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Relationship of Body Mass Index and Cardiorespiratory Fitness With Metabolic Syndrome Risk in Adolescents

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Abstract: **Objectives** *The prevalence of obesity in childhood and adolescence is a major public health problem and has increased dramatically over the last few decades. More attention is needed because it is closely related to some non-communicable diseases and metabolic syndrome. The aim of this study was to investigate the correlation of body mass index and cardiorespiratory fitness to the prevalence of metabolic syndrome in adolescents.* **Methods** *The sample of the study was 44 adolescents. This research is an observational analytic study. The sample of this study measured body mass index, cardiorespiratory fitness, and metabolic syndrome through measurement of abdominal circumference, blood pressure, triglycerides, HDL-cholesterol, and blood fasting glucose.* **Results** *The results of the simultaneous test showed that both body mass index and cardiorespiratory fitness had a significant effect on the risk of metabolic syndrome (p = 0.000). The higher BMI tended to have metabolic syndrome 1.746 times higher than not having metabolic syndrome. The propensity of the unfit condition of cardiorespiratory having metabolic syndrome is 4.283 times higher than the one that has the fit condition. This logistic regression model is quite good because it can predict correctly 72.7% of the conditions that occur.* **Conclusions** *This study showed that the higher body mass index and cardiorespiratory fitness conditions can be used as predictors of metabolic syndrome in adolescents.*
Keywords: *Body mass index, cardiorespiratory fitness, metabolic syndrome, adolescent*

Backgrounds

The prevalence of childhood and adolescent obesity is a major public health problem and has increased dramatically over the last few decades (Ng M *et al*, 2013). This is a massive public health problem worldwide (de Onis *et al*, 2010). Great attention is needed because it is closely related to some non-communicable diseases and metabolic syndrome (WHO, 2010), defined as a combination of three or more metabolic abnormalities, consisting of abdominal obesity, high blood pressure, dyslipidemia, and dysglycemia. Epidemiological studies have shown that obesity and poor cardiorespiratory fitness performance contribute significantly to the prevalence of cardiovascular disease, where the factor is found from childhood to adolescent. Obesity in childhood is also a significant risk factor for some types of cancer and type 2 diabetes mellitus in adulthood (Perez and Huffman, 2008).

Much evidence suggests that this set of metabolic indicators is prevalent in adolescents, this occurs parallel to the increasing prevalence of obesity worldwide. For example, among North American, Asian and European adolescents, the prevalence of metabolic syndrome in adolescents with normal weight is <1%, whereas in obese adolescents it ranges from 18-50% (Tailor *et al.*, 2010). Among the Chinese adolescents, the 3.7% prevalence was found in the overall sample but for the prevalence of 35.2%, 23.4%, and 2.3%, respectively, in the obese group, overweight and normal weight (Li Y *et al*, 2008). In addition, a recent review of the prevalence of metabolic syndrome in children from North America, Latin America, Europe, Asia and Australasia (Tailor *et al*, 2010) shows an overall prevalence ranging from 1.2 to 22.6%, only counting children with excess body weight or obesity this value reaches 60%. It has been widely recognized that the prevalence of childhood obesity has increased not only in industrialized countries but also in developing countries (United Nations, 2012). In developing countries, a systematic overweight and obesity increase is a consequence of the transition process associated with the adoption of western lifestyles, characterized by the consumption of high energy-dense foods, low levels of physical activity and increased longer sitting time. For example, in Brazil, the prevalence of childhood obesity increased from 4.1 to 13.9% from 1974-1997; In Thailand, the observed increase was from 12.2 to 15.6% between 1991 and 1993; And in India, the prevalence increased from 9.8 to 11.7% between 2006-2009 (Gupta *et al.,* 2012). In Indonesia, the prevalence of obesity in children aged 6-15 years increased from 5% in 1990 to 16% in 2001 (Soegondo, 2008), and currently, the prevalence of obesity is increasing at 5-12 years 18.8 %, age 13-15 years 10.8% and age 16-18 years 7.3% (Riskesdas, 2013).

Recent studies have shown that cardiorespiratory fitness levels are closely related to metabolic risk in adolescents in Europe and North America (Steele *et al*., 2008), suggesting that high physical fitness reduces the effects of obesity on risk indicators for metabolic syndrome. Decreased physical activity in children and adolescents has also been reported (Muthuri *et al*., 2014; Mak and Day, 2010), can negatively impact their physical fitness levels. It is possible that these changes, associated with an increase in overweight and obesity, may have a negative impact on overall public health. Physical activity is important for improving cardiorespiratory fitness. Several studies have shown that children who are more active have better cardiorespiratory fitness than those who are not active (Aires *et al*., 2011; Boddy *et al*., 2011; Parikh and Stratton, 2011). These findings suggest a link between physical activity and physical fitness, especially in improving cardiorespiratory fitness. Children with high cardiorespiratory fitness and low body mass index (BMI) have a lower risk of metabolic syndrome than those with low cardiorespiratory fitness and high BMI (Padilla-Moledo *et al*, 2012; Wang *et al*., 2011).

Previous studies have shown that gender does not affect the relationship between cardiorespiratory fitness and obesity in childhood (Oda, 2008). Health professionals should design programs to tackle childhood obesity by recognizing the correlation between sex, BMI, and cardiorespiratory fitness, especially in geographic areas with high prevalence of obesity. This will help alleviate chronic diseases and future problems caused by obesity. Studies show that healthcare professionals need to encourage better fitness and overcome obesity-related problems in children to ensure overall positive health during their childhood and into adulthood.

Examining the association of metabolic risk indicators with weight status and cardiorespiratory fitness in adolescents living in different environments may help develop more efficient public health strategies to reduce the incidence of health hazards during this lifetime as well as in adulthood. Research on the relationship of cardiorespiratory fitness levels and body mass index to the risk of metabolic syndrome in these adolescents is rarely performed in Indonesia. This study aims to determine the effect of cardiorespiratory fitness and body mass index on the risk of metabolic syndrome in adolescents. So hopefully this research can contribute much to improving the degree of public health in Indonesia.

Methods

Ethical considerations: The study was approved by the Ethics Review Committee of Dr. Moewardi Hospital with the number 809/VIII/HREC/2017. All research subjects have given their informed consent for participation in this research study.

Participants

The study recruited 44 adolescents (22 males and 22 females) in second grades of Senior High School at Bojonegoro Regency. The purpose of this study was explained to all participants, and written consent was obtained from all participants prior to their participation. Potential participants were excluded if they had a history of cardiorespiratory illness.

Anthropometric measurements

Height and weight were measured to the nearest 0.1 cm and 0.1 kg (OneMed Microtoise, JMI Co Ltd, Indonesia; GEA EB-9063, MPM Co Ltd, Indonesia), with the participants barefoot and in light clothing. Body mass index (BMI) was calculated as weight (kilograms) divided by height (square meters). Waist circumference (WC) was measured at the midpoint between the bottom of the rib cage and the top of the lateral border of the iliac crest with participants in the standing position at the end of a normal expiration. Blood pressure was measured twice at a five-minute interval. Blood pressure readings were taken from the right arm, after a rest period, by use of a sphygmomanometer (Omron HEM-7120; OMRON Co Ltd, Japan).

Blood specimens

Blood samples were collected in the morning after participants had been seated for 30 minutes and had fasted overnight (at least 12 hours). Serum fasting glucose, triglycerides (TG), and high-density lipoprotein (HDL) were measured using a Roche Hitachi 902 Chemistry Analyzer System (HITACHI Co Ltd, Japan).

Definition of metabolic syndrome

This study used the National Cholesterol Education Program Adult Treatment Panel III (NCEP-ATP III) guidelines with some modified from IDAI and Yoshinaga *et al*., (2005) research to determine the presence of metabolic syndrome in adolescents. Abdominal obesity was determined by waist circumference. To address ethnic and regional factors in the diagnostic criteria, abdominal obesity was defined by the Asia-Pacific criteria for waist circumference (APC-WC) (Laaksonen *et al*., 2002).The study used the recent International Diabetes Federation (IDF) metabolic syndrome definition (Lamonte *et al*., 2005), which includes criteria established by the NCEP, IDAI, and Yoshinaga. Participants were considered to have metabolic syndrome if three or more of the following five criteria were met: 1) high blood pressure (≥95th percentiles for boys and girl by height); 2) hyperglycemia (fasting plasma glucose ≥ 100 mg/dL); 3) hypertriglyceridemia (≥110 mg/dL); 4) low HDL cholesterol (<40 mg/dL); and 5) abdominal obesity (waist circumference ≥90thpercentiles for boys and girls by age).

Assessment of CRF

All participants underwent the Multistage Fitness Test (MFT) to determine their CRF values. This test involves continuous running between two lines 20m apart in time to recorded beeps. For this reason, the test is also often called the 'beep' or 'bleep' test. The participants stand behind one of the lines facing the second line and begin running when instructed by the recording. The speed at the start is quite slow. The subject continues running between the two lines, turning when signaled by the recorded beeps. After about one minute, a sound indicates an increase in speed, and the beeps will be closer together. This continues each minute (level). If the line is reached before the beep sounds, the subject must wait until the beep sounds before continuing. If the line is not reached before the beep sounds, the subject is given a warning and must continue to run to the line, then turn and try to catch up with the pace within two more 'beeps'. The test is stopped if the subject fails to reach the line (within 2 meters) for two consecutive ends after a warning.

The subject's score is the level and a number of shuttles (20 m) reached before they were unable to keep up with the recording. Record the last level completed (not necessarily the level stopped at). This norms table below is based on personal experience and gives you a very rough idea of what level score would be expected for adolescents, using the standard Australian beep test version. For analysis purposes, the participant's data were categorized into one of two groups according to CRF, fit and unfit.

Statistics

This research is a descriptive study with the observational analytic approach. The adolescent's sample of this study calculated body mass index by measurement of height and weight, measurement of cardiorespiratory fitness level (VO2max) with Multistage Fitness Test (MFT), and risk of metabolic syndrome through measurement of abdominal circumference, blood pressure, triglycerides, HDL-cholesterol, and blood fasting glucose. To determine the association of metabolic syndrome prevalence with CRF and BMI, logistic regression analyses were performed after adjusting for age. Metabolic syndrome was assigned as a dependent variable, CRF and BMI were assigned as independent variables. A two-sided analysis with $p<0.05$ was considered statistically significant. All data are presented as mean±standard deviation (SD) and percentages. All statistical analyses were conducted using SPSS version 22.0 for Windows.

Results

The sample of the study was 44 adolescents (22 male and 22 female), the measurement data can be seen in table 1. The subject of 44 samples obtained the result of normal BMI 38.6%, 36.4% overweight, and 25.0% obese. Unfit conditions were found in 54.5% of subjects and fit conditions were found in 45.5% of subjects. From the classification of metabolic syndrome, 36.4% did not suffer from metabolic syndrome, 36.4% had the risk of metabolic syndrome, and 27.3% had metabolic syndrome (table 2).

Table 1. *Measurement data*

Measurement data	Mean ± SD	Unit
Age	16,18 ± 0,45	years
Weight	68,42 ± 18,46	kg
Height	1,61 ± 0,08	m
Body mass index	26,27 ± 6,25	Kg/m^2
VO2max	29,77 ± 6,76	mL/kg/minutes
systole	131,34 ± 16,99	mmHg
diastole	83,82 ± 11,15	mmHg
Waist circumference	81,95 ± 15,02	cm
Triglyceride	103,43 ± 46,88	mg/dL
HDL	57,45 ± 8,51	mg/dL
BFG	82,52 ± 4,88	mg/dL

Table 2. *Subject characteristic and data distribution*

Sample characteristic	n (%)
Gender	
Boy	22 (50)
Girl	22 (50)
Body mass index	
Normal	17 (38,63)
Overweight	16 (36,36)
Obese	11 (25)
Cardiorespiratory fitness	
Fit	20 (45,5)
Unfit	24 (54,5)
Metabolic syndrome	
No	16 (36,4)
Risk	16 (36,4)
Yes	12 (27,3)

Samples are categorized as an adolescent with metabolic syndrome if there are at least 3 criteria met, as the risk of metabolic syndrome if 1 or 2 criteria are met, and as not suffering from metabolic syndrome if none of the criteria are met. From the criteria results, the sample can be categorized as follows (Table 3).

Table 3. *Categorical data according to the criteria of metabolic syndrome*

BMI	Fitness	Metabolic syndrome = n (%)		
		No	Risk	Yes
Normal	Fit	13 (29,5)	2 (4,5)	
	Unfit	2 (4,5)		
Overweight	Fit		3 (6,8)	1 (2,2)
	Unfit	1 (2,2)	7 (15,9)	4 (9,1)
Obese	Fit		1 (2,2)	
	Unfit		3 (6,8)	7 (15,9)

The results of the simultaneous test showed that both body mass index and cardiorespiratory fitness had a significant effect on the risk of metabolic syndrome (p = 0.000). Through the partial test, the correlation of body mass index to metabolic syndrome had a significant effect (p = 0.000), but the correlation of cardiorespiratory fitness to metabolic syndrome was not significant (p = 0.451), the result can be seen in table 4. The higher BMI tended to have metabolic syndrome 1.746 times higher than not having metabolic syndrome. In poor condition of cardiorespiratory fitness, the propensity to have metabolic syndrome is 4.283 timeshigher than the one that has good cardiorespiratory fitness. Both high body mass index and inadequate cardiorespiratory conditions had a higher influence on the prevalence of metabolic syndrome. This logistic regression model was quite good because it could predict correctly 72.7% of the conditions that occur (Table 5).

Table 4. *Simultaneous and partial test*

Effect	Model Fitting Criteria	Likelihood Ratio Tests		
	-2 Log Likelihood of Reduced Model	Chi-Square	df	Sig.
Simultaneous	60.971	34.955	4	0.000
BMI	78.789	17.819	2	0.000
CRF	62.563	1.593	2	0.451

Table 5. *Prediction test*

Observed	Predicted			
	No MS	Risk MS	Yes MS	Percent Correct
No MS	14	2	0	87.5%
Risk MS	2	11	3	68.8%
Yes MS	0	5	7	58.3%
Overall Percentage	36.4%	40.9%	22.7%	72.7%

Discussion

Reductions in physical activity and CRF are associated with increased prevalence and incidence of metabolic syndrome. In our study, we found that a lower level of CRF was associated with increased prevalence of metabolic syndrome in an adolescent. A low level of CRF is a known risk factor for both cardiovascular disease and type 2 diabetes (Vaughan *et al.,* 2009). A prior study has validated the Multistage Fitness Test (MFT) as an appropriate measurement to indicate cardiorespiratory fitness (Laaksonen *et al.,*2002). In comparison to the other more elaborate and expensive test approaches previously used to obtain VO2 max, the Multistage Fitness Test (MFT), used in the present study, is a relatively quick and easy method that can be used in most epidemiological and clinical settings (Lamonte *et al.,*2005). Findings from the current study also indicate that the association between CRF and the prevalence of metabolic syndrome was somewhat gender dependent, although this relationship was less clear when the combined association of BMI and CRF with metabolic syndrome prevalence was examined (Hsieh *et al.,*2014).

The association between CRF and metabolic syndrome has been reported previously. Laaksonen *et al.,*(2002) reported a significant inverse association between CRF and prevalence of metabolic syndrome even after adjustment for major confounders. In addition, Lamonte *et al.,*(2005) reported that the incidence of metabolic syndrome was significantly reduced among fit individuals compared with the least fit individuals. The current study and previously reported studies suggest that fitter individuals are less likely to develop metabolic syndrome compared with those who are unfit. However, physical fitness is not the only contributor to the development of metabolic syndrome (Neto *et al.,* 2011).

There are other factors independent of CRF that influence the development of metabolic syndrome. In our study, approximately 63,3% of obese individuals had metabolic syndrome. Similarly, several previous studies found that the components of metabolic syndrome were closely associated with obesity (Despres and Lemieux, 2006). In a prospective cohort study, Katzmarzyk *et al*., (2005) reported that overweight men were 4.5 times (95% CI: 4.2-5.3) more likely to develop metabolic syndrome, and obese men were 30.6 times (95% CI: 26.7-35.0) more likely to develop metabolic syndrome. It is not surprising that more obese individuals have a higher prevalence of metabolic syndrome; one of the five metabolic syndrome components directly reflects the degree of adiposity. In our study, we also confirmed that more obese individuals are more likely to have metabolic syndrome (dos Santos *et al.,* 2015).

The current study has several limitations. First, the level CRF from the MFT might be affected by BMI. The high BMI group could have an increased body mass so they can't run effectively on MFT. Despite this limitation, this MFT test has been frequently used in clinical settings as a representative CRF test (Kim et al, 2014). Second, due to the cross-sectional nature of this study, it was not possible to control some confounding factors as their daily diet and physical activity that may have affected the results. Factors that could have produced confounding influences included the fact that the participants were recruited in this study by using convenience sampling, a relatively small sample size was used, and the limited age range for the group. Due to these biases and limitations, it is difficult to maintain that the findings of the present study accurately represent the Indonesian adolescent population in general.

Conclusion and Suggestion

In conclusion, we found that participants with a high level of CRF have a lower risk of metabolic syndrome. The prevalence of metabolic syndrome increased as the degree of adiposity increased. However, high levels of CRF were associated with lower prevalence of metabolic syndrome among obese individuals. Our findings suggest the importance of physical fitness in the prevention of metabolic syndrome. This study showed that the higher body mass index and inadequate cardiorespiratory fitness conditions can be used as predictors of metabolic syndrome in adolescents.

Conflict ***of Interest***
The authors certify that have NO affiliations and conflict of interest with any organization or entity with any financial interest or nonfinancial interest in the subject matter or materials discussed in this manuscript.

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