Energy cost of walking and body composition changes during a 9-month multidisciplinary weight reduction program and 4-month follow-up in adolescents with obesity

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Energy cost of walking and body composition changes during a 9-month multidisciplinary weight reduction program and 4-month follow-up in adolescents with obesity

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Running Head: Energy cost of walking in adolescents with obesity

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Abstract

The purpose of the present study was to investigate changes in the energy cost of locomotion during walking (Cw) related to the changes in body mass (BM, kg) and body composition in adolescents with obesity. Twenty-six (12 boys and 14 girls) obese adolescents (mean: BMI, 33.6±3.7 kg/m^2; 42.7±4.5 % fat mass) followed a 9-month multidisciplinary inpatient weight-reduction program consisting of lifestyle education, moderate energy restriction, and regular physical activity in a specialized institution. At baseline (M0), by the end of the 9-month program (M9) and after 4-months follow-up (M13), V'O$_2$ and V'CO$_2$ of standardized activity program were assessed by whole-body indirect calorimetry over 24 hours, and body composition was assessed by DXA. At M9, adolescents showed a 18% reduction in BM (p<0.001), 40% in total FM; while FFM (kg) remained stable in boys but decreased by ~6% in girls (p=0.001). Similarly, the mean Cw decreased by 20% (p<0.001). At M13, BM, FM and Cw were slightly higher compared than at M9. In conclusion, moderate energy restriction and regular moderate physical activities improved walking economy, improved exercise tolerance and induced beneficial changes in body composition of adolescents with obesity.

Novelty bullets

- Reduction of FM in the trunk region, and consequently reducing the work carried out by respiratory muscles, contribute to reduce Cw in adolescents with obesity.
- A lower cost of walking can be effective in improving exercise tolerance and quality of life in obese adolescents.

Keywords: Cost of walking; Trunk fat mass; Body composition; adolescents; obesity; physical activity

Introduction

Obesity affects all aspects of childhood life increasing the risk of comorbidities (i.e. cardiovascular disease or diabetes) and mortality (Ortega et al. 2016). Furthermore, adolescent obesity is rising in more industrialized countries (Lim et al. 2012; Ng et al. 2014), where daily habits favour increased food-intake altogether with a reduction of physical activity level. Walking is a convenient form of daily physical activity and is recommended for weight management, but the increased cost of locomotion during walking (Cw, *i.e.* the amount of energy spent above resting to transport 1 kg body mass (BM) over 1 meter distance) observed in subjects with obesity, negatively affects the exercise tolerance due to premature fatigue (Peyrot et al. 2010). Several factors contribute to the increase in Cw in adolescents with obesity such as a greater mechanical work for walking (Peyrot et al. 2012; Peyrot et al. 2010), excess of BM (Molina-Garcia et al. 2019) or excessive adipose tissue around the rib cage and in the visceral cavity, that will increase the resistive load on lungs, while increasing the respiratory pressure, pulmonary volumes and therefore the work of breathing during exercise (Oppenheimer et al. 2014). Hence, an increase trunk mass not only will increase the resting oxygen consumption ($V'O_2$) (Bhammar and Babb 2020) but also the oxygen uptake of muscles involved in breathing, which reduces oxygen availability to the muscles involved during exercise (Alemayehu et al. 2018), reducing exercise tolerance.

However, in adolescents with obesity, a weight-reduction program including moderate intensity continuous training, changes in food and behavioural habits, has been found effective in improving walking economy (Delextrat et al. 2015; Peyrot et al. 2012), reducing the O_2 cost of breathing (Babb et al. 2011; Bhammar et al. 2016), fat mass (FM) in the trunk region while maintaining fat-free mass (FFM) (Lazzer et al. 2004). Optimising the work of diaphragm and abdominal muscles in patients with obesity, even simply by reducing the external load of excessive fat mass around the rib cage, can be extremely effective in improving ventilatory parameters, increasing exercise tolerance and breaking the vicious cycle of inactivity (LoMauro et al. 2016).

Therefore, the main objective of the present study was to evaluate the effects of a 9-month multidisciplinary weight-reduction program on the Cw of adolescents with obesity, walking at various speeds and slopes. We hypothesised that our intervention could lead to (a) a decrease in the Cw and (b) this decrease was related to reductions of BM and trunk FM.

Materials and Methods

Subjects

Twenty-six (12 boys and 14 girls) adolescents with severe obesity, were recruited from the Paediatrics Department of Clermont-Ferrand University Hospital**.** The inclusion criteria were: age between 12 and 16 years, BMI above the 99th percentile for gender and chronological age (Rolland-Cachera et al. 1991). However, adolescents who had previously participated in weight management programs, were not in good health (eg, diabetes, hypothyroidism…), and those taking medications regularly or use of any medication known to influence energy metabolism, were excluded. All subjects had a full medical history and physical examination, with the routine haematology and biochemistry screens and urine analysis. BM was stable during the previous last two months. None of the subjects had evidence of significant disease, non-insulin-dependent diabetes mellitus or other endocrine disease, and none were taking medications regularly or any medication known to influence energy metabolism. The data considered in the present study are part of a larger study but had never been taken into account previously. The scientific questions being addressed in previous publications are related to the effects of a 9-months weight reduction program in obese adolescents on energy expenditure, lipid oxidation and adipocyte hormones regulation, and on leisure physical activities and sedentary behaviours level in free-living conditions (Lazzer et al. 2004; Lazzer et al. 2005a; Lazzer et al. 2005b)

Study protocol

The study was approved by the University Ethical Committee on Human Research for Medical Sciences (AU # 361). The purpose and objective of the study were explained to each subject and his or her legal representative, and written informed consent was obtained before beginning the study. The adolescents spent 10 months, 5 days per week, in a specialized nursing institution, and weekend and four holiday weeks at home. Subjects followed a 9-month personalized weight-reduction program consisting of lifestyle education, physical activity, dietary and psychological follow up. At the end of the weight-reduction program the adolescents returned home. Four months later they spent one week in the specialized institution. Full testing sessions were conducted just before the beginning (month 0, M0), at completion of the 9-month weight-reduction period (month 9, M9), and four months later (month 13, M13). The testing session included assessment of anthropometric characteristics, body composition, energy expenditure by whole-body calorimetry and ventilatory parameters by spirometry. In addition, individual anthropometric indexes and physical capacities were evaluated monthly to adjust physical training and food allowances. The latter were specially adjusted during the last two months to stabilize BM.

Diet and nutritional education

During the 9-month weight reduction period, personalized diets were offered on the basis of the baseline basal metabolic rate (BMR) test and physical activity level for each adolescent. Energy supply was adjusted to be close to 1.3 times initial BMR, that is about 15-20 % less than the estimated daily energy expenditure. Diet composition was formulated according to the French recommended daily allowances (Martin 2001). During the weight-reduction period the adolescents had dietetics lessons including choice and cooking of foods, and they were instructed to maintain their food habits after the end the weight-reduction period.

Physical activity

During the 9-month weight-reduction period, the adolescents participated in an exercise-training program including two 40-min endurance and strength training sessions (preceded and followed by 5-7 min stretching) per week under heart rate monitoring and medical supervision. Intensity of endurance exercises (cycle ergometer, treadmill walking, stepper, and stationary rowing) was set at a HR corresponding to 55-60 % of the initial V'O_2max. Strength training was performed on universal gym equipment. Physical training intensity was adjusted monthly according to the results of the physical capacity tests. In addition, subjects had two hours of physical education lessons (PEL) at school, and two hours of aerobic leisure activities at the institution per week. The adolescents and their parents were also advised to practice leisure physical activities during the weekend and holidays.

Measurements

Anthropometric characteristics and body composition

BM was measured to the nearest 0.1 kg using a calibrated manual weighing scale (Seca 709, Les Mureaux, France). Stature was measured to the nearest 0.5 cm on a standardized wall-mounted height board. Circumferences at the waist and hip were measured in triplicate to the nearest 0.1 cm using a steel tape according to the atlas of Sempè et al. (1979). Total and regional body composition was assessed by dual X-ray absorptiometry (DXA) using Hologic QDR-4500 equipment and version 9.10 of total body scans software (Hologic Inc, Bedford, MA, USA). FFM was defined as the sum of non-bone lean tissues and bone mineral content. Hydration of the FFM was assumed to be constant (73.2 %). The ability to measure changes in body composition by DXA was showed by Tylavsky et al. (2003).

Physical capacities

The aerobic capacities of the subjects were assessed by means of maximal oxygen uptake tests performed under medical supervision during walking on a treadmill before the beginning (M0), at completion of the weight-reduction program (M9), and four months later (M13). The subjects achieved several successive 2.5 min steps at constant speed (between 4.5 and 5.5 km/h according to the subject physical capacities) and increasing slope by 3% steps until exhaustion. Heart rate was recorded continuously (Cardiovit CS6/12, Scheller AG, Baar, Switzerland). Oxygen dioxide production were measured during the last 30 seconds of each step using the Douglas bag method. Oxygen consumption and carbon dioxide production were determined using a Tissot spirometer and gas analyzers (CPX ID; Medical graphics, St Paul). The oxygen and carbon dioxide analysers were calibrated using standard gas mixtures before each test period. Blood samples for lactate concentration measurement ([La]) were obtained by micro-puncture of the ear lobe within the 3 minutes following the completion of the tests. [La] were measured with lactate analyser (Analox LM5). The criteria for reaching maximal $V'O_2$ were: a respiratory exchange ratio (RER)> 1.1, and a maximal heart rate close to the theoretical maximum [220 – age (y)].

Energy cost of locomotion during walking

The Cw was measured by indirect calorimetry using two comfortable open-circuit whole-body calorimeter (Lazzer et al. 2004). Measurements were obtained three times: before the beginning (M0), at completion of the weight-reduction program (M9), and four months later (M13), as previously described by Lazzer et al. (2004). Briefly, the adolescents spent 36 hours in the whole-body calorimeters, one evening and one night for adaptation and 24 hours for measurement. They followed the same standardized activity program composed of five main periods: 1) sleeping, 2) sedentary activities (watching television, video games, listening to music, board games, school work, 10.5 hours), 3) miscellaneous activities (washing and dressing, making the bed and tidying the room, 1 hour), 4) meals (breakfast, lunch, snack and dinner, 2 hours), 5) six 20-min-exercises of walking at six different speeds (2 hours). Before the beginning of the weight-reduction program subjects walked at their own speed on the treadmill and the slope was altered to obtain different intensities of exercises.

Gas exchanges were computed from outlet air flow, differences in gas concentrations between air entering and leaving the calorimeter, atmospheric pressure, chamber air temperature and hygrometry, after correction for the drift of the gas analysers and the response time of the whole system. The gas analysers were calibrated twice a day using the same gas mixture during the whole study. In addition, the validity of gas exchange measurements was checked gravimetrically by injecting gas (N_2 and CO_2) into the chambers. HR was measured by telemetry (Life scope 6, Nikon Kohden, Tokyo, Japan)(Lim, #79) and recorded continuously during the stay in the calorimeters.

The Cw ($J \cdot kg^{-1} \cdot m^{-1}$) was calculated by dividing net V'O_2 by speed and BM. V'O_2 is obtained by subtracting pre-exercise rest V'O_2 from gross V'O_2, and converted to joules according to the formula given by Garby and Astrup (1987), which accounts for the RER (dependent variation of O_2 energy equivalence). In addition, RER was monitored to ensure that it remained under the specific threshold of 1.0. All these precautions were required to indicate that the metabolism was essentially oxidative.

Spirometry

Before the beginning of the weight-reduction program (M0), at completion (M9), and four months later (M13), the adolescents performed standard spirometry tests (forced vital capacity, FVC; forced expiratory volume in 1 sec, FEV1; $FEV1 \cdot FVC^{-1}$ ratio) by utilizing a metabolic cart (MedGraphics CPX/D, Medical Graphics Corp., USA). Pulmonary function testing was performed according to the guidelines of the American Thoracic Society (Miller 2005). The predicted values were based on Hankinson et al. (1999).

Statistical analysis

Statistical analyses were performed using GRAPH PAD PRISM software, version 8.0.1, 2020 (GraphPad Software, Inc. - San Diego, CA, USA). The data are presented as mean and standard deviation (SD). Differences between the periods (M0-M9 and M9-M13) are presented as mean differences, 95% confidence intervals (CI) and effect size (ES). ES was calculated using Cohen's d ($0 < d < 0.20$, small; $0.20 < d < 0.50$ medium; $d > 0.50$, large) (Cohen 1988). Significance was set at $P < 0.05$. Normality of data set was tested with a Shapiro wilk test. Bivariate associations were determined by Pearson's or Spearman's correlation coefficients. A General Linear Mixed Model repeated measures was used to determine the effects of the period (M0, M9 and M13), gender and their interaction (P x G) on body composition, metabolic and spirometry parameters. Sphericity has been assessed using Mauchly's test. Greenhouse-Geisser estimate correction was used in case of sphericity assumption violation. Significant main effects (P, G) or interactions (P x G) were further analysed by the Tukey post hoc test. The relationships between the different factors were investigated using Pearson product–moment correlation coefficient.

Results

Effects of the weight-reduction program (M9-M0)

Anthropometric characteristics and body composition

At M0, mean age, BM, stature, and BMI were not significantly different between boys and girls (Table 1). Waist circumference was also not significantly different between boys and girls, but boys had lower hip circumferences (-8%, p=0.003) and higher waist/hip ratio (+7%, p<0.001, Table 1).

During the 9-month weight-reduction program, both boys and girls reduced their body mass, BMI, waist and hip circumferences, and waist/hip ratio by mean ~18%, ~21%, ~15%, ~11 and 5%, respectively (p <0.001), without P x G interaction (Table 1).

At baseline, total FFM (kg) and total FM (%) were not significantly different between boys and girls, while FM (kg) was higher in girls (+12%, p=0.003, Table 2) than in boys. Furthermore, boys had similar FFM (kg) but significantly lower FM (kg) than girls in arms, legs and trunk districts (-6%, p=0.007; -11%, p=0.011; and -15%, p=0.002; respectively, Table 2).

During the 9-month weight-reduction period, total FFM (kg) remained stable in boys, while it decreased by ~6% in girls (p=0.001); total FM (kg) decreased by ~50% (p<0.001) in boys and ~30% in girls (p<0.001) (Table 2). FFM (kg) in arms and legs did not change significantly in boys and girls; while trunk FFM (kg) decreased in girls (by ~7%, p=0.023) but not in boys. On the other hand, FM (kg) decreased in boys by ~45% in arms, ~44% in legs and ~59% in the trunk (p <0.001) and in girls by ~26% in arms, ~27% in legs and ~35% in trunk (p <0.001, Table 2).

Physical capacities

$V'O_2max$, $V'O_2max \cdot FFM^{-1}$, HR_{max} and [La] max were not significantly different between boys and girls (Table 1).

During the 9-month weight-reduction program $V'O_2max$, $V'O_2max \cdot FFM^{-1}$ and HR_{max} did not change significantly. Finally, [La] max decreased significantly only in boys (by mean ~31%, p=0.035, Table 1).

Spirometry

At M0, FVC, FEV1 and $FEV1 \cdot FVC^{-1}$ were not significantly different between sexes (Table 3).

During the 9-month weight-reduction program FVC and FEV1 increased by ~7% (p=0.009) and ~9% (p=0.014), respectively, in boys but not in girls; while $FEV1 \cdot FVC^{-1}$ did not change significantly. FVC, FEV1 and $FEV1 \cdot FVC^{-1}$ were not significantly different from the standard reference values at M0 and M9, both in boys and girls (Table 3).

In addition, changes in FVC (ΔFVC, L) were inversely related to changes in TrunkFM (Δ TrunkFM, kg) at M9-M0 (R^2: 0.375, p: 0.0015; Fig. 1 A) and directly related to changes in ΔV'O_2 max during the period M9-M0 (R^2: 0.208, p: 0.0250; Fig. 2 A).

Metabolic parameters measured in the whole-body calorimeters

At M0, V'O_2, HR and Cw were not significantly different between boys and girls (Fig. 3).

At M9, V'O_2 and HR were significantly lower at all slopes by 20% and 16% on average, respectively ($p<0.001$, Fig. 3 B, E). As well, the Cw decreased by ~20% ($p <0.001$, Fig. 3 H) at all slopes. In addition, changes in Cw were not significantly related to changes in BM (ΔBM, kg) or TrunkFM (ΔTrunkFM, kg) at M9-M0.

Changes after the end of the weight-reduction program (M13-M9)

Anthropometric characteristics and body composition

At M13 the body mass of boys was ~7% (p=0.020) higher than at M9 while their BMI, waist and hip circumferences, and waist/hip ratio were not significantly altered; whereas none of the above-mentioned parameters changed significantly in girls. It is worth considering that, even though the parameters recorded were worse at M13 than at M9, they were much better than at M0 for both groups ($p < 0.05$, Table 1).

At M13 total FFM, arms FFM and legs FFM were ~5% (p=0.006), ~8% (p=0.009) and ~5% (p=0.006), respectively, higher than at M9 in boys; whereas trunk FFM was not significantly altered (Table 2). By contrast the above parameters did not show any significant changes in girls (Table 2).

Finally, total FM (kg), arms FM (kg), legs FM (kg) and trunk FM (kg) did not change significantly both in boys and girls and remained 36%, 35%, 34% and 41%, respectively, lower than at M0 ($p<0.05$, Table 2).

Physical capacities

$V'O_2max$, $V'O_2max \cdot FFM^{-1}$, HR max and [La] max were not significantly different at M13 and M9 both in boys and girls. [La] max remained significantly lower than at M0 in boys and girls (by mean ~32%, p=0.014, Table 1)

Spirometry

FVC was ~3% higher at M13 than at M9 (p=0.002, Table 3) in boys but not FEV1 and the $FEV1 \cdot FVC^{-1}$ ratio. In girls, FEV, FEV1 and $FEV1 \cdot FVC^{-1}$ ratio did not change significantly (Table 3). Finally, FVC and FEV1 were ~10% and ~13% higher, respectively, at M13 than at M0 (p<0.001, Table 3) in boys; whereas they were not significantly different in girls (Table 3).

In addition, changes in FVC (ΔFVC) were inversely related to changes in TrunkFM (Δ TrunkFM, kg) at M13-M9 (R^2: 0.280, p: 0.0078; Fig. 1 B) and M13-M0 (R^2: 0.656, p: 0.0001; Fig. 1 C) and directly related to changes in $\Delta V'O_2$ max at M13-M9 (R^2: 0.208, p: 0.0248; Fig. 2 B) but not at M13-M0 (Fig. 2 C).

Metabolic parameters measured in the whole-body calorimeters

$V'O_2$ was significantly higher at M13 than at M9 for all speeds at 2% and 4% slopes (p<0.001) while it was not significantly altered at 0% and 6% slope (Fig. 3 C). HR did not change at any speeds and slopes (Fig. 3 F). As well, Cw did not change at any speeds and slopes (Fig. 3 I). In addition, changes in Cw were not related to changes in BM (ΔBM, kg) and TrunkFM (ΔTrunkFM, kg) at M13-M9.

Discussion

The present study shows that a 9-month multidisciplinary weight-reduction program including physical training, regular physical activity and moderate energy restriction, induced in adolescents with severe obesity: 1) a significant reduction of Cw, 2) considerable reductions of BM and FM, particularly in the trunk region, and 3) no adverse effect on FFM in boys, and a slight but significant FFM loss in girls.

Our intervention was effective in reducing Cw, V'O_2 and HR during walking at different speeds and slopes, which suggested an improved walking economy and exercise tolerance (Alemayehu et al. 2018; Peyrot et al. ; Peyrot et al. 2010). However, our hypothesis was rejected as no correlation was found between changes in Cw and changes in BM or trunk FM. Cw was ≃20% lower at M9 than at M0. Only few studies reported a significant decrease in Cw of this magnitude (i.e. ranging from 9% to 22%) after a weight reduction program (Delextrat et al. 2015; Peyrot et al. 2012; Peyrot et al. 2010). The first factor accounting for the decreased in Cw in adolescents with obesity after weight loss, was the decrease in BM (Lazzer et al. 2004; Peyrot et al. 2010). However, recent studies showed that, when BM was normalized for internal work (i.e., work required to move the limbs with respect to the centre of mass, (Cavagna and Kaneko 1977; Willems et al. 1995), BM did not affect the total mechanical work and was not directly responsible for the higher Cw during walking in adults suffering from obesity (Menéndez et al. 2020). As well, in agreement with previous studies, which considered physical activity and diet as the main components of a weight reduction program, maintaining FFM (Stiegler and Cunliffe 2006) and improving physical capacities (Delextrat et al. 2015), due to physical training, contribute to the reduction of the Cw.

Therefore, respiratory and mechanical parameters were suggested to play an important role in the reduction of Cw (Hunter et al. 2008; Menéndez et al. 2020; Oliveira et al. 2020; Peyrot et al. 2012). Particularly, at the end of the 9 months weight reduction program, we found improvements of the spirometry parameters with an increase in FVC, although the values of FVC were within the range of normality (Kochli et al. 2019; Oliveira et al. 2020). In addition, the reduction of trunk FM was positively related to the improvement in FVC, which reflects the total compliance of both lung and chest wall (Forno et al. 2018). The extra weight or mass added to the chest wall, as in obesity condition, causes a compression of the thorax, thus decreasing respiratory compliance and lung volumes (Wang and Cerny 2004). As previously observed in healthy and lean subjects, a load on the trunk between 15-20% of body weight, as observed in obesity (Hong et al. 2008; Hudson et al. 2020), causes chest wall restriction with a concomitant increase in work of breathing and Cw (Faghy et al. 2016; Faghy and Brown 2014; Phillips et al. 2016). Therefore, previous studies showed that a 12-week diet and physical activity program, induced BM loss and reduction of trunk FM, which significantly enhanced breathing mechanics in men and women with obesity (Babb et al. 2011; Bhammar et al. 2016). Moreover, it was shown (Alemayehu et al. 2020; Salvadego et al. 2017) that a decrease in Cw was associated with a reduction of $V'O_2$ of respiratory muscles after 3 weeks of training of respiratory muscles, or acute respiratory muscle unloading. Potential mechanisms underlying the decrease of O_2 cost of breathing in adolescents with obesity are partially described by decreased FM and load on the trunk region (Babb et al. 2011; Milic-Emili et al. 2007), augmented efficiency of respiratory muscles thanks to an increase in both chest wall and compliance and lung compliance (Babb et al. 2011; Pelosi et al.), and decreased airway resistance (Babb et al. 2011). Reducing the work of the respiratory muscles by decrease in trunk FM, would not only interrupt or attenuate the metaboreflex, but would also positively affect "central" hemodynamics (Alemayehu et al. 2018; Vogiatzis et al. 2011) and enhance O_2 delivery to locomotor muscles, thereby reducing the O_2 cost of these locomotor muscles and further decreasing Cw (Dominelli et al. 2017; Hogan et al. 1999). Increasing O_2 availability to locomotor muscles may also delay or reduce the development of peripheral muscle fatigue, maintaining metabolic stability in these muscles and preventing the recruitment of additional less efficient muscle fibers (Babcock et al. 2002; Cleland et al. 2012; Dominelli et al. 2017). Another potential hypothesis may explain the Cw improvement in subjects with obesity as related to the impact of ectopic muscle lipid infiltration. Indeed, intramyocellular lipid is well recognized as a cause of metabolic disturbances (insulin resistance as well as anabolic resistance) (Beals et al. 2018; Guillet et al. 2009; Tardif et al. 2014) but it is also a possible factor of an impaired muscle contraction (Choi et al. 2016; Collins et al. 2018). So, a weight reduction program is supposed to improve insulin sensitivity, to reduce intramyocellular content, and to improve finally muscle structure and quality, which could contribute to this lower Cw.

It is worth mentioning that, in the present study, a significant reduction in BM and FM, and particularly in TrunkFM, was associated with a significant FFM loss in girls but not in boys.

The adolescents involved in the present study were in a growth phase: boys were in the peak of growth, while girls were in the final phase of growth. Indeed, the growth-related increment in FFM in boys during the 9 months weight-reduction program could have compensated for the FFM loss due to energy restriction, which eventually did not occur in girls (Lazzer et al. 2004).

Finally, it is important to consider that a reduction in TrunkFM could affect FVC and then also V'O_2 max. Nevertheless, because no changes were evaluated in V'O_2max after the weight-reduction program, it is possible to assume that lung volumes explained only partially the variance of the improvements of cardiorespiratory fitness in adolescents with obesity (Mendelson et al. 2016).

In conclusion, a weight-reduction program including regular physical activity and moderate energy restriction decreased BM and FM in adolescents with obesity, together with improvements of Cw and pulmonary parameters. Although the spirometry values of participants were in the normal range, we have shown that reducing FM in the trunk region, and consequently reducing the work carried out by respiratory muscles, may reduce possible respiratory limitations, thus contribute to reduce Cw. In addition, this strategy can be effective in improving exercise tolerance and quality of life of adolescents with obesity, considering that most activities of everyday life are linked to walking activities.

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Conflict of Interest

There are no real or potential conflicts of financial or personal interest with the financial sponsors of the scientific project.

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Table 1. Changes in physical characteristics and capacities of adolescents (Boys, B; Girls, G) before the beginning (M0), at completion of the weight-reduction program (M9), and four months later (M13).

		M0	M9	M13	ΔM9-M0		ΔM13-M9	
					diff (95%CI)	ES	diff (95%CI)	ES
Age	B	13.47 ± 1.27	14.23 ± 1.27	14.63 ± 1.27	0.75* (0.78 to 0.71)	0.59	0.40* (0.40 to 0.40)	0.31
(y)	G	14.87 ± 1.57	15.63 ± 1.57	16.03 ± 1.57	0.75* (0.78 to 0.71)	0.48	0.40* (0.40 to 0.40)	0.25
Body mass	B	89.8 ± 20.1	71.4 ± 14.4	76.2 ± 17.4	-18.4* (-12.9 to -23.9)	0.92	4.8* (-8.86 to -0.77)	0.33
(kg)	G	92.0 ± 14.7	76.1 ± 12.7	78.2 ± 13.3	-15.9* (-11.9 to -19.9)	1.08	2.1 (5.95 to -1.75)	0.17
Stature	B	1.63 ± 11.58	1.68 ± 11.29	1.70 ± 11.09	0.04* (0.05 to 0.03)	0.39	0.02* (0.02 to 0.01)	0.00
(m)	G	1.64 ± 10.64	1.65 ± 10.34	1.65 ± 10.41	0.02* (0.02-0.01)	0.15	0.00 (0.01 to 0.00)	0.00
BMI	B	33.1 ± 4.2	25.0 ± 3.4	26.2 ± 4.2	-8.07* (-6.7 to -9.5)	1.94	1.2 (2.4 to -0.1)	0.34
(kg m^{-2})	G	34.2 ± 3.4	27.7 ± 2.7	28.4 ± 3.0	-6.5* (-5.0 to -8.0)	1.91	0.7 (2.1 to -0.7)	0.27
Waist circum.	B	110 ± 12	90 ± 8	92 ± 11	-20* (-15 to -25)	1.70	3 (6 to -1)	0.32
(cm)	G	110 ± 11	96 ± 12	94 ± 10	-14* (-9 to -19)	1.23	-2 (3 to -7)	0.17
Hip circum.	B	104 ± 9	91 ± 7	93 ± 8	-13* (-11 to -16)	1.51	2 (5 to -1)	0.26
(cm)	G	113 ± 8 †	103 ± 10 †	103 ± 8 †	-10* (-8 to -15)	1.24	0 (3 to -4)	0.05
Waist hip^{-1}	B	1.05 ± 0.05	0.99 ± 0.05	0.99 ± 0.05	-0.06* (-0.04 to -0.09)	1.33	0.01 (0.01 to 0.00)	0.12
	G	0.97 ± 0.06 †	0.93 ± 0.04†	0.91 ± 0.05 †	-0.04* (-0.01 to -0.07)	0.65	-0.01 (0.00 to -0.05)	0.35
VO_2max	B	2.77 ± 0.69	2.86 ± 0.58	2.82 ± 0.46	0.09 (0.32 to -0.13)	0.03	-0.04 (0.21 to -0.29)	0.07
(l/min)	G	2.59 ± 0.40	2.47 ± 0.48	2.45 ± 0.44	0.12 (0.39 to -0.29)	0.37	-0.02 (0.20 to -0.25)	0.05
VO_2max FFM^{-1}	B	51.29 ± 2.87	53.71 ± 3.91	51.42 ± 7.63	2.42 (5.22 to -0.38)	0.84	-2.29 (1.70 to -6.27)	0.58
(ml kg^{-1} min^{-1})	G	49.24 ± 4.88	49.75 ± 4.60	49.10 ± 3.30	0.51 (4.28 to -3.27)	0.10	-0.65 (4.04 to -5.35)	0.14
HR max	B	197 ± 7	191 ± 11	188 ± 14	-6 (2 to -13)	0.76	-3 (1 to -8)	0.28
(bpm)	G	198 ± 11	194 ± 14	193 ± 11	-4 (0.34 to -8)	0.35	-1 (-4 to -6)	0.08
[La] max	B	6.95 ± 2.37	4.78 ± 1.34	4.21 ± 1.20	-2.17* (-0.28 to -4.07)	0.92	-0.57 (0.29 to -1.42)	0.42
(mmol l^{-1})	G	7.36 ± 2.14	6.31 ± 2.98	5.67 ± 2.61	-1.05 (1.43 to -3.53)	0.49	-0.64 (0.47 to -1.75)	0.22

Values are expressed as means and SD. *: significantly different, P<0.05; †: significantly different between genders, P<0.05; 95% CI: 95% confidence interval; ES: effect size.

VO_2max, maximal oxygen consumption; VO_2max FFM, maximal oxygen consumption normalized for fat-free mass; HR max, maximal heart rate; [La] max, maximal blood lactate concentration.

Table 2. Changes in body composition of adolescents (Boys, B; Girls, G) before the beginning (M0). at completion of the weight-reduction program (M9). and four months later (M13).

		M0			M9			M13			ΔM9-M0			ΔM13-M9		
		Mean	±	SD	Mean	±	SD	Mean	±	SD	diff	(95%CI)	ES	diff	(95%CI)	ES
Total body																
Fat-free mass	B	54.21	±	14.46	53.77	±	13.29	56.24	±	13.95	-0.44	(1.33 to -2.21)	0.03	2.47*	(4.35 to 0.60)	0.19
(kg)	G	53.67	±	8.62	50.46	±	7.76	49.88	±	8.71	-3,20*	(-1.57 to -4.83)	0.37	-0.58	(0.86 to -2.02)	0.07
Fat mass	B	35.61	±	6.41	17.62	±	6.40	19.96	±	7.93	-17.99*	(-13.36 to -22.62)	2.57	2.34	(5.65 to -0.38)	0.37
(kg)	G	40.56	±	7.84 †	28.09	±	7.29 †	28.32	±	7.27 †	-12.46*	(-10.01 to -14.91)	1.61	0.23	(3.32 to -2.88)	0.03
Fat mass	B	42	±	4	30	±	7	32	±	8	-12.11*	(-8.45 to -15.77)	3.38	2	(4.20 to -0.92)	0.27
(%)	G	43	±	4	34	±	7	33	±	7	-8.93*	(-6.08 to -11.78)	2.03	-1	(0.81 to -4.15)	0.14
Arms																
Fat-free mass	B	5.66	±	1.84	5.61	±	1.68	6.07	±	1.93	0,05	(0.22 to -0.32)	0.00	0.46*	(0.80 to 0.12)	0.27
(kg)	G	5.21	±	0.93	4.98	±	1.06	4.71	±	0.97	-0.23	(0.04 to -0.49)	0.25	-0.27	(0.01 to -0.55)	0.26
Fat mass	B	4.24	±	0.65	2.29	±	0.55	2.39	±	0.60	-1.96*	(-1.51 to -2.40)	3.16	0.10	(0.37 to -0.17)	0.18
(kg)	G	4.53	±	0.77 †	3.33	±	0.93 †	3.28	±	0.83 †	-1.19*	(-0.80 to -1.59)	2.94	-0.05	(0.37 to -0.47)	0.05
Legs																
Fat-free mass	B	18.40	±	5.09	18.56	±	4.71	19.52	±	4.76	0.16	(1.10 to -0.78)	0.03	0.96*	(1.61 to 0.30)	0.20
(kg)	G	18.92	±	3.59	17.88	±	4.09	17.22	±	3.58	-1.04*	(-0.10 to -1.96)	0.29	-0.66	(0.42 to -1.74)	0.16
Fat mass	B	13.87	±	2.59	7.79	±	1.73	8.61	±	2.06	-6.07*	(-4.29 to -7.85)	2.35	0.82	(1.76 to -0.12)	0.47
(kg)	G	15.61	±	3.19 †	11.30	±	3.36 †	10.98	±	2.31 †	-4.30*	(-3.34 to -5.27)	1.35	-0.32	(0.83 to -1.49)	0.10
Trunk																
Fat-free mass	B	26.23	±	7.35	25.72	±	6.57	26.57	±	6.90	-0.51	(0.45 to -1.48)	0.07	0.85	(1.98 to 0.27)	0.13
(kg)	G	25.77	±	4.03	23.92	±	2.85	24.39	±	4.03	-1.85*	(-0.35 to -3.36)	0.46	0.47	(2.00 to -1.06)	0.17
Fat mass	B	16.49	±	4.38	6.74	±	2.31	8.12	±	3.54	-9.75*	(-7.11 to -12.38)	2.22	1.37	(3.00 to -0.25)	0.59
(kg)	G	19.44	±	4.35 †	12.51	±	4.06 †	13.15	±	3.96 †	-6.93*	(-5.39 to 8.46)	1.59	0.64	(2.37 to -1.10)	0.16

Values are expressed as means and SD. *: significantly different, P<0.05; †: significantly different between genders, P<0.05; 95% CI: 95% confidence interval; ES: effect size.

Table 3. Changes in spirometry parameters of adolescents before the beginning (M0), at completion of the weight-reduction program (M9), and four months later (M13).

		M0			M9			M13			ΔM9-M0			ΔM13-M9		
		Mean	±	SD	Mean	±	SD	Mean	±	SD	diff	(95%CI)	ES	diff	(95%CI)	ES
FVC (L)	B	3.67	±	0.90	3.92	±	1.05	4.05	±	1.04	0.25*	(0.42 to 0.08)	0.28	0.13*	(0.25 to 0.01)	0.13
	G	3.68	±	0.41	3.75	±	0.46	3.84	±	0.53	0.1	(0.17 to -0.03)	0.17	0.09	(0.27 to -0.10)	0.19
FVC (% p)	B	97.7	±	12.6	99.3	±	12.1	98.4	±	12.7	1.6	(6.4 to -3.2)	0.13	-0.8	(6.8 to -3.5)	0.07
	G	108.6	±	5.6	106.0	±	9.9	105.3	±	8.0	-2.6	(3.3 to -8.5)	0.46	-0.8	(4.75 to -6.25)	0.08
FEV1 (L)	B	3.25	±	0.70	3.53	±	0.89	3.68	±	0.81	0.28*	(0.49 to 0.07)	0.41	0.15	(0.34 to -0.04)	0.17
	G	3.19	±	0.37	3.28	±	0.41	3.31	±	0.45	0.1	(0.19 to -0.03)	0.22	0.03	(0.16 to -0.09)	0.08
FEV1 (% p)	B	100.3	±	11.8	103.4	±	10.6	101.8	±	10.7	3.2	(9.1 to -2.7)	0.27	-1.6	(4.6 to -7.7)	0.15
	G	106.0	±	7.4	105.8	±	10.2	104.1	±	10.2	-0.2	(6.1 to -6.4)	0.02	-1.8	(3.0 to -6.5)	0.17
FEV1/FVC	B	0.89	±	0.04	0.91	±	0.04	0.92	±	0.07	0	(0.03 to -0.00)	0.35	0.01	(0.05 to -0.02)	0.28
	G	0.87	±	0.05	0.87	±	0.05	0.86	±	0.06	0	(0.03 to -0.02)	0.11	-0.01	(0.00 to -0.03)	0.20

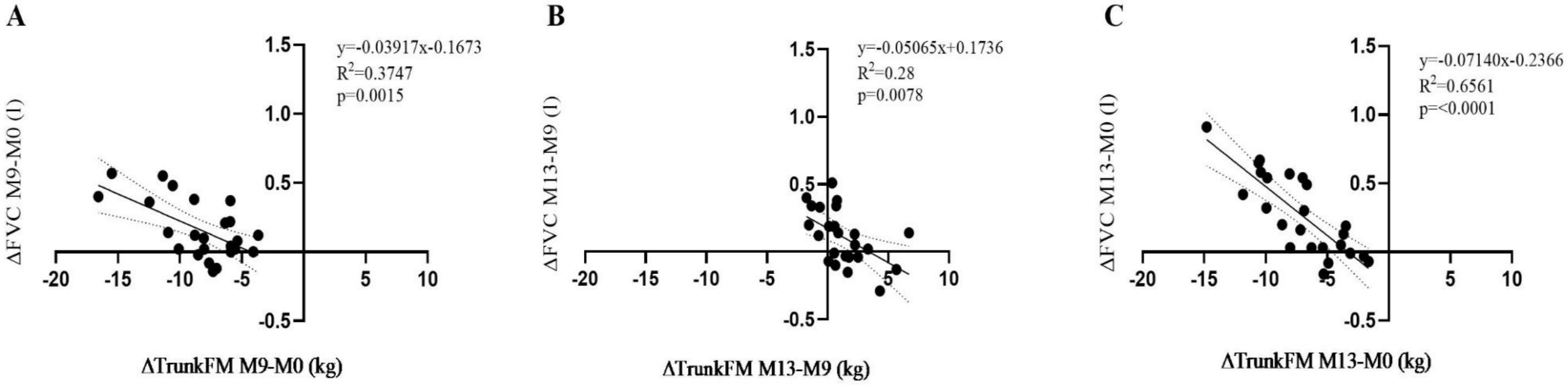
Values are expressed as means and SD. *: significantly different, $P<0.05$; 95% CI: 95% confidence interval; ES: effect size; B, boys; G, girls. FVC, forced vital capacity; FEV1, forced expiratory volume in 1 sec; (% p), values as percentage of reference (predicted) values.

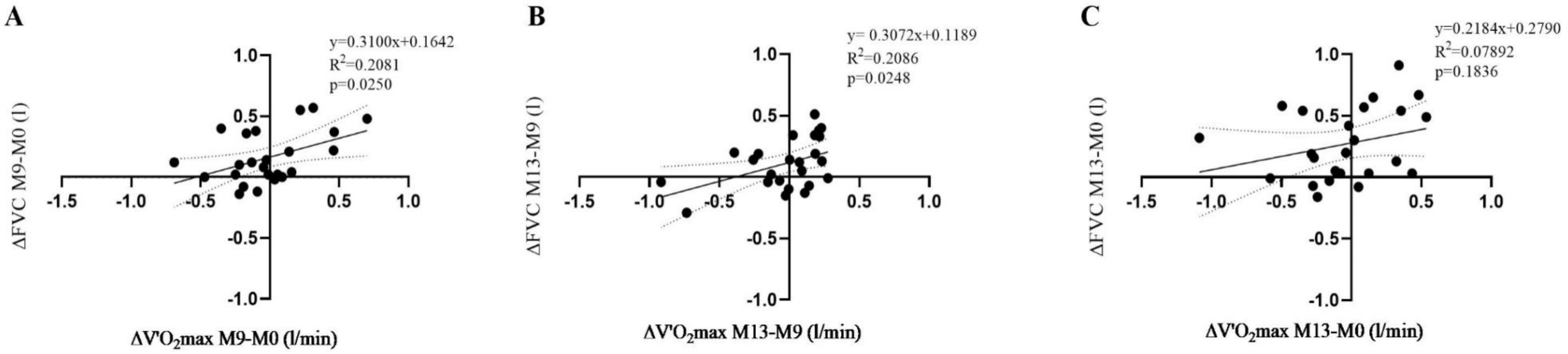
Figure Legends

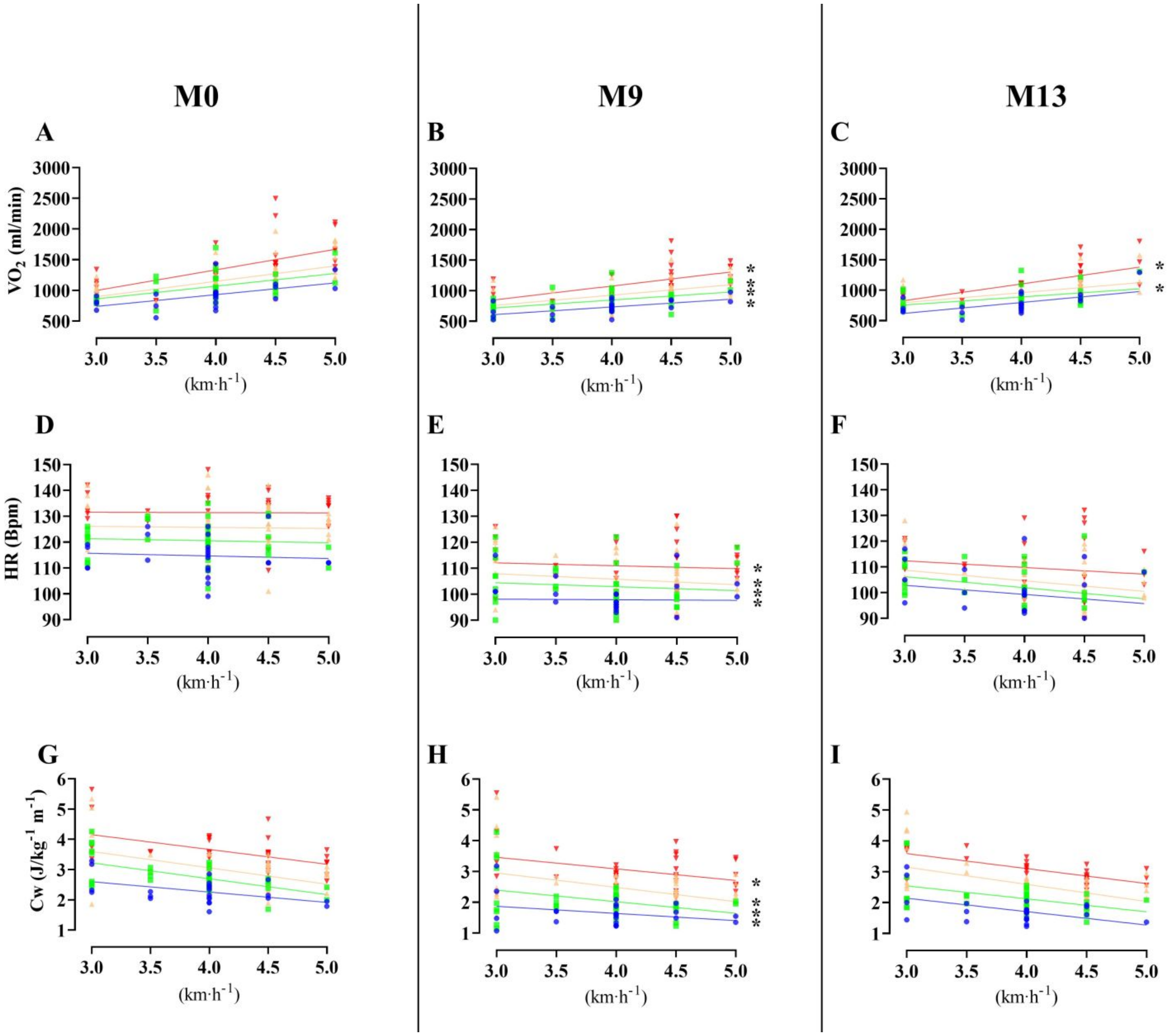
Figure 1. Linear regression between changes in FVC (ΔFVC) and Trunk Fat Mass (ΔTrunkFM, kg) at M9-M0 (panel A), M13-M9 (panel B) and M13-M0 (panel C).

Figure 2. Linear regression between changes in FVC (ΔFVC) and $V'O_2$max ($\Delta V'O_2$max) at M9-M0 (panel A), M13-M9 (panel B) and M13-M0 (panel C).

Figure 3. Changes in oxygen consumption ($V'O_2$, mL min^{-1}; panels A, B and C), Heart Rate (HR, bpm; panels D, E and F) and energy Cost of walking (Cw, J kg^{-1} m^{-1}; panels G, H and I) as a function of speed (km h^{-1}) and slope (0 ---, 2 ---, 4 --- and 6 --- %) of adolescents. Before the beginning (M0; panels A, D and G) at completion of the weight-reduction program (M9; panels B, E and H), and four months later (M13; panels C, F and I).


A
y=-0.03917x-0.1673
R²=0.3747
p=0.0015
ΔFVC M9-M0 (l)
ΔTrunkFM M9-M0 (kg)
1.5
1.0
0.5
-0.5
-20
-15
-10
-5
5
10
B
y=-0.05065x+0.1736
R²=0.28
p=0.0078
ΔFVC M13-M9 (l)
ΔTrunkFM M13-M9 (kg)
C
y=-0.07140x-0.2366
R²=0.6561
p=<0.0001
ΔFVC M13-M0 (l)
ΔTrunkFM M13-M0 (kg)


A
y=0.3100x+0.1642
R2=0.2081
p=0.0250
ΔFVC M9-M0 (l)
ΔV'O2max M9-M0 (l/min)
1.0
0.5
-0.5
-1.0
-1.5
-1.0
-0.5
0.5
1.0
B
y= 0.3072x+0.1189
R2=0.2086
p=0.0248
ΔFVC M13-M9 (l)
ΔV'O2max M13-M9 (l/min)
1.0
0.5
-0.5
-1.0
-1.5
-1.0
-0.5
0.5
1.0
C
y=0.2184x+0.2790
R2=0.07892
p=0.1836
ΔFVC M13-M0 (l)
ΔV'O2max M13-M0 (l/min)
1.0
0.5
-0.5
-1.0
-1.5
-1.0
-0.5
0.5
1.0



*. significantly different from M0: $p<0.05$