Scale of VO_{2peak} in Obese and Non-obese adolescents by different Methods

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Abstract

Background: Peak oxygen uptake (VO_{2peak}) can be defined as the highest oxygen rate consumed during exhaustive or maximal exercise. The evaluation of the aerobic fitness can be expressed as relative to body mass, but this procedure may not fully remove differences when heavy subjects are assessed. Thus, the allometric scaling procedure is an attractive strategy to compare individuals with large differences in body mass.

Objective: Investigate VO_{2peak} in obese and non-obese individuals using body mass correction (conventional) and allometric scaling (allometric) methods and how these methods apply when subjects of different genders exercise on a treadmill.

Methods: VO_{2peak} relative to body weight and measured by the allometric method were compared in 54 obese and 33 non-obese adolescents (10 to 16 years). Indirect calorimetry was used to assess VO_{2peak} during a maximal test. The allometric exponent was calculated taking into account individual body mass. Then, VO_{2peak} was corrected by the allometric exponent. The comparisons were performed using a repeated measures two-way ANOVA ($p<0.05$).

Results: The absolute VO_{2peak} was higher ($p<0.05$) in the obese girls (2.80±0.69) compared to non-obese ones (2.00±0.24), but this association was not observed for the male subjects ($p>0.05$). However, VO_{2peak} calculated by the conventional method was higher ($p<0.05$) among non-obese individuals in both genders (girls: 41.45±3.85; boys: 49.81±7.12) in comparison to the obese subjects (girls: 32.11±4.48; boys: 37.54±6.06). The allometric VO_{2peak} was similar ($p>0.05$) between the groups.

Conclusion: The obese showed lower VO_{2peak} values than non-obese individuals when assessed by the conventional method. However, when the allometric scaling method was applied, differences disappeared. (Arq Bras Cardiol 2009; 93(6):554-557)

Key Words: Obesity; child; adolescent; exercise; physical fitness.

Introduction

The prevalence of obesity in children and adolescents has increased in last years[1]. The absence of physical exercise[2,3] and the increase in calorie intake[4] have been associated with obesity in childhood. These modifications have resulted in inadequate habits, reduction in calorie expenditure and lower level of cardiorespiratory fitness[3].

Many researchers have considered peak oxygen uptake (VO_{2peak}) as one of the best indicators of cardiorespiratory fitness and level of physical aptitude[5,6]. The VO_{2peak} values relative to body weight are expressed by $ml.kg^{-1}.min^{-1}$ and are generally lower in obese than in non-obese individuals[7-10]. On the other hand, the absolute VO_{2peak} values in obese individuals (i.e., with larger body surfaces), have been reported to be similar in some studies[9-10] and higher than in the non-obese individuals in others[4-7].

The aerobic fitness assessment is typically expressed as relative to body mass and has been called into question by some researchers[11-13]. The adjustment of the values by body weight may not be effective to remove body mass differences in very heavy subjects[9]. Thus, some authors have applied the allometric scaling method to compare individuals with large body masse variations[9,14] in an attempt to minimize such influences. The allometric scaling method appears to be a good indicator to compare individuals with differences in body weight and height.

Thus, some researchers have used the allometric scale method to associate and compare the VO_{2peak} between individuals with different body sizes, or children and adults[13], boys and girls[14]. To date, only one study was found in the literature[9], in which VO_{2peak} was assessed in obese and non-obese individuals by both methods (body weight and allometric scaling). Unfortunately, that study assessed only girls and reinforces the need for data that assesses the influence

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Manuscript received September 25, 2008; revised manuscript received March 02, 2009; accepted May 14, 2009.

of body weight over cardiorespiratory parameters, using the conventional ($VO_{2peak-conv}$) and allometric ($VO_{2peak-allo}$) methods, in obese and non-obese teenagers. In addition, the effect of gender when using these methods has not been described.

The aim of this study was to compare the VO_{2peak} values obtained on treadmill using conventional (body weight correction) and allometric scaling (allometric correction) methods in obese and non-obese male and female teenagers.

Methods

Subjects

Eighty-four volunteers of both genders and aged 10 to 16 years participated in the study. They were divided in two groups according to their body mass index (BMI) as proposed by the Center for Disease Control and Prevention (CDC)[15]: Thus, a group was formed by obese (Obese group; n=54; 23 males and 31 females) and the other by non-obese individuals (Non-Obese group; n= 33; 16 males and 31 females). Participants and parents (or caregivers) signed a consent form authorizing their participation in the study. The present study procedures were approved by the Ethical Committee of the Federal University of Paraná.

Procedures

1) Anthropometric assessment – Body mass was measured with the help of an anthropometric scale using a resolution of 0.1 kg for body mass and 0.01 m for height assessments. Body mass index was calculated by dividing body mass (in kg) by the square of the height (in m). Subjects were classified according to their body mass index (BMI) as proposed by the Centers for Disease Control and Prevention (CDC)[15].

2) Clinical assessment – The clinical assessment was performed by a professional in the pediatric field to determine cardiovascular disorders and sexual maturation level[16]. All individuals who had any contraindication to the procedures used in the tests were not included in the study, as well as prepubertal individuals[17]. Individuals that participated in regular physical exercise programs were also excluded.

3) Aerobic Fitness (VO_{2peak}) – The aerobic fitness (VO_{2peak}) was determined in a treadmill, using the modified protocol proposed by Balke. Initial speed was set at 3.25 mph and a 6% inclination, which was increased by 2% every 3 min until complete exhaustion was achieved[18].

The aerobic fitness analysis was performed using a direct gas analyzer (Vista XT metabolic system, USA), which provided information on oxygen uptake (VO_2), carbon dioxide production (VCO_2), pulmonary ventilation (LV), and ratio of respiratory exchange (RER = VCO_2/VO_2). These variables were monitored every 15 seconds. Heart rate was monitored using a heart rate monitor (Polar – model A1, São Paulo, SP, Brazil). In order to ensure that a maximum VO2 was attained, at least two of the following criteria were observed: a) exhaustion or inability to maintain the required speed; b) RER >1.0; c) maximum heart rate (HR) >190 bpm. Participants were not allowed to hold the frontal support of the treadmill during the test.

The procedures proposed by Welsman et al[19] were used to calculate the allometric scaling coefficient, after determining $VO_{2\ and}$ body mass. The average data of each group and gender were logarithmically transformed; VO_2 (liters per minute), body mass (kg), and height (me) were used. The following equation was used to calculate the VO_2 with allometric exponents: Log Y = Log a + b Log X[19], with "Y" being the value of the mean VO_{2peak} relative to the body mass ($ml.kg^{-1}.min^{-1}$), "a" the mean value of VO_2 peak in absolute terms ($l.min^{-1}$), "X" the mean body mass (kg), and "b" the allometric exponent.

Statistical analysis

Standard descriptive statistics (mean ± SD) were calculated. The Kolmogorov-Smirnov test was applied and confirmed data normality. A factorial ANOVA was used to determine the influence of gender (male and female), groups (obese and non-obese) and methods (conventional and allometric) on $VO2_{peak}$ determination. The statistical analysis was performed using the software Statistica 6.0 and the significance level was set at $p<0.05$.

Results

Table 1 shows the physical characteristics of the 54 obese (23 boys and 31 girls) and 33 non-obese (16 boys and 17 girls) participants. Age was similar between groups ($p>0.05$; obese vs. non-obese) and genders ($p>0.05$; males and females). All participants were pubertal. Mean body mass and BMI were higher in the obese than in the non-obese group ($p < 0.001$) irrespective of gender, as a consequence of the criteria applied to compose the experimental groups in the present study. The mean height and daily energy expenditure did not differ ($p>0.05$) between genders and groups (Table 1).

The parameters obtained during the maximal cardiorespiratory test on the treadmill showed that the HR_{max} and the RER did not differ between genders ($p>0.05$) and groups ($p>0.05$). The mean duration of the test was longer in the non-obese ($p < 0.05$) than in the obese group.

The $VO_{2peak-abs}$ were higher ($p<0.05$) in the obese than in the non-obese females, but no differences were found between males in the two group ($p>0.05$). No significant differences in $VO_{2peak-abs}$ were observed when gender was considered (Table 2).

The allometric scaling method produced a similar index for obese boys (0.57) and girls (0.59). The non-obese group showed coefficients of 0.78 and 0.73 for females and males, respectively.

Finally, the $VO_{2peak-conv}$ was 22.5% lower in the obese girls in comparison to the non-obese group. The $VO_{2peak-conv}$ of the obese boys was 25.1% lower than their non-obese counterparts. The $VO_{2peak\ -alo}$ was higher in boys than in girls ($p<0.05$).

Discussion

In the present study, $VO_{2peak\ -abs}$ was higher in the obese than in the non-obese girls ($p<0.05$), although the boys

showed no differences (p>0.05). Obese girls showed a $VO_{2peak\ -abs}$ 27% higher than the non-obese ones. The obese individuals were subject to a higher metabolic demand due to their higher body mass during the test, which resulted in a higher absolute VO_{2peak} value. Other studies reported that the $VO_{2peak-abs}$, is directly related to body size. In fact, a number of studies reported greater $VO_{2peak-abs}$ in obese than in non-obese teenagers[6-7,20], while others have found comparable values in both groups[9,10]. Ekelund et al[7], have stated that $VO_{2peak-abs}$ found in obese individuals denotes a preserved functional capacity. Indeed, Fick's equation, which relates the circulating oxygen captured by the tissues, showed an adequate amount of oxygen available to the muscles.

VO_{2peak} was lower in the obese subjects irrespective of gender (p<0.05). When VO_{2peak} was expressed relative to body mass, obese individuals presented lower values than the non-obese ones[6-10,21].

The conventional cardiorespiratory assessment is influenced by body size[14]. In order to minimize the influence of body mass on VO_{2peak}, authors have suggested the use of allometric scaling[9,12,22]. Normalizing the data using allometric scaling has been proposed as an efficient method when large body mass differences are present. It has been advocated that it may produce a more realistic VO_{2peak} value. The allometric scaling exponent decreases oxygen consumption by correcting subject's body mass (i.e., as if they were slimmer). Surprisingly, Loftin et al[9] was the only study that compared obese and non-obese girls[9]. They reported an allometric scaling coefficient of 0.48 and 0.92 for the obese and non-obese groups, respectively. The allometric scaling applied by Loftin et al[9] produced a greater impact in the obese group than that applied in the present study. Therefore, it is not possible to compare our results with those presented by Loftin et al[9]. Probably the obese subjects studied by Loftin et al[9] were heavier than ours.

The allometric scaling was similar when gender was compared in the non-obese group, indicating that gender has a small effect (~ 1.6%).

The differences in the allometric scaling factor between groups (obese and non-obese) indicated that the obese presented an approximately 30% higher oxygen consumption than the non-obese group. Using the allometric scaling factor to calculate the VO_{2peak} produced similar peak oxygen uptake between groups. It is not possible to determine if the allometric scaling factor has underestimated or overestimated VO_{2peak}. The maturation phase and the comparison of subjects with large body mass (i.e., obese *vs.* non-obese), reinforces the arguments in favor of allometric scaling correction. Although it is difficult to point a precise $VO_{2peak,}$ discrepancies were much smaller when the allometric correction was applied in comparison to the conventional method. The results of the present study are in agreement with others[9,13,20,23] who

Table 1 – Mean and standard deviation of the general characteristics of the obese and non-obese groups, males and females.

Variables	Males					Females				
	Non-obese (*n* = 16)		Obese (*n* = 23)		p	Non-obese (*n* = 17)		Obese (*n* = 31)		p
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Age (years)	14.19	1.12	13.25	1.40	p > 0.05	14.43	1.57	13.87	1.43	p > 0.05
BM (kg)	51.93	11.17	79.66	14.85	p<0.001	48.39	5.17	84.85	12.15	p < 0,001
Height (cm)	163.27	11.91	164.44	9.51	p > 0.05	158.56	6.20	161.96	5.58	p > 0,05
BMI (kg/m^2)	19.26	2.02	29.24	3.36	p<0.001	19.22	1.57	32.11	3.87	p < 0.001

Table 2 – Mean and standard deviation of VO_{2peak} in obese and non-obese boys and girls

Variables	Males							Females						
	Non-obese (n = 16)			Obese (n = 23)			p	Non-obese (n = 17)			Obese (n = 31)			p
	Mean	SD	CI	Mean	SD	CI		Mean	SD	CI	Mean	SD	CI	
$VO_{2max-abs}$	2.61	0.72	2,22 - 2,99	2.84	0.96	2,38-3,17	p > 0.05	2.00	0.24	1,87-2,12	2.80	0.69	2,54-3,05	p < 0.001
$VO_{2max-conv}$	49.81	7.12	46,01-53,61	37.54	6.06	34,82–39,79	p<0.001	41.45	3.85	39,46-43,43	32.11	4.48	30,46-33,75	p < 0.001
$VO_{2max-alo}$	68.24	9.76	60,13–70,22	60.56	15.62	54,13-66,75	p > 0.05	56.78	5.27	54,07-59,49	58.21	13.2	53,36-63,05	p > 0,05

have proposed the allometric scaling factor as an attractive strategy to correct VO_{2peak} when large body mass differences are present.

In summary, the VO_{2peak} values obtained by the conventional method were lower in the obese than in the non-obese participants, but when VO_{2peak} was expressed by the allometric scaling method, differences between groups disappeared. Therefore, the use of allometric scaling seems to be a more suitable method to compare VO_{2peak} in obese and non-obese teenagers of both genders.

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