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ORIGINAL PAPER

Relation between body mass index, waist circumference, and a body shape index with VO_2 max among medical students in Jakarta, Indonesia

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Abstract

Background: Individuals with low VO_2 max have higher potential of chronic disease in later life. Body fat composition is a factor that affects VO_2 max. A sedentary lifestyle and poor diet in medical students can lead to excess body fat mass, which can be measured through BMI, WC, and ABSI.

Objective: The study aimed to determine the relation between BMI, WC, ABSI, and VO_2 max in medical students.

Methods: This study used an observational analytic method and a cross-sectional approach. It was conducted at the Medical Education and Research Center UPNVJ from January to December 2024. The sampling technique was simple random sampling with total sample size of 46 respondents. Data collection involved filling out a questionnaire and measuring BMI, WC, ABSI, and VO_2 max. Statistical analysis in this study was performed using the Mann-Whitney test.

Results: Most respondents had normal BMI, normal WC, and low ABSI. The results of bivariate analysis showed relation between WC and VO_2 max ($p = 0.000$), and there was no relation between VO_2 max with BMI ($p = 0.344$) and ABSI ($p = 0.956$).

Conclusion: The study's results conclude that WC and VO_2 max are related. However, there was no relation between BMI and ABSI and VO_2 max in medical students.

Keywords: body mass index, waist circumference, a body shape index, VO_2 max

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Introduction

Currently, Indonesia is experiencing a double burden of malnutrition, which includes high malnutrition and increasing prevalence of obesity.[1] According to Riskesdas data, the prevalence of obesity was 14.8% in 2013 and increased to 21.8% in 2018.[2,3] Based on the latest data from the 2023 Indonesian Health Survey, the prevalence of obesity in adults over 18 years old has reached 23.4%, consistently increasing compared to previous years.[4]

Obesity is a multifactorial problem. Apart from genetics, lifestyle, and environmental factors play a major role in the occurrence of obesity in most people.[5] Medical students tend to have a sedentary lifestyle due to long and busy lecture activities.[6] In addition, the busy lectures make students tend to consume fast food, which contains high calories and fat, which, if consumed excessively, can increase body fat.[7,8] If excessive energy intake is not balanced with adequate physical activity, it can sustainably lead to obesity.[9]

A common way to detect obesity is through anthropometric measurements, including body mass index (BMI) and waist circumference (WC).[10] Body mass index is a fairly effective measurement tool because it only uses a simple formula, inexpensive, and the results are relatively precise. However, it lacks the ability to distinguish between being overweight due to fat or due to muscle.[11] Waist circumference is used to measure central obesity and is known better to predict metabolic and cardiovascular disease risk than BMI.[12,13] In 2012, ABSI, or a body shape index, was developed to overcome the weaknesses of BMI by measuring abdominal adiposity based on WC adjusted for height and weight. The ABSI measurement is known to be superior in predicting the risk of premature mortality and quantifying the risks associated with central obesity.[14] High ABSI indicates higher concentration of visceral fat around the abdomen. The ventilatory function of the respiratory system becomes inefficient due to fat accumulation in the abdominal area, which increases pressure on the abdomen and restricts lung expansion.[15,16]

Obesity is a risk factor for non-communicable diseases such as diabetes mellitus, heart disease, cancer, hypertension, and other metabolic and non-metabolic diseases.[1] Some of these non-communicable diseases are a reminder of how important physical fitness is. Physical fitness is related to various aspects such as health, performance, productivity, and quality of life.[17] A person's physical fitness can be measured through cardiorespiratory fitness.

The indicator to assess cardiorespiratory fitness is VO_2 max, defined as the maximum amount of oxygen consumed per minute by a person when performing maximum effort.[18] VO_2 max reflects functional capacity and human performance. It is a strong, independent predictor of all-cause and disease-specific mortality, regardless of sex or race.[19] Higher VO_2 max enhances energy levels and human performance by lowering the metabolic strain on cardiac muscle, preventing the heart from excessive workload, and supporting increased cardiac output when needed.[20]

Individuals with low VO_2 max have a higher tendency to develop various chronic diseases.[21] Unhealthy lifestyles, such as sedentary lifestyles and poor diet, could result in excess body fat mass. Excess fat mass causes a decrease in VO_2 max because the presence of fat deposits disrupts oxygen intake to the lungs and oxygen perfusion from peripheral blood vessels to the muscles.[22] Gender, age, genetics, body composition, physical activity, cardiorespiratory diseases, and smoking habits are several variables that affect VO_2 max. This study only used female subjects, as male VO_2 max tends to be higher than females due to greater muscle mass, hemoglobin levels, and stroke volume in males.[23]

Methods

Study design and participants

This study used an observational analytic method and a cross-sectional approach. The research was conducted at the Medical Education and Research Center UPN "Veteran" Jakarta in January - December 2024. This study has received ethical approval from the UPNVJ Research Ethics

Committee with number 346/VII/2024/KEP. The population in this study were medical students of UPN "Veteran" Jakarta who met the inclusion and exclusion criteria. The sampling technique was carried out by the probability sampling method using simple random sampling with the number of samples obtained as many as 46 respondents. The inclusion criteria in this study include female gender, and aged 18-22 years. The exclusion criteria in this study were respondents who had a history of pulmonary disease, cardiovascular disease, musculoskeletal disease, chronic disease, were in a state of illness, were undergoing treatment, blood pressure more than 140/90 mmHg, smoking, and had heavy physical activity from the measurement results of the GPAQ (Global Physical Activity Questionnaire). The GPAQ questionnaire measures physical activity by classifying it according to MET (Metabolic Equivalent). It consists of three categories, heavy physical activity (MET>3000), moderate (3000>MET>600), and light (600<MET). Because physical activity can significantly influence VO_2 max, this study restricted participants to light and moderate activity levels.

Measurements

BMI measurements were done using digital scales and microtoise to obtain body weight and height data. Then, the IMT value is calculated by using the formula body weight in kilograms divided by height in square meters. Waist circumference was measured using a measuring tape. A body shape index (ABSI) was measured using digital scales, microtoise, and measuring tape to obtain data on body weight, height, and WC. Furthermore, the ABSI value was calculated using the following formula.

$$\text{ABSI} = \frac{\text{WC (cm)}}{\text{BMI}^{\frac{2}{3}}\left(\frac{\text{kg}}{\text{m}^2}\right) \text{ x Height}^{\frac{1}{2}}\text{ (m)}}$$

The protocol used for VO_2 max measurement was the Astrand-Rhyming Cycle Ergometer Test (ARCET) using a cycle ergometer (Monark Ergomedic 828E). The procedure began with setting the seat height on the cycle ergometer and warming up for 3 minutes at 50 rpm using a 1 kg leg load. This study set the initial power output at 300 kgm (kilogram-force meter/minute) or 50 Watts because all subjects were female. After the warm-up, a 6-minute test with a pedal speed of 50 rpm followed, aiming to produce a heart rate between 125-170 bpm. Heart rate was measured using a pulse oximeter during the last 30 seconds of the second to sixth minute. The test ended when the heart rate was within the target heart rate zone and differed by less than 10 beats per minute for two consecutive minutes (minutes five and six). If this criterion was not met, the test was extended by adjusting the power output until the heart rate was within 10 beats per minute for two consecutive minutes. The last two heart rate values were then averaged and used for calculation using the Astrand-Rhyming normogram and adjusted by a correction factor to obtain the VO_2 max value. Subjects cooled down after the test was finished.

Data analysis

The data obtained were then processed and analysed. Univariate analysis in this study is presented as frequency distributions and percentages because the data are ordinal categorical. Bivariate analysis was performed using the Mann-Whitney test.

Results

The majority of respondents in this study were 20 years old, which amounted to almost half of total respondents. Most respondents had a BMI <23, which was 1.5 times more than BMI >23. Most respondents had a normal WC, almost 3 times more than those with central obesity. Most respondents had low ABSI, almost 7 times more than those with high ABSI. Most respondents had high VO_2 max, 5 times more than low VO_2 max, and 1.5 times more than moderate VO_2 max (**Table 1**).

Table 1. Distribution of respondent characteristics

Characteristics	n	Percentage %
Age		
18	3	6.5
19	7	15.2
20	21	45.7
21	11	23.9
22	4	8.7
Body mass index		
BMI<23	28	60.9
BMI≥23	18	39.1
Waist circumference		
Normal	34	73.9
Central obesity	12	26.1
A body shape index		
Low	40	87
High	6	13
VO_2 Max		
Low	5	10.9
Moderate	16	34.8
High	25	54.3

Young adult women often pursue an ideal body shape by consciously reducing meal portions or skipping meals. Coupled with the demanding schedule of medical students, which frequently prevents them from eating three full meals a day. This reason may help them maintain normal body composition despite occasional consumption of unhealthy foods.

The results of this study showed that respondents with BMI<23 mostly had high VO_2 max (57.1%). Most respondents with BMI>23 (50%) have high VO_2 max. The statistical analysis showed no significant relation between BMI and VO_2 max, with p-value of 0.344 (p>0.05).

The data also showed that most respondents with normal WC had a high VO_2 max (67.6%), while respondents with central obesity had a low (41.7%) and moderate (41.7%) VO_2 max. The statistical analysis showed a significant relation between WC and VO_2 max, with p-value of 0.000 (p<0.05).

The results of this study also showed that respondents with low ABSI had a high VO_2 max (55%), while respondents with high ABSI had a VO_2 max with an equal amount in the moderate (50%) and high (50%) categories. The statistical analysis showed no significant relation between ABSI and VO_2 max, with p-value of 0.956 (p>0.05) **(Table 2)**.

Discussion

BMI and VO_2 max

The majority of both respondents, with IMT< 23 and IMT >23, have high VO_2 max. BMI measurements are used to determine the degree of obesity because it correlate with body fat.[24] The statistical analysis showed no significant relation between BMI and VO_2 max, with p-value of 0.344 (p>0.05).

Several previous studies revealed that the higher the BMI, the lower the value of VO_2 max.[25,26] Fat accumulation could build up in areas such as the chest and stomach. An increase in subcutaneous and visceral fat in these parts could press the diaphragm and limit lung expansion, ultimately reducing oxygen supply to the lungs.[27] Increased body fat could overburden the cardiorespiratory system, inhibiting the distribution and uptake of oxygen for intracellular metabolism in tissues. In addition, fat deposits in musculoskeletal tissue would make taking oxygen during exercise less effective.[28,29]

Table 2. Relationship between BMI, WC, and ABSI with VO2 max

Characteristics	*VO₂ Max*						*p-value*
	Low		Moderate		High		
	n	%	n	%	n	%	
BMI							
BMI < 23	1	3.6	11	39.3	16	57.1	0.344
IMT ≥ 23	4	22.2	5	27.8	9	50	
WC							
Normal	0	0	11	32.4	23	67.6	0.000
Central obesity	5	41.7	5	41.7	2	16.7	
ABSI							
Low	5	12.5	13	32.5	22	55	0.956
High	0	0	3	50	3	50	

Source: Primary Data, 2024

However, the results of this study showed that BMI and VO_2 max have no significant relation. Despite having a higher BMI, 50% of respondents with a BMI>23 have high VO_2 max. This difference in results can be caused by the fact that one of the weaknesses of BMI is that it cannot distinguish between fat and muscle mass. Apart from fat mass, being overweight can also occur due to a lot of muscle mass.[13,30]

The value of VO_2 max is determined by the respiratory system, cardiovascular circulation, and oxygen extraction/utilization by muscles.[16] Better maximum oxygen volume is related to better muscle extraction of peripheral oxygen. Maximum oxygen uptake during physical exercise depends on the maximum speed of oxygen transport toward the mitochondria in the working muscle tissue. Lack of muscle mass can lead to lack of metabolic oxygen utilization, and vice versa.[5,16]

WC and VO_2 max

The majority of respondents in this study had a normal WC and VO_2 max, which is high (67.6%). These findings can be caused by the fact that the subjects in this study are female students aged 18-22 years. The Indonesian Health Survey Report 2023 states that 24% of women aged 15-24 years in Indonesia have central obesity. The number has doubled in the next age group, 25-34 years, reaching 54.2%, and continues to increase in the subsequent age groups.[4] This could occur because the subjects in this study are also not married or pregnant. Pregnancy is associated with increased storage of abdominal visceral adipose tissue.[31] The study showed that most respondents with a normal WC had a high VO_2 max. Respondents with central obesity have a low and moderate VO_2 max. The statistical analysis showed a significant relation between WC and VO_2 max, with a p-value of 0.000 ($p<0.05$).

Waist circumference is used to identify central obesity and is considered more effective than BMI in predicting the risk of metabolic and cardiovascular diseases.[12,13] Obesity can be caused by low physical activity and high consumption of snacks, fried foods, and fast food.[32] Students with central obesity have a higher calorie intake, one of which is from eating fast food.[33] Medical students frequently experience high stress levels, resulting in increased consumption of unhealthy foods. Stress can trigger the release of cortisol, a hormone that increases appetite and can lead individuals to engage in overeating high-calories, high-fat, and high-sugar foods.[34,35]

Central obesity is characterized by a higher proportion of visceral fat. This visceral fat is more dangerous than subcutaneous fat because it releases a number of "bad" adipokines that can cause insulin resistance and chronic inflammation, potentially triggering the development of cardiovascular diseases such as atherosclerosis.[36] Fat accumulation in the body can trigger the release of pro-inflammatory cytokines that lead to endothelial dysfunction and reduced production nitric oxide (NO) as a vasodilator. This results in the narrowing of the arteries and increased peripheral resistance, leading to hypertension. As a result, less blood is pumped, and less oxygen is delivered to the muscles, which strains the cardiorespiratory

system. It can lead to a decrease in cardiovascular ability.[37,38]

Several previous studies have stated that the larger the WC, VO_2 max will continue to decline.[39,40] Each centimetre increase in WC decreases the value of VO_2 max by 0.48 ml/kg/min in men and 0.27 ml/kg/min in women.[40] Individuals with low VO_2 max have a greater tendency to develop various chronic diseases and premature death. In contrast, individuals with a high VO_2 max have a lower chance of developing chronic diseases.[21]

ABSI and VO_2 max

The majority of respondents have low ABSI and high VO2 max (55%). A body shape index (ABSI) is associated with visceral fat thickness and cardiovascular disease risk.[41] The statistical analysis showed no significant relation between ABSI and VO_2 max, with a p-value of 0.956 ($p > 0.05$).

A body shape index or ABSI is defined as central obesity if the value is ≥ 0.080.[42] ABSI values that exceed the normal range indicate a larger-than-expected increase in WC based on certain weight and height according to body volume. This indicates a higher concentration of visceral fat around the abdomen.[15]

The risk of cardiometabolic morbidity and mortality is related to the amount of excess fat and its distribution in the body. Visceral fat causes metabolic dysregulation, triggering inflammation, endothelial dysfunction, and insulin resistance. This is considered the main risk factor for the occurrence of various chronic diseases, such as hypertension, cardiovascular disease, and type 2 diabetes mellitus.[43]

Any heart disease that reduces maximum cardiac output will decrease the body's overall muscle power achievement due to reduced oxygen supply to muscle tissue.[5] In addition, the respiratory system's ventilation work becomes inefficient due to the accumulation of fat in the chest wall and stomach, which increases pressure in the abdomen, thereby inhibiting lung development. The physiological implication is that it is more difficult for obese individuals to do the same amount of work as people of normal weight due to the decrease in cardiorespiratory capacity.[16]

However, using ABSI to predict VO_2 max in this study did not show results consistent with Krakauer's findings when ABSI predicted a better risk of premature death than BMI and WC.[44] This result difference can be caused by the ABSI formula being developed based on data from the original study conducted in the United States. The body characteristics of Americans may differ from those of Indonesians, for example, average height, body fat distribution, and genetic factors that cause differences in results when the ABSI formula is applied to different populations.[45] Research on ABSI with VO_2 max is still lacking, so further research is needed to describe the causal relation between ABSI and VO_2 max.

This research still has some limitations. First, there are risk factors that can affect VO_2 max that have not been eliminated in this study, such as genetic and ethnic factors. Second, the determination of respondent's criteria regarding disease history is only based on interviews and filling out questionnaires, not original diagnoses taken from medical records.

Conclusion

Based on the study's results, most students have a normal BMI (52.2%), normal WC (73.9%), low ABSI (87%), and high VO_2 max (54.2%). The statistical analysis showed a relation between WC and VO_2 max, but there was no relation between BMI, ABSI, and VO_2 max. These results suggest that WC may be a more relevant predictor of cardiorespiratory fitness in this population compared to BMI or ABSI. Although ABSI did not show a significant association in this study, it remains a valuable anthropometric tool due to its ability to account for body shape and central adiposit factors that are strongly linked to cardiometabolic risk. Further research is needed to explore ABSI's role in early detection of metabolic and cardiovascular abnormalities.

Conflict of interest

The authors declared no conflict of interest regarding this article.

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