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Ventilatory efficiency and rate of perceived exertion in obese and non-obese children performing standardized exercise

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Summary

Sixty children, in the age span 6–17 years originally divided into two groups, matched by age, sex and height – 30 obese subjects [15 girls/15 boys; body mass index (BMI) = 27·4 ± 4·5 m kg^{-2}; ideal body weight (IBW) range = 122–185%] and 30 controls (BMI = 18·8 ± 2·7 m kg^{-2}) performed incremental treadmill exercise test. Perceived exertion was assessed by means of Category-Ratio Borg scale. The duration of the exercise for the children in the obesity group was significantly shorter than controls (P = 0·010) but obese children have greater absolute values for oxygen uptake (VO_{2peak} ml min^{-1} = 1907 ± 671 versus 1495 ± 562; P = 0·013) and ventilatory variables (V_E, VT), which adjusted for body mass decrease significantly (VO_2/kg ml min^{-1} kg^{-1} = 29·2 ± 3·8 versus 33·6 ± 3·5; P<0·001). Among the various methods for 'normalizing' absolute values of VO_{2peak} for body size, dividing it by body surface area (BSA) yielded the best results (VO_2/BSA ml min^{-1} m^{-2} = 43·5 ± 4·6 versus 44·7 ± 5·6; P = 0·335). The ventilatory efficiency determined either as a slope of V_E versus VCO_2 or as a simple ratio at anaerobic threshold did not differ between obese and non-obese children in the incremental and recovery periods of exercise. There was a negative correlation of V_E/VCO_2 slope with age and anthropometric parameters. Obese children rated perceived exertion significantly higher than controls despite the standard workload (Borg score = 6·2 ± 1·2 versus 5·2 ± 1·1; P = 0·001). In conclusion, the absolute metabolic cost of exercise is higher in the obesity group compared with the control subjects. Both groups have similar ventilatory efficiency but an increased awareness of fatigue that furthermore limits their physical capacity.

Introduction

Several studies demonstrated that physical fitness of obese children is worse than that of their normal counterparts in both sexes (Pongprapai *et al.*, 1994; Dupuis *et al.*, 2000; Goran *et al.*, 2000). It is universally acknowledged that maximal oxygen uptake (VO_{2max}) is significantly higher in the obese subjects but expressed relative to body weight becomes lower (Gutin *et al.*, 1994; Wasserman *et al.*, 1999). Severe obesity is often associated with poor conditioning and often brings to exertional dyspnoea and early fatigue.

According to Dupuis *et al.* (2000) obese children's psychomotor capacities are lower and their psyche is affected by the disease and hence the perception of exercise is exaggerated. This fact has a negative impact on their ability to tolerate physical load and brings increased ratings of perceived exertion (RPE) (Ward & Bar-Or, 1990).

The ventilatory equivalent for CO_2 (V_E/VCO_2) defines ventilatory efficiency because it reflects the matching of ventilation and perfusion in the lung. Ventilatory efficiency can be examined at certain points of exercise, like the anaerobic threshold (AT) or expressed as the slope of the relationship between ventilation (V_E) and carbon dioxide output (VCO_2) throughout the test. Elevated values of this parameter indicate ineffective ventilation and are present in the functional profile in a number of lung and heart diseases (Habedank *et al.*, 1998). In paediatric age group, ventilatory efficiency is analysed only in healthy children (Cooper *et al.*, 1987; Armstrong *et al.*, 1997; Nagano *et al.*, 1998).

Aim

The aim of this paper is to study the ventilatory efficiency and the perception of effort in obese and non-obese children subjected to standardized workload.

Materials and methods

Sixty children in the age span 6–17 years originally divided into two groups took part in the present study: 30 obese subjects [15 boys/15 girls; body mass index (BMI) = 27·4 ± 4·5 kg m^{-2}; BMI range = 20·1–35·9 kg m^{-2}; ideal body weight (IBW) range = 122–185%] and 30 controls (BMI = 18·8 ± 2·7 kg m^{-2}) matched by age, sex and height (Table 1). For stratifying children by their BMI into obese and non-obese, we used the cut-off points published by Cole *et al.* (2000), based on body mass index centiles for subjects aged 2–18 years. The adopted cut-off points for obesity in children in this pooled reference values correspond to BMI = 30 kg m^{-2} in adults. All of the studied children were in good health, without chronic diseases, taking no medications that could have affected exercise performance. The children in the control group were generally physically active, but not engaged in competitive sports. Determination of the level of sexual development was not an objective of this study and therefore was not assessed. Prior to the test procedures written informed consent was obtained from a parent or guardian and the associated risks and benefits were explained. The procedures used in this study were approved by the Institutional Ethics Committee at the University of Medicine – Plovdiv.

All the participants underwent comprehensive pulmonary function assessment – conventional spirometric tests (slow vital capacity and forced vital capacity), maximal inspiratory pressure (PImax), and determination of diffusion capacity by Single Breath method (MasterScreen Diffusion™, Jaeger, Wurzburg, Germany) in a certified laboratory applying European Respiratory Society (ERS) (1993) and American Thoracic Society (ATS) (1995) criteria to ensure quality. All measurements were performed in a seated position with a nose clip.

Table 1 Anthropometric and pulmonary function data in control and obese groups.

Parameters	Controls (n = 30)	Obese children (n = 30)	P-value
Age (year)	11·0 ± 3·1	10·9 ± 3·1	0·836
Height (cm)	150·6 ± 16·9	151·8 ± 16·3	0·781
Weight (kg)	43·9 ± 13·9	65·1 ± 20·9	<0·001
BMI (kg m^{-2})	18·8 ± 2·7	27·4 ± 4·5	<0·001
BSA (m^2)	1·36 ± 0·28	1·67 ± 0·3	<0·001
IBW (%)	100 ± 12	144 ± 17	<0·001
Fat (%)	22·4 ± 6·4	34·7 ± 5·1	<0·001
VC (l)	2·9 ± 1·1	3·1 ± 1·1	0·654
TLC (l)	4·0 ± 1·4	3·8 ± 1·2	0·566
$FEV_{1·0}$ (l)	2·6 ± 0·9	2·7 ± 0·8	0·656
Pimax (cm H_2O)	62·7 ± 19·4	60·0 ± 19·6	0·617
$T_{L,CO}$ (mmol min^{-1} kPa^{-1})	7·4 ± 3·4	7·1 ± 3·1	0·762

BMI – body mass index; BSA – body surface area; IBW – ideal body weight; VC – vital capacity; TLC – total lung capacity; $FEV_{1·0}$ – forced expiratory volume in 1 s. PImax – maximal inspiratory pressure; $T_{L,CO}$ – carbon monoxide diffusion capacity.

Maximal voluntary ventilation (MVV) was predicted from the following equation: FEV_1 (L) × 35 (Orenstein, 1993).

All tests were scheduled for the morning hours in a laboratory compliant with the guidelines of the AHA (Pina *et al.*, 1995). The children were habituated to both the general environment and the actual test procedures. The cardiopulmonary exercise test was performed on a motor driven, electronically controlled treadmill TrackMaster™ (JAS Fitness Systems, Pensacola, FL, USA) with standard predefined workload implemented by our modification of Balke protocol (Marinov *et al.*, 2000) which involved:

(i) Two warm up stages of 1 min each, at 2·7 and 4·0 km h^{-1}, respectively, with zero elevation.

(ii) Nine 1-min increments with constant velocity of 5·4 km h^{-1} starting from 6% elevation and increasing with 2% every minute until exhaustion or elevation of 22%.

Recovery period had standard 3-min duration (2·7 km h^{-1} and zero elevation).

Throughout the test, gas exchange variables were determined with an on-line computerized system $CardiO_2^{TM}$ (Medical Graphics, St. Paul, MN, USA) using standard open circuit techniques. Subjects breathed through a mouthpiece and a pneumotachometer was used for recording of tidal volume (VT; ml min^{-1}, BTPS) and minute ventilation (V_E; l min^{-1}, BTPS). Expired gas samples were analysed for oxygen and carbon dioxide by zirconium oxide and infrared analysers, respectively. Data were averaged every 30 s and used to calculate oxygen uptake (VO_2; ml min^{-1}, STPD), carbon dioxide production (VCO_2; ml min^{-1}, STPD) and respiratory exchange ratio (RER). The system was calibrated before each test with gases of known concentrations. Heart rate was monitored electrocardiographically (Hellige, Freiburg, Germany) and the oxygen saturation was traced with pulseoxymeter Pulseox DP-8 (Minolta, Osaka, Japan).

Anaerobic threshold was determined as the level of VO_2 at which at least one of the following is present: (1) increase in V_E/VO_2 without simultaneous increase in V_E/VCO_2; (2) disappearance of the linear relation between VCO_2 and VO_2 (V-slope method).

Ventilatory equivalents for carbon dioxide (V_E/VCO_2 at AT) and oxygen (V_E/VO_2) were determined in the standard way as well as engaging more sophisticated method of calculating the relationship using slopes of regression equation.

Ventilatory efficiency during exercise was depicted by the slope (a) of the total V_E (in l min^{-1}) versus VCO_2 (in l min^{-1}) values for each individual in the equation $V_E = a\, VCO_2 + b$. The first linear portion of this relationship (from the onset of exercise to AT; $r = 0·96–0·99$ for different cases) was termed slope 1; the second portion – between AT and end point of the exercise – slope 2, and the last portion representing the recovery period (also linear) – slope 3.

At the end of each exercise increment and throughout the recovery period the children were asked to rate the perceived exertion (RPE) using the Borg Category Ratio scale – CR-10 (Borg, 1982) depicting fatigue (dyspnoea) from 'not at all' to 'maximal' by means of 10 grades.

The measurements of skinfold thickness over the triceps and subscapular regions by caliper were added together to give the sum of skinfolds and percentage of body fat was calculated using Slaughter equations (Slaughter *et al.*, 1988). Ideal body weight was determined from weight for a given height according to the standards established by the National Sports Academy of Bulgaria (Slunchev, 1992).

Body surface area (BSA) was calculated using the equation of Gehan & Georges (1970): $BSA\ (m^2) = 0{\cdot}02350 \times Ht^{0{\cdot}42246} \times Wt^{0{\cdot}51456}$ where Ht is height in cm and Wt is weight in kilogram.

All values are expressed as mean ± SD. The results from peak exercise data, lung function measurements and anthropometric variables were assessed using descriptive statistics, independent and paired samples t-test, Kendall's tau-b (for ordered values), correlation, stepwise regression and curve estimation analysis in SPSS for Windows (SPSS Inc., Chicago, IL, USA).

Results

The children's anthropometric characteristics and pulmonary function data are presented in Table 1. There were no significant differences in age, height and sex distribution between the subjects. As expected body mass, BMI, IBW, percentage of fat and BSA were significantly higher in the obese group. No considerable differences were found between the cohorts regarding the vital capacity (VC), total lung capacity (TLC), forced expiratory volume in 1 s (FEV_1), maximal inspiratory pressure (PImax) and diffusion capacity ($T_{L,\ CO}$).

Twenty-three controls and only 13 obese subjects reached the end point of the applied standard treadmill protocol. This difference is statistically significant (Kendall's tau-b = 0·005). Children who reached the end of the exercise protocol had lower perception of exercise intensity compared with the rest that were symptom-limited (Borg score = 5·31 ± 1·26 versus 6·29 ± 1·0; P = 0·001). Twenty-seven children (nine controls and 18 obese) achieved RER >1·10 – established measure for a maximal exercise test. This difference between groups is also statistically significant (Kendall's tau-b = 0·014). The AT was not determined only in two control children. Obese children had significantly lower AT than controls – VO_2/kg at AT ($ml\ min^{-1}\ kg^{-1}$) = 24·1 ± 3·4 versus 28·5 ± 4·7; P<0·001 and their breathing frequency (BF) at this moment was higher – BF (min^{-1}) = 41·2 ± 8·1 versus 36·7 ± 7·9; P = 0·046.

Peak exercise data of the studied groups is shown in Table 2. The peak oxygen uptake (VO_{2peak}) appeared to be significantly higher in the obese group, but when 'normalized' for body mass (VO_2/kg) it was significantly lower than in controls.

Corresponding to these findings there are significant differences between the two groups regarding the exercise ventilatory variables. Minute ventilation (V_E) and exercise VT follow the same pattern as seen in oxygen uptake – higher values in obese children which decline when expressed relative to body mass (V_E/kg and VT/kg).

Table 2 Peak exercise variables in control and obese groups.

Parameters	Controls (*n* = 30)	Obese children (*n* = 30)	*P*-value
VT (ml)	1122 ± 482	1376 ± 607	0·077
VT/kg (ml kg^{-1})	25·1 ± 4·9	20·7 ± 3·5	<0·001
BF (min^{-1})	43·9 ± 10·7	47·4 ± 9·2	0·182
V_E (l min^{-1})	46·2 ± 15·6	62·7 ± 23·7	0·002
V_E/kg (l min^{-1} kg^{-1})	1·07 ± 0·17	0·97 ± 0·18	0·034
V_E/MVV	0·53 ± 0·12	0·67 ± 0·13	<0·001
VO_{2peak} (ml min^{-1})	1495 ± 562	1907 ± 671	0·013
VO_2/kg (ml kg^{-1} min^{-1})	33·6 ± 3·5	29·2 ± 3·8	<0·001
VO_2/FFM (ml kg^{-1} min^{-1})	43·5 ± 4·6	44·7 ± 5·6	0·335
VO_2/BSA (ml min^{-1} m^{-2})	1065 ± 189	1111 ± 204	0·368
VO_2/HR (ml min^{-1} $beat^{-1}$)	8·6 ± 3·8	10·9 ± 4·5	0·040
HR (min^{-1})	178·4 ± 18·7	180·7 ± 26·6	0·703
RER	1·09 ± 0·07	1·15 ± 0·10	0·006
V_E/VO_2	31·9 ± 5·7	33·3 ± 4·7	0·330
V_E/VCO_2 AT	29·3 ± 3·1	28·6 ± 2·5	0·401
Slope 1	26·3 ± 3·7	27·0 ± 2·8	0·403
Slope 3	26·6 ± 4·3	26·3 ± 3·2	0·754
Borg score	5·2 ± 1·1	6·2 ± 1·2	0·001

VT – tidal volume; BF – breathing frequency; V_E – minute ventilation; V_E/MVV – minute ventilation/maximal voluntary ventilation ratio; VO_{2peak} – peak oxygen uptake; FFM – fat-free mass; BSA – body surface area; VO_2/HR – oxygen pulse; RER – respiratory exchange ratio; V_E/VO_2 – ventilatory equivalent for oxygen; V_E/VCO_2 – ventilatory equivalent for carbon dioxide; AT – anaerobic threshold.

Dividing VO_{2peak} by fat-free mass (FFM) instead of body mass removes the difference between groups completely. The 'normalization' of VO_{2peak} by dividing it to BSA also yielded favourable result. The difference between groups with respect to VO_{2peak} was decreased from 27·5 to 15·1% in relative oxygen uptake (VO_2/kg) and finally to 7·7% (P = 0·108, NS) after 'normalizing' with BSA (VO_{2peak}/BSA) (Table 2).

There is not a significant difference in BF. Respiratory exchange ratio at peak exercise is higher in obese children and surpasses the value of 1·0 in the earlier stages of exercise reflecting the greater CO_2 load derived from the premature anaerobic supplementation to energy metabolism. In addition a trend is observed for maintaining higher values for this parameter in the recovery period (peak recovery RER = 1·30 ± 0·07 versus 1·22 ± 0·11; P = 0·004).

There was a significant difference in the ratio V_E/MVV between groups. Because of the higher ventilation used in obese children, the breathing reserve in this group was smaller than in controls.

The differences in ventilatory equivalents for oxygen and carbon dioxide (V_E/VO_2; V_E/VCO_2 AT) in both groups were insignificant. We did not find significant differences between obese and non-obese children with respect to the separate portions of the V_E/VCO_2 slope as well as between slopes 1 and 3. There is a strong correlation (r = 0·804; P<0·001) between slope 1 and V_E/VCO_2 at AT. The values of slope 1 are smaller than those of V_E/VCO_2 at AT ($P<0{\cdot}001$; paired samples t-test) (Table 1).

The distribution of individual data for V_E/VCO_2 slope 1 versus V_E/VCO_2 slope 3 in the two studied groups and corresponding regression line for the total population are shown in Fig. 1.

The slope 1 demonstrates significant negative relationships with height ($r=-0{\cdot}623$; $P<0{\cdot}001$), VT ($r=-0{\cdot}513$; $P<0{\cdot}001$), age ($r=-0{\cdot}499$; $P<0{\cdot}001$), BSA ($r=-0{\cdot}484$; $P<0{\cdot}001$), FFM ($r=-0{\cdot}459$; $P<0{\cdot}001$), and weight ($r=-0{\cdot}375$; $P=0{\cdot}003$), and significant positive correlation with BF ($r=0{\cdot}441$; $P<0{\cdot}001$). Applying stepwise regression analysis to the factors that influence slope 1 for the whole studied population gave the following equation:

$$V_E/VCO_2 \text{ slope } 1 = 39{\cdot}4 - 0{\cdot}106 \times \text{Ht (cm)} + 0{\cdot}07 \times \text{ BF}$$

$$r^2 = 0{\cdot}430;\ \text{SEE} = 2{\cdot}5;\ n = 60$$

where Ht is height, BF is breathing frequency and SEE is standard error of estimate.

The distribution of individual data for slope 1 versus height (cm) in the two studied groups and corresponding regression line for the total population are shown in Fig. 2.

The values of slope 1 were slightly higher in girls but the difference was statistically insignificant ($27{\cdot}5 \pm 3{\cdot}1$ versus $25{\cdot}9 \pm 1{\cdot}4$; $P=0{\cdot}067$).

The duration of the exercise for the children in the obesity group was significantly shorter than controls ($9{\cdot}2 \pm 2{\cdot}1$ versus $10{\cdot}4 \pm 1{\cdot}2$ min; $P=0{\cdot}010$). Obese children rated RPE significantly higher than controls in the course of the applied standard workload – Borg score $=6{\cdot}2 \pm 1{\cdot}2$ versus $5{\cdot}2 \pm 1{\cdot}1$ ($P=0{\cdot}001$); range = 4–8 for obese children versus 3–7 for controls. There were no significant gender differences in perception of exercise of the studied children – see Fig. 3.

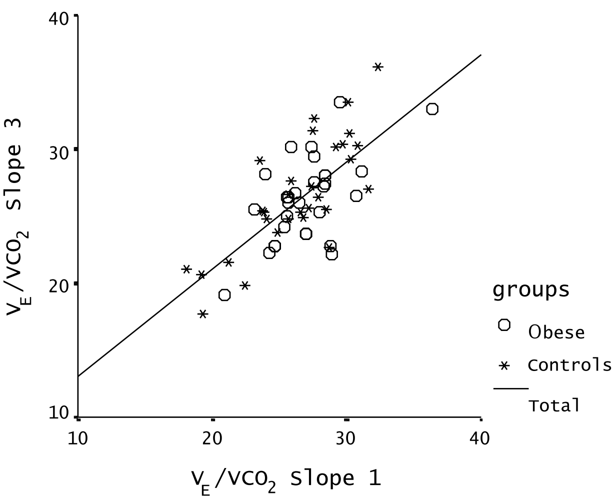

Figure 1 Scatter plot of individual data for V_E/VCO_2 slope 1 versus V_E/VCO_2 slope 3 in the two studied groups and corresponding regression line for the total population.

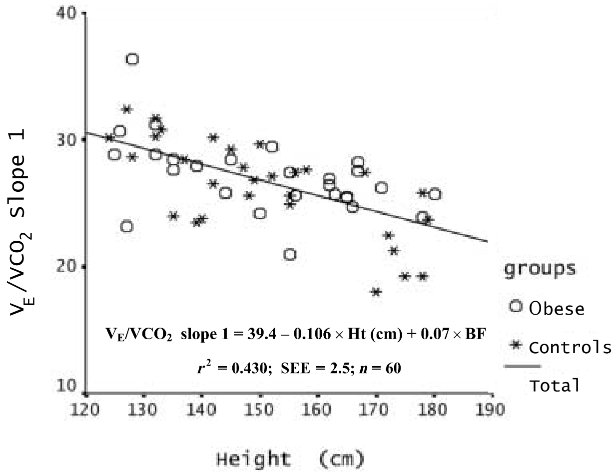

Figure 2 Scatter plot of individual data for slope 1 versus height (cm) in the two studied groups and corresponding regression line for the total population.

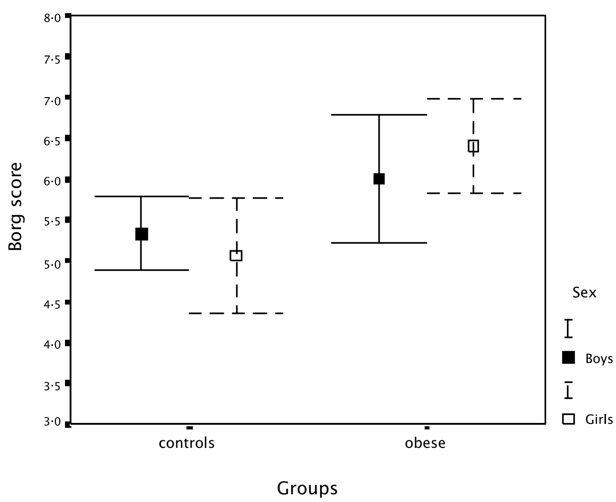

Figure 3 Error bars (95% CI) of Borg scores in obese children and controls divided by sex.

Discussion

This study shows that obese children rate RPE significantly higher than controls when subjected to standardized workload. They have greater absolute values for oxygen uptake and ventilatory variables (V_E, VT). These differences disappeared when the respective parameters were adjusted for body mass. The relatively sophisticated method for calculation of ventilatory equivalents that we applied has some advantages. We think it is better to measure the ventilatory equivalent for CO_2, expressed as slope of the relationship V_E/VCO_2, than as a simple ratio at a certain point of exercise, like AT – V_E/VCO_2 AT. The existing differences can be compared provisionally with the difference between longitudinal and cross-sectional measurements. The exact measurement of ventilatory equivalent is important for complex functional assessment in a broad range of pulmonary and cardiac diseases because the impairment of ventilatory efficiency has been recognized to contribute significantly to hyperpnoea and dyspnoea (Habedank et al., 1998).

We did not find any statistically significant differences in the lung function parameters between the studied groups in contrast to Inselma et al. (1993). This can be explained by the fact that they studied children with extremely high level of obesity – ideal body weight = 147–300 versus 122–185% in our subjects. Spirographic parameters are mainly dependent on the physical growth of the body and the respiratory system (Cotes, 1993). As all of the children had normal physical development, there was no reason for divergence in the main lung function parameters excluding the cases in which excessive obesity leads to extrinsic compression of the chest and impairment of its mechanics. We share the point of Lazarus et al. (1997) that the effect of adiposity on lung function parameters was relatively small in clinical terms.

Applying a standard testing protocol allowed us to make unbiased comparisons between the groups and process the exercise data with greater accuracy. We used a modification of the Balke treadmill protocol (Marinov et al., 2000) because of the disadvantages of the original protocol – greater duration and minimal elevation at start up. In this way an overall timing of 11 min was achieved, e.g. within the 'gold standard' (Washington et al., 1994; Pina et al., 1995). This protocol proved to be an effective tool for diagnosing exercise tolerance in children and in patients with limited physical capacity (Marinov et al., 2000).

In accordance with the results published by Cooper et al. (1987) we also find negative correlation of slope 1 with age, height and body mass, which are interdependent in children. The impact of tidal volume (negative correlation) and breathing frequency (positive correlation) on slope 1 is in agreement with the well-established fact that an increase in either anatomical or physiological dead space can impair the ventilatory efficiency. The effect of non-pulmonary factor on ventilatory efficiency – the decrease in the $PaCO_2$ set point, as a compensatory mechanism, can be seen in metabolic acidosis during heavy exercise. Despite that the portion of the curve beyond RER>1 is non-linear, the magnitude of the slope (controls = 41·0 ± 12·1 versus obese = 40·4 ± 14·5) reveals the tendency in this phase of exercise. The values of this parameter were rather high and can be regarded as a proof of the significant effect that the acidotic drive exerts on ventilation, as well as an indicator of the relative impairment of matching of ventilation and perfusion in the lungs during heavy exercise. We consider extremely interesting the fact that during the recovery phase the values of the index of ventilatory efficiency return to those found in the preceding incremental exercise phase. As the acidotic drive is at its maximum, the can be suggested that the decline of the maximal ergometric receptor stimulation and higher level of perceived exertion enables the respiratory system to restore its physiological efficiency.

A study from Bandini et al. (1990) suggests that obese children have higher total daily energy expenditures because of the excess fat they have to transport when active. Because of the increased metabolic rate to perform a certain amount of external work, i.e. work to move larger body mass, there must be greater than normal cardiorespiratory response to exercise (Wasserman et al., 1999). Fatness and excess body weight do not necessarily imply a reduced ability to consume oxygen, but excess fatness does have a detrimental effect on sub-maximal aerobic capacity (Goran et al., 2000).

It is well known that absolute VO_{2max} is strongly influenced by change in body size. For that reason, the appropriate adjustment of this parameter for body size should help to explain the impact of other factors. The VO_2/kg is most commonly used and the easiest to calculate. The influence of body mass is not completely removed by this method, thus penalizing heavier individuals (Loftin et al., 2001). This is one of the main reasons for lower values of VO_2/kg in obese children. The so-called allometric scaling technique was proposed as a better alternative of the conventionally used ratio method. The scaling exponent of 0·87 for V_E and 0·96 for VO_{2max} relative to mass in our children did not remove the differences in those parameters between obese and non-obese group probably because of the broader age span of the subjects. In that case, Nevil (1997) recommends further covariates as height or age to be incorporated in the allometric model. Although, it is not surprising that 'standardizing' VO_{2max} by dividing it with BSA (it includes both weight and height in formula) removes differences between obese and non-obese groups.

It is acknowledged that utilizing of FFM in a normalization procedure has the same disadvantage as the conventional ratio method – the approach does not take into account the non-zero intercept (Toth et al., 1993). In contrast to this data dividing VO_{2max} by FFM in our children, removes completely the difference between groups.

The earlier and at the same time greater anaerobic supplementation in the obesity group (RER_{peak} = 1·15 ± 0·10 versus 1·09 ± 0·07; $P = 0{\cdot}006$) are suggestive of the level of deconditioning associated with the lower physical activity of these children. This corresponds to the production excessive acid load as seen from the values of VCO_2. Consequently, V_E in obese children reaches significantly higher levels than in control subjects. The intense output of CO_2 continues during the recovery period represented by the peak recovery RER values. Our results showed that the applied standard exercise test is maximal in nature for the majority of the children in the obesity group. It appeared to be symptom limited for 17 (56·7%) of the obese children.

Many studies deal with the exercise capacity in childhood but only some of them touch the perceived exertion issue. Therefore, this investigation is among the few exploring the application of rating scales for assessment of exercise perception in obese children. As we expected, greater awareness of fatigue was found in the obese children (Ward et al., 1986). The fact that they RPE significantly higher and disconnect the test earlier can be explained with the higher aerobic cost of exercise as well as with the greater CO_2 turnover. Certainly, a factor of importance is the lower AT measured in obese children.

At our laboratory, we prefer the Category Ratio Borg scale – CT-10, especially when working with children. It is plain and better understood by the youngsters. The natural number sequence makes it easy for the children to define their effort perception (Tolfrey & Mitchell, 1996). The opportunity to communicate with finger signs is an additional advantage for the subject and simplifies the conduction of the test. Our practice has proven that all the children who are carefully instructed and habituated to the test can reliably rate their perception of fatigue by the 10 grades of the Borg scale. We share the point of Eston & Lamb (2000) that whatever scale is used, it is important to provide the child with an understanding of the range of sensations that correspond to categories of effort within the scale (an effect which they called 'anchoring'). The best way to 'anchor' a sensation to a given exercise intensity is through direct experience during the process of habituation to the exercise test. There are also other advantages of applying rating scale – evaluation of therapeutic interventions as well as exercise prescription (Ward & Bar-Or, 1990).

Our study has the following limitations: the mean IBW of our children is 144 ± 17%, which means we do not have children with extreme obesity. The effect of body weight on functional parameters correlates with the magnitude of fatness and the observed changes are not strongly expressed. Statistical significance of the results shows that even the initial grades of obesity exert negative effect on exercise tolerance. In addition, the applied exercise protocol is not intended to be maximal or symptom-limited by nature, as 36 of the children (60%) completed the entire protocol. Maximal test could discriminate better the studied groups with respect to parameters of ventilation and oxygen uptake. It is our belief that the eventual benefits drawn from maximal exercise are not ethically justified (Harris, 1999). Many researchers support our point of view that sub-maximal exercise tests are more appropriate in childhood, because VO_{2max} is difficult to reach, especially in paediatric population.

Conclusion

In the studied population, the absolute metabolic cost of exercise is higher in the obesity group compared with the control subjects. The obesity children have an increased awareness of fatigue that furthermore limits their physical capacity. The ventilatory efficiency measured as a slope of V_E versus VCO_2 did not differ between obese and non-obese children, as well as in incremental and recovery periods of exercise.

References

American Thoracic Society (Statement) Standardization of spirometry. *Am J Resp Crit Care Med* (1995); **152**: 1107–1136.

Armstrong N, Kirby BJ, McManus AM, Welsman JR. Prepubescents' ventilatory responses to exercise with reference to sex and body size. *Chest* (1997); **112**: 1554–1560.

Bandini L, Schoeller D, Dietz W. Energy expenditure in obese and nonobese adolescents. *Pediatr Res* (1990); **27**: 198–203.

Borg GAV. Psychophysical bases of perceived exertion. *Med Sci Sports Exerc* (1982); **14**: 377–381.

Cole T, Bellizzi C, Flegal M, Dietz H. Establishing standard definition for child overweight and obesity worldwide: international survey. *BMJ* (2000); **320**: 1240–1243.

Cooper D, Kaplan M, Baumgarten L, Weiler-Ravell D, Whipp B, Wasserman K. Coupling of ventilation and CO_2 production during exercise in children. *Pediatr Res* (1987); **21**: 568–572.

Cotes J. Lung function throughout life. Determinants and reference values. In: *Lung Function Assessment and Application in Medicine* (ed. Cotes, J.) (1993), pp. 445–513. Blackwell Science Publishers, Oxford.

Dupuis JM, Vivant JF, Daudet G *et al.* Personal sports training in the management of obese boys aged 12–16 years. *Arch Pediatr* (2000); **7**: 1185–1193.

Eston R, Lamb K. Effort perception. In: *Pediatric Exercise Science and Medicine* (eds. Armstrong, N. & Van Mechelen, W.) (2000), pp. 87–91. Oxford University Press, Oxford.

European Respiratory Society (Official statement). Standardized lung function testing. *Eur Resp J* (1993); **6** (Suppl. 16): 5–52.

Gehan E, Georges S. Estimation of human body surface area from height and weight. *Cancer Chemotherapy Report* (1970); **54**: 225–235.

Goran M, Fields DA, Hunter GR, Herd SL, Weinsier RL. Total body fat does not influence maximal aerobic capacity. *Int J Obes Relat Metab Disord* (2000); **24**: 841–848.

Gutin B, Islam S, Manos T, Cucuzzo N, Smith C, Stachura M. Relation of percentage of body fat and maximal aerobic capacity to risk factors for atherosclerosis and diabetes in black and white seven-to eleven-year-old children. *J Pediatr* (1994); **125**: 847–852.

Habedank D, Reindl I, Vietzke G *et al.* Ventilatory efficiency and exercise tolerance in 101 healthy volunteers. *Eur J Appl Physiol* (1998); **77**: 421–426.

Harris J. The principles of medical ethics and medical research. *Cad Saude Publica* (1999); **15** (Suppl. 1): 7–13.

Inselma L, Milanese A, Deurloo A. Effect of obesity on pulmonary function in children. *Pediatr Pulmonol* (1993); **16**: 130–137.

Lazarus R, Colditz G, Berkey CS, Speizer FE. Effects of body fat on ventilatory function in children and adolescents: cross-sectional findings from a random population sample of school children. *Pediatr Pulmonol* (1997); **24**: 187–194.

Loftin M, Sothern M, Trosclair L, O'Hanlon A, Miller J, Udall J. Scaling VO_2 Peak in Obese and Non-obese Girls. *Obes Res* (2001); **9**: 290–296.

Marinov B, Kostianev S, Turnovska T. Submaximal treadmill test for screening of physical capacity in pediatric age group. *Pediatria* (2000); **XL**: 38–41 (in Bulgarian).

Nagano Y, Baba R, Kuraishi K *et al.* Ventilatory control during exercise in normal children. *Pediatr Res* (1998); **43**: 704–707.

Nevil A. The appropriate use of scaling techniques in exercise physiology. *Pediatric Exercise Sci* (1997); **9**: 295–298.

Orenstein DM. Assessment of exercise pulmonary function. In: *Pediatric Laboratory Exercise Testing: Clinical Guidelines* (ed. Rowland, T.W.) (1993), pp. 141–163. Human Kinetics Publishers, Champaign, IL.

Pina I, Balady G, Hanson P, Labovitz A, Madonna D, Myers J. Guidelines for clinical exercise testing laboratories. *Circulation* (1995); **91**: 912–921.

Pongprapai S, MO-Suwan L, Leelasamran W. Physical fitness of obese school children in Hat Yai, southern Thailand. *Southeast Asian J Trop Med Public Health* (1994); **25**: 354–360.

Slaughter M, Lohman T, Boileau R *et al.* Skinfold equations for estimation of body fatness in children and youth. *Hum Biol* (1988); **60**: 709–723.

Slunchev P. *Physical Growth, Physical Capacity and Neuro-Psychic Reactivity of the Population in Bulgaria* (1992). Edition of the Bulgarian Sports Academy, Sofia (in Bulgarian).

Tolfrey K, Mitchell L. Ratings of perceived exertion at standard and relative exercise intensities in prepubertal, teenage and adult males. *J Sports Sci* (1996); **14**: 101–102.

Toth M, Goran M, Ades P, Howard D, Poehlman E. Examination of data normalization procedures for expressing peak VO_2 data. *J Appl Physiol* (1993); **75**: 2288–2292.

Ward D, Bar-Or O. Use of the Borg scale in exercise prescription for overweight youth. *Can J Sport Sci* (1990); **15**: 120–125.

Ward D, Blimkie C, Bar-Or O. Rating of perceived exertion in obese adolescents. *Med Sci Sports Exerc* (1986); **18**: S72.

Washington R, Bricker J, Alpert B. *et al*. Guidelines for exercise testing in the paediatric age group. *Circulation* (1994); **90**: 2166–2179.

Wasserman K, Hansen J, Sue D, Casaburi R, Whipp B. Pathophysiology of disorders limiting exercise. In: *Principles of Exercise Testing and Interpretation* (ed. Wasserman, K.) (1999), pp. 96–99. Lippinkott Williams & Wilkins, Baltimore.