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Association between adiposity indicators and cardiorespiratory fitness among rural northeastern Thai adolescents

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ABSTRACT

Introduction: Obesity or high adiposity is known to be associated with various medical consequences, such as diabetes mellitus, hypertension, coronary heart disease and metabolic syndrome. High adiposity and poor cardiorespiratory fitness (CRF) have been found to be related with higher risks of developing cardiovascular disease (CVD). However, previous studies in Asia reported inconsistent findings on the association between obesity or high adiposity, based on various indicators, with impaired CRF. This study investigated the association between adiposity indicators and CRF in terms of maximal oxygen uptake (VO_2 max) in adolescents from rural northeastern Thailand. **Methods:** This study was performed among 486 adolescents aged 14-15 years old in Khon Kaen province, Thailand. Adiposity indicators included body mass index-for-age *z*-scores (BAZ), waist circumference (WC), waist-to-hip ratio (WHR), waist-to-height ratio (WHtR) and percent body fat (%BF) based on deuterium dilution technique. **Results:** Male adolescents had higher WHR and VO_2 max than female adolescents, while female adolescents had higher %BF and WHtR. Adolescents who had higher adiposity tended to have lower VO_2 max, especially among females in which the lowest VO_2 max was found in the highest quintile of adiposity indicators, including BAZ, WC, WHtR and %BF. **Conclusion:** Adolescents with higher adiposity tended to have poorer CRF. Based on previous knowledge that both high adiposity and poor CRF may lead to higher risks of developing CVD, this suggests that obese adolescents should be considered and managed at an early age in order to maintain optimal CRF.

Keywords: Adiposity, cardiorespiratory fitness, adolescent

INTRODOCTION

Unhealthy eating habits, physical inactivity and sedentary lifestyle are regarded as important contributors to an increase in obesity prevalence. Obesity is known to be associated with various medical consequences, such as diabetes mellitus, hypertension, coronary heart disease and metabolic syndrome (Holvoet *et al.*, 2004). Currently, the prevalence of cardiovascular disease (CVD) is increasing and it is the leading cause of mortality and morbidity worldwide. Cardiorespiratory fitness (CRF) and body composition have been found to be related with the risk of CVD, even among children and adolescents (Eisenmann *et*

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al., 2007; Jago *et al.*, 2010). Eisenmann *et al.* (2007) studied the relationship between CRF and fatness with CVD risk score among children and found that both high fatness or high adiposity and low fitness were related with higher CVD risk scores. Similarly, another study reported that both high fatness and low fitness increased cardiometabolic risk factors among children (Jago *et al.*, 2010). Moreover, the relationship between high adiposity and low CRF has been reported in children and adolescents (Jambarsang, Dana & Farzanegi, 2014; Watanabe, Nakadomo & Maeda, 1994; Burns *et al.*, 2013). In Western countries, percent body fat (%BF) was reported to be negatively associated with CRF (Burns *et al.*, 2013; Ramirez-Velez *et al.*, 2017). A study in the Middle Eastern country also reported similar findings - a negative association between body mass index (BMI) and CRF, although BF was not assessed in this study (Jambarsang *et al.*, 2014). However, findings were not consistently significant when BMI was used as an adiposity indicator (Burns *et al.*, 2013; Ramirez-Velez *et al.*, 2017; Mota *et al.*, 2006). Inconsistent findings were also reported among Asian countries. Several studies reported a negative association between adiposity and CRF among children and adolescents based on either anthropometric or BF indicators (Watanabe *et al.*, 1994; Gonzalea-Suarez *et al.*, 2013; Kim *et al.*, 2016).

Inconsistent findings might be due to the variations in adiposity indicators used among the studies. Adiposity indicators namely BMI, %BF, waist circumference (WC) and hip circumference (HC), are accepted globally as indicators of nutritional status in children and adolescents (Chatterjee, Chatterjee & Bandyopadhyay, 2006). It is known that at a certain BMI, %BF varies depending on age, sex and ethnic groups (WHO Expert Consultation, 2004). Among the various anthropometric adiposity indicators, waist-to-hip-ratio (WHR), a marker of central adiposity, was found to be the best adiposity risk indicator for acute myocardial infarction in most populations worldwide (Yusuf *et al.*, 2005). Waist-to-height-ratio (WHtR), which is another central adiposity indicator, has the advantage of not requiring an age and sex-specific reference table, contrary to WC (Burns *et al.*, 2013). High WHtR has been shown to be related with a higher risk of CVD (Mokha, Srinivasan & DasMahapatra, 2010; Hara *et al.*, 2002).

The evidences above indicate that high adiposity and poor CRF are related with the risk of developing CVD, as high adiposity is related with poor fitness. Since abnormal CVD risks in children or adolescents with high adiposity may not be shown, evidence of a relationship between adiposity and CRF should be ascertained in these groups. The strength of evidence on the negative relationship between adiposity and CRF may help to advocate people in managing or preventing adiposity early in life in order to lessen the risks of CVD later. Although there is a well-known association between body composition and CRF in children and adults (Jambarsang *et al.*, 2014; Watanabe *et al.*, 1994; Burns *et al.*, 2013), studies conducted in the Asian adolescent population are limited and those with the use of various indicators have reported inconsistent findings. Since different adiposity indicators may reflect adiposity differently depending on age, sex and ethnic groups, studies that could strengthen the evidence of a relationship between adiposity and CRF in Asian adolescents are needed.

Hence, this study was designed to evaluate adiposity based on BMI-for-age z-scores (BAZ), WC, WHR, WHtR and %BF, with CRF in terms of maximal oxygen uptake (VO_2 max) among rural Thai adolescents. Correlations between adiposity indicators and VO_2 max were assessed. We hypothesised that negative relationships between adiposity indicators and CRF would be shown in the adolescent population.

MATERIALS AND METHODS

Study population

The study was performed among adolescents who previously participated in a randomised controlled trial for iron and/or zinc supplementation during infancy from 1998 to 1999, in Khon Kaen province, northeastern region of Thailand (Wasantwisut *et al*., 2006). 486 adolescents (257 males and 229 females), aged between 14-15 years old voluntarily participated in this study. These adolescents did not have any health conditions, including respiratory tract diseases, physical disabilities, mental problems, or other diseases that affected the assessment of CRF. The required sample size was estimated based on the correlation coefficients (r) of the relationships between %BF and WHtR with CRF (r=0.261 and r=0.241, respectively) from a previous study (Burns *et al*., 2013). Sample size estimates of 185 and 218 adolescents were considered as adequate to detect the relationship of interest with a 95.0% power and 0.05 significance level. All procedures were approved by the Mahidol University Central Institutional Review Board (COA. No.2013/008.1501). Written informed consent and assent were obtained from the parents and adolescents prior to the study. The study was registered at ClinicalTrials.gov (NCT01979770).

Anthropometric assessment

Body weight was measured to the nearest 0.1kg with a calibrated digital scale (Tanita, BC-541), while height was measured to the nearest 0.1cm with a stadiometer. BMI (kg/m^2) was calculated as weight in kilogramme (kg) divided by height in metres squared (m^2). BAZ was calculated and classified based on the 2007 World Health Organization (WHO) growth reference for school-aged children and adolescents (De Onis *et al*., 2007). All adolescents were in light clothing and without shoes while taking these measurements. WC was taken at the midway between the lowest rib and the iliac crest (Callaway *et al*., 1988). HC was measured at the widest part of the buttock. All the data were taken in triplicates and the average measurement was used in data analysis. WHR was obtained by dividing WC with HC and WHtR was obtained by dividing WC with height.

Body fat (BF) assessment

BF was estimated from total body water (TBW) assessed by the deuterium dilution technique. A baseline urine sample was collected and the deuterated water containing approximately 0.05g/kg body weight of 99.0 atom % deuterium oxide was administered orally. Three post-dose samples were collected at 3-, 4- and 5-hour after the initial dose was given. All urine samples were analysed for deuterium enrichment using the Isotope Ratio Mass Spectrometry (Sercon Limited, Cheshire, United Kingdom). TBW content was derived using the plateau approach (IAEA, 2009). Fat-free mass (FFM) was calculated from TBW using the Lohman's age appropriate hydration constants. BF (kg) was obtained by subtracting FFM from total body weight and was presented as %BF.

Maximal oxygen uptake (VO_2 max) assessment

VO_2 max is considered to be the gold standard in determining CRF (Wilmore & Costill, 2005; Chatterjee, Chatterjee & Bandyopadhyay, 2005). Nevertheless, the use of direct methods to measure VO_2 max is limited because of its exhausting and impractical protocols, and requirement of a well-equipped laboratory. However, an earlier study had established the use of Queen's college step test to predict VO_2 max indirectly (Chatterjee, Chatterjee & Bandyopadhyay, 2004).

The Queen's college step test is a physical fitness test that was conducted to measure CRF (McArdle *et al.*, 1972). The step test performed by the individuals involved step up and step down on a bench with a standardised step height of 16.25 inches (41.25cm). The rates (cadence) at 24 steps per minute for males and 22 steps for females were set by a metronome. The test began after a brief demonstration and practice period. Adolescents were instructed to perform the steps using a four-step cadence, "up-up-down-down" continuously for 3 min. They had to maintain their determined stepping rhythm during the test and stop immediately on completion of the test. After that, they were required to remain standing and a heart rate monitor was used (Polar FT4, Kempele, Finland) to measure their heart rates at the 20th second post-test. VO_2 max was calculated using the McArdle's equations (McArdle *et al.*, 1972):

Male: VO_2 max (mL/kg/min) =
111.30 – 0.42 x heart rate (bpm)

Female: VO_2 max (mL/kg/min) =
65.81 – 0.1847 x heart rate (bpm)

Those who were fit would have a higher VO_2 max and would be able to perform exercises with higher intensity for a longer period of time than unfit subjects.

Statistical analysis

Data were checked for normality and descriptive statistics were presented accordingly. Comparisons between male and female adolescents were performed using the independent sample *t*-test or Mann-Whitney U test. Spearman's correlation was used to determine the correlation between VO_2 max and adiposity indicators. Adiposity indicators including BAZ, WC, WHR, WHtR and %BF were categorised into quintiles. One-way analysis of variance (ANOVA) was used to test the differences of VO_2 max among quintiles of adiposity indicators and for linear trends across quintiles. All statistical analyses were performed using SPSS for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). A *p*-value of <0.05 was considered statistically significant.

RESULTS

Characteristics of participating adolescents are presented in Table 1. Male adolescents have higher WHR and VO_2 max than female adolescents (0.78 vs. 0.76 and 49.6mL/kg/min vs. 35.2mL/kg/min, respectively). BMI, HC, WHtR and %BF were higher in females than males (19.0kg/m^2 vs. 18.5kg/m^2, 86.3cm vs. 84.0cm and 26.6% vs. 15.8%, respectively), while BAZ and WC were not significantly different in both genders.

Table 2 shows the correlation between VO_2 max and adiposity indicators (BAZ, WC, WHR, WHtR and %BF). VO_2 max had a significant, negative correlation with %BF in both male and female adolescents (r=-0.17, p=0.009 and r=-0.38, p=0.000, respectively). In female adolescents, VO_2 max was also significantly negatively correlated with BAZ, WC, WHR and WHtR (r=-0.24, p=0.000, r=-0.24, p=0.000, r=-0.14, p=0.040 and r=-0.23, p=0.000, respectively). For illustrative purposes, the negative relationships between %BF and VO_2 max among males and females are shown in Figure 1.

Mean VO_2 max by quintiles of adiposity indicators in males and females are presented in Table 3. Among males, there were no differences in VO_2 max by

Table 1. Descriptive characteristics of study participants

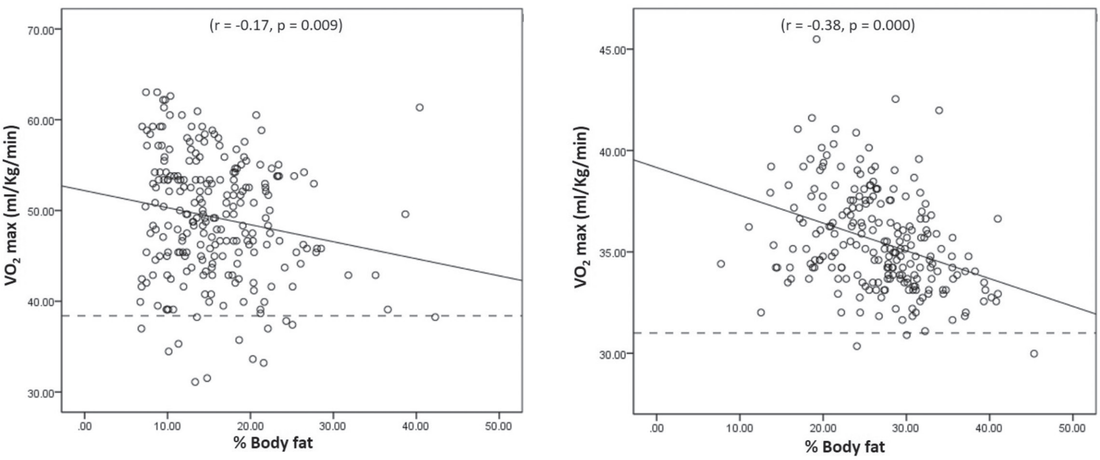
Characteristics	*n (%)*		*Mean±SD*		*Median (P25, P75)*		*p value*
	Male (n=257)	*Female (n=229)*	*Male (n=257)*	*Female (n=229)*	*Male (n=257)*	*Female (n=229)*	
Age (years)			14.8±0.3	14.7±0.3			0.114
Height (cm)			164.5±6.8	155.3±5.4			0.000
Weight (kg)					50.2 (45.4, 56.5)	46.2 (41.9, 50.8)	0.000
BMI (kg/m^2)					18.5 (17.1, 20.2)	19.0 (17.4, 20.8)	0.038
BAZ					-0.47 (-1.20, 0.19)	-0.39 (-1.08, 0.25)	0.223
Nutritional status							
Thinness (BAZ<-2SD)	20 (7.8)	14 (6.1)					
Normal (-2SD≤BAZ≤1SD)	214 (83.3)	194 (84.7)					
Overweight (1SD<BAZ≤2SD)	15 (5.8)	16 (7.0)					
Obesity (BAZ>2SD)	8 (3.1)	5 (2.2)					
WC (cm)					65.4 (62.7, 69.3)	65.2 (62.7, 68.9)	0.516
HC (cm)					84.0 (80.6, 88.4)	86.3 (83.3, 89.6)	0.000
WHR					0.78 (0.76, 0.81)	0.76 (0.74, 0.79)	0.000
WHtR					0.40 (0.38, 0.42)	0.42 (0.40, 0.45)	0.000
%BF			15.8±6.3 (n=234)	26.6±6.3 (n=222)			0.000
VO_2 max (mL/kg/min)					49.6 (45.0, 54.2)	35.2 (33.7, 37.2)	0.000

BMI: body mass index; BAZ: BMI-for-age Z scores; WC: waist circumference; HC: hip circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat; VO_2 max: maximal oxygen uptake; SD: standard deviation

Table 2. Correlation coefficients (*r*) between VO_2 max (mL/kg/min) and adiposity indicators

Adiposity indicator	*r*	*p-value*	*n*
Male			
BAZ	-0.07	0.274	257
WC (cm)	-0.02	0.760	257
WHR	0.01	0.851	257
WHtR	-0.04	0.499	257
%BF	-0.17	0.009	234
Female			
BAZ	-0.24	0.000	229
WC (cm)	-0.24	0.000	229
WHR	-0.14	0.040	229
WHtR	-0.23	0.000	229
%BF	-0.38	0.000	222

BAZ: BMI-for-age z-scores; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat



(A) Male (B) Female

Figure 1. Negative relationship between %BF and VO_2 max (mL/kg/min) in male (A) and female (B) adolescents

quintiles of BAZ, WC, WHR and WHtR. However, there was a significant trend of decreasing VO_2 max with increasing %BF quintiles (*p* for trend <0.05). Among females, VO_2 max significantly declined with increasing quintiles of BAZ, WC, WHtR and %BF (*p* for trend <0.05). However, this relationship did not show significance for the quintiles of WHR.

DISCUSSION

Overall, this study showed that adolescents who had higher adiposity indicators tended to have lower CRF, especially among females. However, this relationship was not consistent among all adiposity indicators in male adolescents. Nonetheless, male

Table 3. VO_2 max (mL/kg/min)† by quintiles of adiposity indicators

Adiposity indicator	*Mean±SD*					*p-trend*
	Q1	*Q2*	*Q3*	*Q4*	*Q5*	
Male						
VO_2 max by BAZ quintiles	49.4±6.1	49.6±7.6	49.7±7.5	50.9±5.6	47.5±6.4	0.421
VO_2 max by WC quintiles	48.9±5.4	49.4±8.0	49.9±7.2	50.7±5.9	48.1±6.7	0.950
VO_2 max by WHR quintiles	50.2±7.1	47.4±6.7	49.5±6.5	50.8±6.6	49.1±6.4	0.681
VO_2 max by WHtR quintiles	50.3±6.7	48.6±7.7	48.7±6.3	51.0±5.9	48.5±6.7	0.691
VO_2 max by %BF quintiles	51.2±7.5	49.5±7.0	49.4±6.4	48.8±5.6	47.2±6.8	0.006
Female						
VO_2 max by BAZ quintiles	36.1±2.5	36.0±2.8	35.8±3.0	35.8±2.1	34.2±2.1	0.001
VO_2 max by WC quintiles	35.9±2.5	35.9±2.3	36.7±3.3	35.3±2.1	34.2±2.2	0.001
VO_2 max by WHR quintiles	35.5±2.1	36.2±2.9	36.1±3.0	35.5±2.2	34.7±2.5	0.055
VO_2 max by WHtR quintiles	35.8±2.3	36.1±2.9	36.0±2.2	35.9±2.9	34.1±2.1	0.002
VO_2 max by %BF quintiles	36.7±2.7	36.2±2.5	35.6±2.1	34.8±2.3	34.3±2.1	0.000

VO_2 max: maximal oxygen uptake; BAZ: BMI-for-age z-scores; WC: waist circumference; WHR: waist-to-hip ratio; WHtR: waist-to-height ratio; %BF: percent body fat; SD: standard deviation

adolescents who had higher %BF tended to have lower CRF. Our findings were not entirely in agreement with previous studies conducted in Asia (Watanabe *et al.*, 1994; Gonzalez-Suarez *et al.*, 2013; Kim *et al.*, 2016). Similar negative associations of adiposity and CRF in both males and females were reported earlier in a study among Japanese children and adolescents, when adiposity was assessed as %BF and CRF was assessed as VO_2 max (Watanabe *et al.*, 1994). However, the sample size in that study was quite small (*N*=37) and it might be due to the limitation of the underwater weighing technique used for body composition assessment. In comparison with a study in the Philippines (Gonzalez-Suarez *et al.*, 2013), our study population was older and had lower proportion of overweight and obesity. Hence, this may explain the discrepancy between our findings and that of theirs. We reported significantly negative associations of BAZ, WC, WHR and WHtR with CRF only in female adolescents, while they reported significantly negative associations between BMI and WC with CRF in both sexes. A study by Kim *et al.* (2016) in South Korea included both boys and girls aged 9-10 years old, as well as boys of older age (12-13 years old) only. As the proportion of overweight and obesity was quite high compared to our study (28.0% vs. 8.9%), this might explain the significant, negative associations between anthropometric adiposity indicators with CRF reported in their study, while there were no such significant associations among males in our study.

A study conducted among US children also found that BMI, WC and WHtR were not associated with CRF, while %BF was significantly associated with CRF (Burns *et al.*, 2013). BF might be more appropriate to reflect adiposity among male adolescents compared with adiposity indicators developed from anthropometric measures such as BMI, WC, WHR or WHtR. A longitudinal study among healthy Caucasian children indicated the differences in the contribution of BF and FFM to BMI increase in male and female adolescents when they reached 13 years old of age (Maynard *et al.*, 2001; Kirchengast, 2010). Although BMI increased in both sexes as age increased, however, the major contribution to BMI increase was total BF among females, while FFM among males. This may imply that high BMI or high levels of other anthropometric adiposity indicators may not be related with high BF in male adolescents, thus consequently resulting in no associations between anthropometric adiposity indicators and CRF.

The strengths of this study were that we used multiple indicators of adiposity. In this study, BF was assessed using the deuterium dilution technique. Although many methods exist to measure BF, some methods may be expensive, expertise and appropriate equation-required, or not field applicable (IAEA, 2009). The deuterium dilution technique is an accurate and suitable method for population-based studies. The use of BF as an adiposity indicator provided more reliable and consistent evidence on the relationship between adiposity and CRF compared with other proxy adiposity indicators developed from anthropometric measures.

We used VO_2 max to reflect CRF. CRF can be assessed by various ergometer exercise techniques such as walking on treadmill, cycling, swimming and bench stepping. In this study, CRF was estimated using the Queen's college step test because it is one of the common physical fitness tests feasible for field application. This technique is usually performed at a fixed rhythm on a bench having a fixed height (McArdle *et al.*, 1972). A previous study suggested that local muscular fatigue may occur before a true assessment of aerobic capacity if a step is too high. Consequently, the test may be more of a measurement of muscular endurance of the legs than of aerobic capacity (Shamsi *et al.*, 2011). Thus, the height of the step bench should be adjusted to the participant's stature and this may decrease the inter-individual variability in oxygen cost and heart rate during a task and, as such, may produce a valid prediction of VO_2 max (Shamsi *et al.*, 2011; Shahnawaz, 1978). However, a study that assessed aerobic capacity based on a fixed height and adjusted height of the bench (90° knee joint angle) confirmed no significant difference in the aerobic capacity between these two levels of bench height (Ashley, Smith & Reneau, 1997).

In addition to the height of the bench, accuracy of the heart rate should be considered when measuring VO_2 max. Pulse rate counting might lead to an underestimation of post-exercise heart rate (John, Sforzo & Swenson, 2007). Hence, we used an automatic heart rate monitor, which administration was simple and accurate.

This study had some limitations in which only young adolescents with a narrow age range (14-15 years old) were included and the prevalence of obesity was rather low (male=3.1% and female=2.2%) among the study population. These limitations may restrict the generalisation of the findings.

CONCLUSION

Adolescents with higher adiposity tended to have lower CRF in this study. Especially among female adolescents, the highest quintile of adiposity indicators, e.g. %BF and BAZ resulted in the lowest VO_2 max. This may suggest that adolescents who have higher %BF have lesser physical fitness and therefore, cannot perform well in physical activities, especially in a CRF task. In order to maintain optimal CRF, which may consequently lessen the risk of CVD, obesity in individuals should be considered and managed at an early age. Future research is needed to develop suggested cut-off points for adiposity indicators that may contribute to low levels of VO_2 max and to assess the extent to which high adiposity and low level of VO_2 max during adolescence contribute to the higher risks of developing CVD later in life.

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Authors' contributions

WS, designed the study, collected data, contributed to statistical analysis, drafted the manuscript; TP, designed the study, collected data, drafted the manuscript; KJ, designed and supervised total body water sample analysis; PW, designed the study, critically revised the manuscript; SG, collected data, contributed to statistical analysis, drafted the manuscript; WW, contributed to statistical analysis; all authors read and gave final approval of the manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

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