,9 kg/m2) (CDC., 2022; Pierce et al., 2017). BMI still a useful indicator for screening of nutritional status in community, although in several research, BMI tends to make a false positive result in detection of obesity in compare to BFP (Junior et al., 2017; Khairani & Sudiarti, 2021). BMI also should not be used for body-builder athletes and elite special force personnel (Tafeit et al., 2019). Additional nutritional assessment beside BMI is recommended to be done to confirm the nutritional status of subjects, especially those who have malnutrition results (Bhattacharya et al., 2019; Tafeit et al., 2019).

The BIA examination results indicated that the average body fat percentage of the subjects was 28,303% ± 6,37%. It can be interpreted that the average of the subject, has normal BFP based on NIH classification (National Institutes of Health, 1998). This result agreed with several studies. A study by Khairani showed that the average of BFP in adolescent girl aged 12-18 years old at a school in West Java was 26,51%±5,48% (Khairani & Sudiarti, 2021). A study with 400 subjects in China showed that the average of BFP in woman ages < 30 years old was 30.65%±6.08 (Liang et al., 2018). Using the Bod Pod Body Composition System, Pletcher found that the mean BFP of 84 female marine subjects was 24.4±4.9 (Pletcher et al., 2023). Another study with 229 active military personnel who volunteered to take part in a study aimed at preventing weight gain in United States of America showed different result that based on BFP NIH classification, there were 98.3 obese female subjects with the average of BFP in obese subjects was 39.7%±4 and the average of BFP in

normal BFP subjects was 28.8%±1 (Heinrich et al., 2008). It showed that the mean BFP of that study was much higher than that of our study. The average BFP in our study fell within the normal range, which might be explained by the participants' degree of physical activity and their appropriate intake of calories from meals (Rodrigues et al., 2020). Excessive food consumption combined with inactivity can lead to an imbalance in the body's energy intake and expenditure, which raises body fat percentage and fat mass (Robinson & Stensel, 2022; Romieu et al., 2017; Westerterp, 2018).

Correlation test results between anthropometric measurements and BFP, as well as between age and BFP, are presented in Table 2.

Table 2. Correlation Coefficients of Variables

No	Variable	r	P value
1.	BFP BIA vs Waist Circumference	0,624	0[a]
2.	BFP BIA vs Age	0,191	0,047[b]
3.	BFP BIA vs BMI	0,722	0 [a]

[a]*Pearson correlation test*

[b]*Spearman correlation test*

Age, BMI, and WC were significantly related to BFP among female RIDU cadets. The least correlated variable to BFP was age, and the strongest correlation to BFP was BMI. All assumptions for multivariate linear regression analysis were fulfilled. The prediction model developed through multivariate analysis in this study is as follows:

$$BFP = -94{,}055 + 39{,}064*WC + 1{,}073*age + 1{,}420*BMI$$

BFP is body fat percentage (%), WC is waist circumference (cm), and BMI is body mass index ((kg/m2).

The adjusted R-squared value for this predictive model was 0.535, indicating that this formula can predict 53,5% BFP of the subjects. This outcome followed conducted by Khairani, who showed that the strongest correlation to BFP was BMI, followed by waist circumference and age (Khairani & Sudiarti, 2021). Several studies also showed that BMI and waist circumference were related to BFP (Costa-Urrutia et al., 2019; Liang et al., 2018; Zhu et al., 2020). The increase in BMI and waist circumference corresponded with the rise in body fat, body fat percentage, and visceral fat area (Azzeh et al., 2017; Liang et al., 2018). BMI is a body fat discriminator in both men and women. This indicator is widely used and can be used by health professionals for the quick assessment of body fat in adolescents and adults with low operating costs (Junior et al., 2017; Javed et al., 2015; Woolcott & Bergman, 2018). Other studies showed that BMI is strongly correlated with BFP, as measured using densitometry, magnetic resonance imaging, or dual-energy X-ray absorptiometry (DXA). However, BMI measurement should be performed with caution in athlete's subjects (Van Haute et al., 2020), because of redistribution of body fat changes (Junior et al., 2017).

Another research supported the result of this research. Waist circumference has a strong correlation with body fat at the central region (Xi et al., 2022), measured by using DXA (Junior et al., 2017), and MRI (Pasanta et al., 2021). Age may relate to body composition. Age is correlated with BFP. With aging, the percentage of body fat will increase, whereas fat-free mass and bone mineral density will decrease (Chang et al., 2022; Zamboni & Mazzali, 2012). Aging processes tend to increase the percentage of body fat (Ponti et al., 2020; Wang et al., 2022; Zong et al., 2016). An increase in fat mass is largely due to a decrease in muscle mass (Ponti et al., 2020; Zong et al., 2016).

CONCLUSIONS

In conclusion, the prediction model developed through multivariate linear regression analysis was BFP= -94,055 + 39,064*WC+ 1,073*age + 1,420*BMI. Age, BMI, and WC were predictors of BFP among female RIDU cadets in Indonesia. The restricted anthropometric measurement indicator that was used for the predictor in the BFP model prediction formula was the study limitation.

However, BMI and waist circumference were strong predictors in other studies included in this study analysis. Further research with larger subjects and additional anthropometric measurements, such as skinfold thickness, and validation of the estimated formula should be conducted with female RIDU cadets in Indonesia.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

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