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Exercise training improves breathing strategy and performance during the six-minute walk test in obese adolescents☆

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ABSTRACT

Objectives: We aimed to examine ventilatory responses during the six-minute walk test in healthy-weight and obese adolescents before and after exercise training.
Methods: Twenty obese adolescents (OB) (age: 14.5 ± 1.7 years; BMI: 34.0 ± 4.7 kg·m^{-2}) and 20 age and gender-matched healthy-weight adolescents (HW) (age: 15.5 ± 1.5 years; BMI: 19.9 ± 1.4 kg·m^{-2}) completed six-minute walk test during which breath-by-breath gas analysis and expiratory flow limitation (expFL) were measured. OB participated in a 12-week exercise-training program.
Results: Comparison between HW and OB participants showed lower distance achieved during the 6MWT in OB (−111.0 m, 95%CI: −160.1 to 62.0, $p < 0.05$) and exertional breathlessness was greater (+0.78 a.u., 95%CI: 0.091–3.27, $p = 0.039$) when compared with HW. Obese adolescents breathed at lower lung volumes, as evidenced by lower end expiratory and end inspiratory lung volumes during exercise ($p < 0.05$). Prevalence of expFL (8 OB vs 2 HW, $p = 0.028$) and mean expFL (14.9 ± 21.9 vs 5.32 ± 14.6% VT, $p = 0.043$, in OB and HW) were greater in OB.

After exercise training, mean increase in the distance achieved during the 6MWT was 64.5 meters (95%CI: 28.1–100.9, $p = 0.014$) and mean decrease in exertional breathlessness was 1.62 (95%CI: 0.47–2.71, $p = 0.05$). Obese adolescents breathed at higher lung volumes, as evidenced by the increase in end inspiratory lung volume from rest to 6-min exercise (9.9 ± 13.4 vs 20.0 ± 13.6%TLC, $p < 0.05$). Improved performance was associated with improved change in end inspiratory lung volume from rest to 6-min exercise ($r = 0.65$, $p = 0.025$).
Conclusion: Our results suggest that exercise training can improve breathing strategy during submaximal exercise in obese adolescents and that this increase is associated with greater exercise performance.

1. Introduction

Childhood obesity has reached epidemic proportions although its prevalence seems to have reached a plateau (Olds et al., 2011). Obesity in childhood and adolescence is particularly alarming since it has been associated with increased cardiovascular mortality and morbidity in adulthood (Mossberg, 1989). It has been suggested that the adverse effects of obesity can be countered by increasing physical activity, which leads to higher cardiorespiratory fitness (Ortega et al., 2008). Non-physically active children are more likely to become non-physically active adults thus encouraging the development of physical activity habits in adolescents helps establish patterns that continue into adulthood (Telama, 2009).

Abbreviations: 6MWT, six-minute walk test; EELV, end-expiratory lung volume; EILV, end-inspiratory lung volume; expFL, expiratory flow limitation; EXT, exercise training; FEV1, forced expired volume in 1 s; FVC, forced vital capacity; HR, heart rate; IC, inspiratory capacity; HW, healthy-weight; OB, obese; MIP, maximal inspiratory pressure; MEP, maximal expiratory pressure; TLC, total lung capacity; $\dot{V}E$, minute ventilation; $\dot{V}O_2$, oxygen consumption; VT, tidal volume.

☆ Clinical Trials registration number: Clinical Trials ID: NCT014116.

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Respiratory factors that accompany obesity such as increased work of breathing due to altered pulmonary function have been shown to contribute to increased risk of expiratory flow limitation and exertional breathlessness (Wang and Cerny, 2004). In obese adults, lung function abnormalities are frequent, in particular reduction in lung volumes and forced expiratory flow (Parameswaran et al., 2006). In children and adolescents, similar data is limited and conflicting (Li et al., 2003; Spathopoulos et al., 2009). Exertional breathlessness has been reported in obese children (Marinov et al., 2002) and can be a barrier to the achievement of recommended levels of physical activity in this population (Page et al., 2005). However, it remains unclear whether this breathlessness is due to the increased metabolic cost of locomotion associated with obesity, altered perception of effort, altered breathing strategy or ventilatory constraint resulting from increased thoracic fat mass. Ventilatory constraint refers to the extent of expiratory flow limitation, alterations in the regulation of end-expiratory lung volume (EELV) relative to total lung capacity, and a proposed estimate of ventilatory capacity based on the shape of the maximal flow volume loop and the breathing strategy (regulation of end expiratory and inspiratory lung volumes) adopted during exercise (Babb, 2013; Johnson et al., 1999).

The increased metabolic cost of weight-bearing exercise in obesity (e.g. walking) is amplified for a given external work rate when compared with non-weight bearing exercise (e.g. cycling) (Lafortuna et al., 2008). However, most activities in daily life are weight bearing, therefore it is important to have access to a test that reflects and mirrors this type of activity. The six-minute walk test (6MWT) is classified to represent the most suitable method to assess the submaximal level of functional exercise capacity (Enright, 2003), even though it does not reflect the highly sporadic, high-intensity natural play patterns of children. Validity and reproducibility of the 6MWT have been investigated in healthy children and in obese children and adolescents (Li et al., 2005; Morinder et al., 2009; Vanhelst et al., 2013).

Exercise training has been shown to improve performance (i.e. distance achieved) on the 6MWT (Geiger et al., 2011). Other studies have shown improved ventilatory efficiency (i.e. $\dot{V}E/\dot{V}O_2$) and decreased exertional breathlessness in obese children and adolescents (Kaufman et al., 2007; Mendelson et al., 2012; Prado et al., 2009). However, to our knowledge, the effects of exercise training on ventilatory constraint and breathing strategy during a weight-bearing submaximal exercise in obese adolescents have yet to be examined.

Thus, the aims of the present study are to firstly describe ventilatory constraint and breathing strategy during submaximal exercise in healthy-weight and obese adolescents and secondly, before and after a 12-week supervised exercise-training program in obese adolescents. We hypothesized that obese adolescents would present a lower distance achieved on the 6MWT and higher exertional breathlessness at the end of the test compared with healthy-weight peers and that this would be accompanied with expiratory flow limitation in obese participants due to the excess trunk fat. Secondly, we hypothesized that after 12 weeks of exercise training, 6MWT performance would increase and expiratory flow limitation would decrease and that improved breathing strategy would be associated with improved performance.

2. Methods

2.1. Participants

Twenty obese adolescents (OB) and twenty healthy-weight adolescents (HW) matched for sex, age and puberty status were included in this study. A complete clinical examination was carried out by a physician to search for contraindications to exercise in all subjects. Obesity was defined by reporting participants' body mass indexes (BMI) on age and sex-specific BMI curves of the International Obesity Task Force (Cole et al., 2000). Participants were considered obese if their BMI was above the cutoff that passes through a BMI of 30 kg m^{-2} at age 18. Sexual maturation was assessed by a trained pediatrician using brief observation, according to Tanner and Whitehouse (Tanner, 1981). Breast development in girls and genital development in boys were used for pubertal classification (Tanner, 1981). All participants were free of cardiac or respiratory diseases and were only physically active in school-based physical education, which consisted in 3 h of moderate to high intensity exercises. The experimental protocol was approved by the local Ethics Committee (*Comité de Protection des Personnes Sud Est V:* 2007-A00714-49). Participants and their parents received a verbal description of the experiment and completed a written informed consent form. The OB group participated in a 12-week exercise-training program and were re-evaluated after exercise training. The primary aim of this study was to evaluate the influence of cardio-ventilatory factors on exercise tolerance in obese adolescents before and after exercise training (*Clinical Trials* NCT01411605) and some results have been published previously (Mendelson et al., 2012). The results presented here are a secondary analysis of the results obtained during the six-minute walk test.

2.2. Anthropometry

Standard measures of height and weight were made at the initial visit of the subjects. Standardized procedures and identical equipment were used to obtain weight (SECA, Semur-en-Auxois, France) to the nearest 0.1 kg and height to the nearest 0.1 cm (COMED, Strasbourg, France). Participants were measured without shoes on a horizontal surface. BMI was calculated from weight in kilograms divided by height in meters squared.

2.3. Lung function

All subjects had standard spirometry and lung volume determinations (Medisoft Bodybox 5500, Dinan, Belgium) and all lung function tests were carried out by the same technician and followed the guidelines of the American Thoracic Society (Miller et al., 2005).

2.4. Six-minute walk test

The six-minute walk test was performed in an enclosed corridor on a 30-m long course, in accordance with the American Thoracic Society guidelines (2002). Patients were asked to walk as fast as possible for 6 min. Only standardized phrases of encouragement were used during the test. Two experimenters were involved in the testing of all participants, one of which recorded flow-volume loops and the other who counted laps and encouraged the participant. Identical procedures were used before and after training. To calculate the work of walking (6MWORK), distance on the 6MWT was converted to kilometers and multiplied by the weight in kilograms.

2.5. Gas exchange measures

Inspired and expired gases were monitored continuously with measurement of breath-by-breath rate of oxygen consumption, carbon dioxide production and ventilation using the MetaMax 3B (Cortex Biophysik GmbH, Leipzig, Germany). Gas analyzers were calibrated prior to each test according to manufacturer's instructions. Gas exchange and ventilation were averaged to minute-by-minute values.