ASSOCIATION BETWEEN BODY MASS INDEX AND CARDIORESPIRATORY FITNESS AMONG PATIENTS UNDERGOING CARDIAC STRESS TEST IN DR HASAN SADIKIN GENERAL HOSPITAL BANDUNG

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Abstract

Body mass index (BMI) and cardiorespiratory fitness are considered risk factors for cardiovascular disease. Chronic inflammation associated with adiposity as well as the hemodynamic changes that occur when there is an increase in BMI suggest a possible association between BMI and cardiorespiratory fitness. This study aims to analyze the relationship between BMI and cardiorespiratory fitness. A cross-sectional study was conducted using weighted cardiac training test results for the period January 1st, 2014 to December 31, 2019 from the Non-Invasive Diagnostic Division, the Department of Cardiology and Vascular Medicine, Dr. Hasan Sadikin Bandung. Subjects included in the study were those who achieved the maximum estimated heart rate based on age or less than 10 beats per minute, and / or the exercise test was stopped due to fatigue with a Borg 17 scale. Patients with multiple conditions were excluded from the study (taking beta-blockers, having history of heart failure and diabetes mellitus, currently undergoing cardiac rehabilitation), along with patients with incomplete data. The maximum oxygen consumption in the form of the metabolic equivalent of tasks (METs) was estimated based on the speed and inclination of the stage reached during the treadmill training test using the Bruce protocol. Percentage of fitness is obtained by comparing the METs achieved with the estimated maximum METs based on age and gender. The relationship between BMI and percentage of fitness was analyzed using the Pearson correlation test. The total subjects included in the study were 51 subjects. The mean BMI of the subjects was 25.65 ± 3.22 kg / m2. The mean fitness percentage was 107.29 ± 23.89. Analysis of the relationship between BMI and fitness showed a negative but insignificant relationship (r = -0.135, p = 0.345). An increase in body mass index has a tendency to be associated with a decrease in cardiorespiratory fitness.

Keywords: body mass index, cardiorespiratory fitness, weight training test

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INTRODUCTION

Cardiovascular diseases are a burden to both national and global health due to their morbidity and mortality rate.[1,2] Due to the multifactorial nature in the development of the disease, an efficient prevention of the disease would be modification of the risk factors. Having an overweight or obese body mass index (BMI) is well-known as one of those factors. Risk of cardiovascular diseases increases in people within the overweight and obese BMI categories. It is so widely accepted as a modifiable risk factor for cardiovascular disease that annual measurement of body weight is among the recommended preventive measures for the disease.[3] The adverse effect obesity to the development of cardiovascular diseases is attributable to a chronic inflammatory state that is induced as adiposity increases.[4]

Another factor that is associated with cardiovascular disease is cardiorespiratory fitness. Cardiorespiratory fitness (CRF) represents the capability of the circulatory and respiratory systems to sustain the body during a moderate-vigorous intensity physical activity.[5] It was observed that there is an 11% reduction of cardiovascular disease risk for every increase in CRF by one MET.[6] Cardiorespiratory fitness is assessed in the form of maximal oxygen consumption (VO$_{2max}$), defined as maximum amount of oxygen consumed each minute during maximum physical activity. Oxygen consumption is also commonly expressed in the form of metabolic equivalent of task (MET) that is the basal oxygen consumption of 3.5 ml·kg^{-1}·min^{-1}. Measurement of CRF is performed by the cardiac stress test, in which a physiologic stress is given to the subject by exercising to assess the maximal oxygen consumption.[5] Direct measurement of CRF by respiratory gas analysis has the best accuracy, yet it requires special resources that are not widely available. Indirect measurement by estimation of CRF serves as a valid and more cost-effective alternative to the direct method.[5]

With both being the risk factors for cardiovascular disease, the relation between BMI and CRF became questionable. Studies had suggested that adiposity-related chronic inflammation is associated with CRF level.[7,8] Cardiovascular responses to an increase in BMI might lead to changes in hemodynamic, particularly alteration in cardiac output, which has a significant role in oxygen transport and consumption.[4] These facts indicate a possible relationship between BMI and CRF. Several studies had proposed to analyze possible relationship between these two variables. Most studies found a negative association between both variables but some studies had different results.[9–18] The objective of this study is to analyze the association between BMI and CRF that is measured by cardiac stress test.

METHOD

A cross-sectional study was performed using the data from exercise stress test records obtained in Non-Invasive Diagnostic Division, Department of Cardiology and Vascular Medicine Dr. Hasan Sadikin General Hospital Bandung. This study had been approved by Health Research Ethics Committee, Faculty of Medicine Universitas Padjadjaran (1070/UN6.KEP/EC/2020) and by Dr. Hasan Sadikin General Hospital Bandung (LB.02.01/X.2.2.1/24991/2020). Data of patients who underwent exercise stress test from January 1st, 2014 to December 31st, 2019 were obtained. These criteria were used to identify subjects who accomplished maximal testing: (1) achieving the estimated maximum heart rate (HR) by age or 10 beats per minute (bpm) less, and/or (2) the test was terminated due to fatigue with Borg Scale of 17. Maximum HR was predicted by the formula: HR predicted = 220 – age (years). To avoid potential confounders, subjects with these conditions were excluded from the study: currently consuming beta-blocker; having history of heart failure and diabetes mellitus; currently undergoing cardiac rehabilitation. Records with incomplete data of variables included in this study were also excluded. Consecutive sampling method was used with a calculated minimum sample of 38 subjects.

Information regarding body height and body weight was obtained from the record. The following formula was used to calculate body mass index: BMI = body weight (kg)/ body height (m^2). The calculated BMI was used for the analysis of its relation with CRF. For descriptive purpose, BMI was also categorized into underweight ($< 18,5$ kg/m^2), normal ($18,5 – 22,9$ kg/m^2), overweight ($23 – 24,9$ kg/m^2), obese I ($25 – 29,9$ kg/m^2), and obese II (≥ 30 kg/m^2) based on criteria from World Health Organization for Asia-Pacific region.[19]

All subjects underwent treadmill stress test with Bruce protocol. Subjects were considered to achieve the VO$_{2max}$ of a stage if they had spent at least one-minute exercising in that stage. The formula used to estimate VO$_{2max}$ was obtained from American College of Sports

Medicine (ACSM) according to speed and grade of the achieved stage.[5,20] For stage 1 to stage 3, ACSM walking formula was used: $VO_{2max} = 3.5 + (0.1 \times$ speed (m/min)) + ($1.8 \times$ speed (m/min) $\times$ grade (%)). ACSM running formula was used for subjects that reached stage 4 of the protocol: $VO_{2max} = 3.5 + (0.2 \times$ speed (m/min)) + ($0.9 \times$ speed (m/min) $\times$ grade (%)). Afterward, the estimated VO_{2max} was divided by 3,5 to convert them into METs. Fitness classification into functional class I, II, III, and IV was also presented.[20]

To assess individual fitness, maximal fitness according to age and sex of each subject was also predicted using the formula for males: estimated METs = 14,7 – (0,11 $\times$ age (years)). As for females, the formula used was: estimated METs = 14,7 – (0,13 $\times$ age (years)).[20] The percentage of achieved METs to maximal predicted fitness was presented as percentage of CRF. Data on hemodynamic parameters such as resting blood pressure (BP), maximum BP, resting HR, and maximum HR were also gained.

Normality test was conducted for each numeric variable. The relationship between percentage of CRF and BMI was then analyzed using Pearson correlation test. Significance level was set on p-value of 0,05. Data were processed using Microsoft Excel 2016 and IBM SPSS 22.

RESULT

A total of 220 exercise stress test records from January 1st, 2014 to December 31st, 2019 were obtained. Adjustment with inclusion and exclusion criteria resulted in 51 data to be included in the study. Subjects were predominantly male (72,55%) and the average age was 50.61 years with a range of 20 – 73 years old. Diagnosis of CAD was the most common purpose of the subjects to do the test (56.86%). Average BMI of subjects was 25.65 ± 3.22 kg/m². Characteristics of subjects including the hemodynamic changes during the test was shown on Table 1.

Analysis of body weight and height resulted in BMI categorization as presented on Table 2. Majority of subjects fell into the obese I category (45.10%). Subjects with overweight (33.33%) BMI outnumbered subjects with normal (11.76%) and obese II (7.84%) BMI. Only one (1.96%) subject had an underweight BMI.

Cardiorespiratory fitness indicated by maximum METs achieved during the test was shown on Table 3. Most subjects had a good CRF (> 7 METs) thus classified as functional class I. Average percentage of CRF was 107.29%. The data of BMI and percentage of CRF was normally distributed. Analysis of association between BMI and percentage of fitness using Pearson test resulted in a weak negative correlation coefficient (r = -0.135) with p-value of 0.345. Hence, the association between BMI and cardiorespiratory fitness was considered to be insignificant. (Table 4).

Table 1. Characteristics of Subjects

Characteristic	N (%)	Mean/Median
Sex		
Male	37 (72.55)	-
Female	14 (27.45)	-
Age (years), mean ± SD	-	50.61 ± 11.57
Indication of test		
Diagnosis of CAD	29 (56.86)	-
Medical check-up	7 (13.72)	-
Post PTCA	2 (3.92)	-
Unknown	13 (25.50)	-
Hemodynamic		
Systolic resting BP, median (IQR)	-	120.00 (30.00)
Diastolic resting BP, median (IQR)	-	80.00 (0.00)
Systolic maximum BP, mean ± SD	-	154.90 ± 20.58
Diastolic maximum BP, median (IQR)	-	80.00 (10)
Resting HR, mean ± SD	-	79.76 (15.49)
Maximum HR, mean ± SD	-	157.45 (20.41)
BMI, mean ± SD		25.65 ± 3.22

SD: standard deviation; CAD: coronary artery disease; PTCA: percutaneous transluminal coronary angiography; BP: blood pressure (mmHg); IQR: interquartile range; HR: heart rate (beat per minute); BMI: body mass index (kg/m²)

Table 2. Distribution of BMI

Category	N	%
Underweight	1	1.96
Normal	6	11.76
Overweight	17	33.33
Obese I	23	45.10
Obese II	4	7.84

BMI: body mass index (kg/m^2)

Table 3. Distribution of CRF

CRF	N (%)	Mean/Median
Maximum METs, median (IQR)	-	10.16 (3.11)
Functional class		
Class I (≥ 7 METs)	50 (98.04)	-
Class II (5 - <7 METs)	0 (0)	-
Class III (2 - <5 METs)	1 (1.96)	-
Class IV (<2 METs)	0 (0)	-
CRF (%), mean ± SD	-	107.29 ± 23.89

CRF: cardiorespiratory fitness; METs: metabolic equivalent of tasks; SD: standard deviation; IQR: interquartile range

Table 4. Pearson Correlation Test Result of BMI and CRF

Variables	R	p	N
BMI and percentage of CRF	- 0.135	0.345	51

BMI: body mass index, CRF: cardiorespiratory fitness; r: correlation coefficient

DISCUSSION

This study found that there was a negative association between BMI and CRF which corresponds to several other studies but in our study the association was considered to be not significant. The study done by Afshari et al that measured VO_{2max} directly by gas analyzer in 50 young adults and found a significant negative correlation between and BMI ($r^2 = 0.919$, $p <0.001$).[9] The difference in measurement method could explain the different result with our study, because although indirect method is valid and more feasible, direct method still has the best accuracy in assessing VO_{2max}.[20] Similar finding was shown in the study by Bonney et al[10] ($r = -0.336$, $p < 0.001$) among 151 adolescent girls and Hingorjo et al[11] ($r = -0.558$, $p < 0.001$ in males, $r = -0.246$, $p < 0.028$ in females) among 133 young adults, and De Araujo et al[12] ($r^2 = 0.907$, $p = 0.026$ in girls, $r^2 = 0.850$, $p = 0.012$ in boys) among 288 children. On the contrary, a study conducted by Hawari et al found a significant but weak positive relationship ($\beta = 0.11$, $p = 0.000$) between BMI and duration of cardiopulmonary exercise testing in 138 study subjects consisted of

waterpipe tobacco smokers and non-smokers. Although not clearly discussed, this might have happened due to the effect of waterpipe tobacco smoking that interfered VO_{2max} of subjects.[13] A study conducted by Teresa et al found a negative correlation between VO_{2max} and BMI ($r = -0.287$, $p < 0.01$) in 96 university students, but there was not any significant difference of VO_{2max} between overweight and obese I subjects, which is interesting to note because subjects in our study mostly had either obese I (45.10%) or overweight (33.33%) BMI.[14]

Some other studies had similar results to the present study. In a study participated by 100 Indian adults, the estimated VO_{2max} from treadmill test with Bruce protocol was not significantly associated with BMI, both in males ($r = -0.26$, $p > 0.05$) and females ($r = -0.16$, $p > 0.05$), although when grouped according to their BMI classification, overweight group was significantly lower in their VO_{2max} compared to normal weight group.[15] A study in India among 96 athletes also concluded that there was no significant relationship between BMI and CRF ($r = -0.037$, $p = 0.721$) that was measured by 20

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meter shuttle run test, which was thought to be caused by different body composition of athletes from various types of sports.[16] The lack of significant association between CRF level and BMI (p = 0.257) was also found by Mustakim and Djokosujono when observing 134 Indonesian middle-aged women within the age range of 45 -59 years old, which is similar to the average age of our study subjects.[18] We found several studies with relatively smaller sample size compared to other studies that also reported insignificant association between BMI and CRF. For instance, the association between BMI and VO_{2max} measured by Queen's College Step Test in 23 diver fishermen was found to be not significant (r = - 0.01, p = 0.944).[17] CRF level of 16 normal weight and 16 overweight medical students were significantly different.[21] We assume a difference in sample size could be the reason for discrepancies of findings in these studies from others, which may also be taken into consideration when interpreting the result of the present study since we included a total of 51 subjects.

Despite being a very practical and widely-used anthropometric measurement method, BMI has a limitation namely its assessment is based merely on the total body weight. However, the total body weight itself is built by many components that can be divided in the simplest manner into the fat mass and the fat free mass[22]. Yanek et al discovered that in overweight and obese individuals, muscle mass was found to influence 27% of men 21% of women CRF level.[23] This suggests that body muscle mass has a significant influence on CRF, possibly explaining the reason BMI alone was not related to CRF as shown in our study.

On the other hand, fat mass had been found to negatively correlate with CRF. Waist circumference, an indicator of abdominal fat, was observed to have a significant relationship with CRF (r = -0.62, p < 0.0001).[24] Estimated VO_{2max} and total body fat percent had a significant association (r = -0.39 in males and r = -0.33 in females, p < 0.05) in Indian adults, yet their estimated VO_{2max} and BMI was not significantly related.[15] Due to limited resources available in our study, measurement of adiposity indices was not able to be carried out. Therefore, the effect of fat mass to VO_{2max}

could have been an uncontrolled confounding factor.

An increase in body fat level, which leads to a higher body weight, is observed to elicit a chronic inflammatory state due to rising level of adipocytokines production.[4] A recent study reported a negative relationship between VO_{2max} and biomarkers of oxidative damage in blood that supposedly would lead to release of inflammatory cytokines, suggesting that a more fit person would have a lesser degree of chronic inflammation.[7] Pro-inflammatory cytokines such as TNF-α has been observed to play important role in cardiovascular disease development, which is counteracted by anti-inflammatory cytokines such as IL-6 and IL-10 generated during exercise, implying that more active person would likely experience less inflammation and thus, lower risk cardiovascular diseases.[8] Furthermore, a higher body weight could possibly alter the normal hemodynamics. One possible mechanism is by an increase in aldosterone level leading to increased blood volume, and consequently a greater ventricular preload. A long-standing additional preload to the ventricle could cause ventricular dilatation, which would disturb systolic function of the heart. The latter would negatively affect cardiac output, which has an important role in the process of oxygen transport and consumption during exercise, i.e., CRF level.[4] Therefore, BMI and CRF are possibly related to each other, particularly via the inflammatory and hemodynamic pathway. However, there are many other factors that also affect CRF level.

Physical activity is considered to be the main factor in determining CRF level.[25] Endurance training induces remodeling of left ventricle, mainly in a form of eccentric hypertrophy, that facilitates rapid filling of the ventricle and leads to a greater end-diastolic volume. This causes the heart to reach a greater stroke volume and thus greater cardiac output. There are also changes at peripheral level in response to endurance training, including increased arterial compliance, enhanced vasodilatation, and growth of muscular microvasculature.[26] A high-intensity interval training for 6 weeks had a positive effect on VO_{2max} in obese, sedentary women, even

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without significant changes in body mass.[27] In sedentary adults that were given an exercise regime of short-duration (5-10 minutes), moderate-intensity jogging performed 3 times daily, an improvement of VO_{2max} was noticed after 24 weeks of intervention.[28] Therefore, it is likely that possible variability of habitual physical activity of each subjects in our study had also affected their CRF level.

Other habitual factor that could interfere CRF level is smoking. Lauria et al evaluated VO_{2max} of adult smokers and it was evident that they had lower-than-expected CRF level, regardless of the smoking load.[29] Wiatrak et al. discovered that inactive smokers had the least and active non-smokers had the best achieved distance during a 6-minute walk test.[30] A plausible explanation was that the carbon monoxide generated by smoking would reduce efficient oxygen transport to muscle during exercise, resulting in a poor exercise testing performance.[30] However, smoking history of our subjects was not able to be documented so that their possible influence on CRF was not taken into account in the present study.

Hypertension also seems to have an effect on CRF level as demonstrated by Liu et al in their study which discovered that those with high CRF had lower BP and slower development of age-related elevation of systolic BP compared to the less-fit individuals.[31] Hypertension had become a prevalent condition in Indonesia, as reported in Riskesdas (Riset Kesehatan Dasar) 2018.[2] Prevalence of hypertension was 34,11% nationally and even higher in West Java (39.60%). In concordance to the average age of our study subjects, among age group of 45-54 years and 55-64 years, prevalence of hypertension was 45,32% and 55,23%, respectively. Thus, it is reasonable to consider the possibility of undetected hypertension in our study subjects that could have influenced CRF level of the subjects.

Another factor related to CRF level is the hemoglobin content of blood. Hemoglobin is responsible for oxygen transport to tissues, making an essential role in oxygen delivery and consumption during physical activity.[32] Hariyanti et al. analyzed the correlation between VO_{2max} and hemoglobin level among men's softball athletes and it was concluded that these two variables had a positive correlation (r = 0.489 , $p = 0.047$).[33] Since the data regarding hemoglobin level of the subjects was not available in our study, it could also have been a confounding factor that affect CRF of our study subjects.

Regarding the maximum HR criteria to conclude maximal testing, we used the equation by Fox et al. (220 – age) to predict maximum HR which is the most commonly used criteria and was shown to have better performance compared to some other equations.[34] However, there appears to be a risk of overestimation from the actual maximum HR, particularly for females.[35] Consequently, it was possible that some patients might did their test maximally but were excluded from this study due to their inability to reach the predicted maximum HR.

However, this study has limitations. Availability of anthropometric assessment data was limited to BMI only thus other body composition indices that might also had influences to CRF was not able to be analyzed in the study. Complete medical history also was not accessible, therefore other pathologic conditions such as pulmonary diseases and anemia that could also alter the CRF level of subjects could not be identified. Our study also used indirect measurement of CRF instead of the direct method.

CONCLUSION

In this study, higher body mass index has a tendency to be associated with decrease of cardiorespiratory fitness. However, further evaluation with a larger sample size is needed to validate this finding. Further studies that is able to identify and control more potential confounding factors are encouraged. If possible, those studies should use direct measurement of CRF and provide complete anthropometric assessment.

FUNDING

CONFLICT OF INTEREST

This research has no conflict of interest.

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