

Dual-energy X-ray absorptiometry and forced expiratory volumes in sedentary and trained children

Absorciometria dual de rayos x y volúmenes espirométricos forzados en niños sedentarios y entrenados

**Álvaro Fernández-Luna¹, María Plaza-Carmona², Esther Ubago-Guisado², Ignacio Ara³,
María Martín-García³, Jorge García-Unanue⁴ & Leonor Gallardo²**

1. Universidad Europea de Madrid. España
2. Grupo IGOID. Universidad de Castilla-La Mancha. España
3. Grupo de Investigación GENUID-Toledo. Universidad de Castilla-la Mancha. España
4. Universidad Europea de Madrid. Grupo IGOID. Universidad de Castilla-La Mancha. España

Resumen

Information regarding the influence of physical activity and fat mass in the human trunk on respiratory health is scarce. The aim of this study was to evaluate the influence of body composition and physical activity in forced expiratory volumes in children. The sample comprised 87 children between 8 and 13 years of age (9.62 ± 1.25), at Tanner stages I-III, participated in this study. Sixty played sports (trained children, TC) and 27 were assigned to the sedentary children control group (SC). Body composition (DXA), anthropometric variables (weight and height), and forced expiratory volumes (FEV1 and FVC) were determined in all subjects. Results showed that higher FEV1 and FVC values were found in the SC group compared to the TC group. Multiple regression analysis showed that physical activity, total fat mass, and android fat mass, had the highest predictive value for FEV1 as did height for the FVC. In SC group there was a positive association between FEV1/FVC ratio and Body Mass Index and trunk fat mass. We did not find any associations between forced respiratory volumes and the whole body and trunk region fat mass in trained and sedentary children.

Key words: DXA; fat mass; forced expiratory volumes; physical activity.

Abstract

La información sobre los diferentes efectos de la actividad física y la masa grasa del tronco en la salud respiratoria es escasa. El objetivo fue evaluar la influencia de las variables de composición corporal y la práctica de actividad física en los volúmenes espirométricos forzados en edad infantil. 87 niños entre los 8 y 13 años ($9,62 \pm 1,25$) (Tanner I-III) participaron en el estudio. 60 practicaban diferentes deportes (niños entrenados, TC) y 27 niños sedentarios fueron asignados al grupo control (SC). Se llevó a cabo la evaluación en todos los participantes de la composición corporal a través de DEXA, variables antropométricas (peso y altura) y volúmenes espirométricos forzados (FEV1 and FVC). Los resultados mostraron que el grupo SC tenía unos volúmenes FEV1 y FVC superiores respecto al grupo TC. El análisis de regresión múltiple indica que la actividad física, la masa grasa total y el porcentaje de grasa del segmento androide son las variables con mayor valor predictivo para los volúmenes de FEV1, mientras que la altura lo es para la FVC. En el grupo SC se observó una relación positiva entre el índice de masa corporal, la masa grasa en tronco y el ratio FEV1/FVC. No se encontró ninguna relación entre los volúmenes respiratorios forzados y la cantidad de masa grasa en el tronco y en el cuerpo entero en el grupo de niños sedentarios ni en los que realizaban actividad física.

Palabras clave: actividad física; DXA; masa grasa; volúmenes espirométricos forzados.

Correspondencia/correspondence: Álvaro Fernández Luna
Universidad Europea de Madrid. España
Email: alvaro.fernandez2@uem.es

Introduction

Obesity and overweight are one of the main health diseases in children worldwide. World Health Organization recognizes obesity within diseases with coronary risks (WHO, 1997). In this line, levels of obesity are associated with respiratory symptoms regardless of ethnicity (Figuroa-Muñoz, Chinn, & Rona, 2001). Moreover, asthma is the most typical chronic respiratory disease in children, affecting their quality of life (Astudillo, 2003). Recently, governments of different countries are making an effort to prevent health problems associated to obesity in children. For this cause, they have started different types of campaigns against sedentary behaviors and promoting good health habits, such as healthy diets and sports. Sports is the most popular activity to fight obesity.

The main effects of obesity and overweight in respiratory health are: reduced forced residual capacity (FRC) and tidal volume, breathing at lower lung volumes and reduced changes in airway calibre during efforts (Boulet, 2012). Different studies have shown the relation between the increasing of obesity and the development of asthma in postpubertal male and female (Ford, Mannino, Redd, Mokdad, & Mott, 2004), and only in male (Huovinen, Kaprio, & Koskenvuo, 2003). However, obesity is not considered to induce any significant airway obstruction by other authors (Thomsen, Ulrik, Kyvik, Sørensen, Posthuma, Skadhauge, Steffensen & Backer, 2007).

Forced expiratory volumes are considered by far the most well-established outcome variable in pulmonary diseases as chronic obstructive pulmonary disease (COPD) and asthma (Rabe, 2004). These volumes are used as respiratory health improving predictor after sport in cross sectional and longitudinal studies. The volumes more frequently used in this area of research are forced expiratory volume in 1 second (FEV1) and forced vital capacity (FVC) (Cheng, Macera, Addy, Sy, Wieland, & Blair, 2003; Pellegrino, Viegi, Brusasco, Crapo, Burgos, Casaburi, Coates, van der Grinten, Gustafsson, Hankinson, Jensen, Johnson, MacIntyre, McKay, Miller, Navajas, Pedersen & Wanger, 2005). It has been observed that FEV1 and FVC values were significantly lower in overweight children (Figuroa et al., 2001) and higher in trained children (Cheng et al., 2003). Other studies had showed an improvement in FEV1 and FVC in persons with COPD or asthma that have participated in a physical activity program (Denguezli, Ben Chiekh, Ben Saad, Zaouali-Ajina, Tabka, & Zbidi, 2008; McNamara, Alison & McKeough, 2011).

For many years, the most used method to establish obesity has been the Body Mass Index (BMI). In a recent study, the fat mass has been related with the respiratory function in adults using dual-energy X-ray absorptiometry (DXA) (Sutherland, Goulding, Grant, Cowan, Williamson, Williams, Skinner, & Taylor, 2008). DXA scanning allows to differentiate fat mass, lean mass and bone mass with high image quality and giving the same data as other measure systems like the skin-fold thickness and bioelectrical impedance (Wattanapenpaiboon, Lukito, Strauss, Hsu-Hage, Wahlqvist & Stroud, 1998). DXA system gives us the exactly percentage of body fat mass and the different percentage of body segments (trunk, arms, legs...).

DXA system will allow us to know the amount of fat mass that covers the lung chest and abdomen. Using DXA and spirometry we can make a relation between the respiratory function and the fat mass of trunk region. Thus the main objective of this research is to measure the fat mass values in full body and trunk and forced expiratory volumes in a sample of sedentary and trained prepubertal children, and to measure how the fat mass in trunk and physical activity affects to the forced expiratory volumes at this age.

Methods

Participants

Participants were recruited from different schools and sports clubs in Toledo and Madrid (Spain). Initially, they were recruited into two groups: Sedentary (SC) and Trained (TC) children. In total, 87 subjects were recruited. TC trained at least three days per week in sports clubs, and SD only undertook physical education in school. Both groups were between 8 and 14 years old and in a similar sexual development stage (Tanner's Stage I-III). Participants' parents were fully informed of the nature and possible risks associated with the study before they volunteered to participate, and after their parents signed to give their informed consent. The children answered a medical and a general questionnaire that included information regarding the number of hours of physical activity, medication, and any known diseases. The exclusion criteria for participants included passive smokers and those who suffer from asthma, chronic obstructive pulmonary disease or allergies.

Statistical power was previously considered. Sample size was calculated using the variables of interest with more variability, FEV1 and trunk fat mass, to get a power of 99,0% to detect differences in the contrast of null hypothesis $H_0: \mu_1 = \mu_2$ with a bilateral Student t-test for two independent samples. Taking into account that significance level is 1%, and assuming that the mean of the reference group is 1,20 units, the mean of the experimental group is 1.25 units and standard deviation of both groups is 0,02 units, it will be needed to include 10 experimental units in the reference group. In accordance to these calculations, all groups included in the study had at least 10 subjects.

The study was approved by the Clinical Research Ethical Committee of Castilla-La Mancha University (CEIC) (13/10) and the experiments conformed to The Declaration of Helsinki. None of the participants were on medication at the time of the study.

Procedure

Pubertal status assessment

The pubertal status of subjects was determined by auto-evaluation, a method of recognized validity and reliability, the test classifies adolescents in one of the five states that provide pubertal maturity (Duke, Litt, & Gross, 1980). This test has been used in different studies related to bone accretion and sports practice (Karlsson MK, Nordqvist A, & Karlsson, 2008; Plaza-Carmona, Vicente-Rodriguez, Martín-García, Burillo, Felipe, Mata, Casajús, Gallardo, & Ara, 2014; Ubago-Guisado, Gómez-Cabello, Sánchez-Sánchez, García-Unanue, & Gallardo, 2015).

Fat Mass

The fat mass was measured using dual-energy X-ray absorptiometry (DXA) (Hologic Serie Discovery QDR., Software Physician's Viewer, APEX System Software Version 3.1.2. Bedford, MA, USA). DXA equipment was calibrated using a lumbar spine phantom and following the Hologic guidelines. Subjects were scanned in supine position and the scans were performed at high resolution. Fat mass (g), total area (cm²), and body mass index (BMI) were calculated from total and regional analysis of the whole body scan.

Respiratory Function

A forced pulmonary function test was used to assess the respiratory function parameters FEV1, FVC and FEV1/FVC using a portable spirometer (Spirobank II, Medical International

Research slr, Rome, Italy), following standard recommendations (Miller, Hankinson, Brusasco, Burgos, Casaburi, Coates, Crapo, Enright, van der Grinten, Gustafsson, Jensen, Johnson, MacIntyre, McKay, Navajas, Pedersen, Pellegrino, Viegi & Wanger, 2005). FEV1 and FVC volumes were expressed in liters (L).

Statistical Analysis

Results are presented as a mean \pm SD, if not otherwise stated. All the residuals showed a satisfactory pattern (normal distribution). Analysis of covariance (ANCOVA) was performed to evaluate differences in the fat masses, establishing as covariates height, body mass, age and Tanner. A multiple linear regression and a partial correlation (adjusted for age and height) were applied to identify the relationship among physical activity, fat mass in trunk and whole body, and forced expiratory volumes. For controlling the practice or not of physical activity and gender in the regression analysis, we create a variable that takes values of 0 if for SC and 1 for TC, and another variable that takes values of 0 for males and 1 for females. SPSS 21.0 package (IBM, Chicago, USA) for personal computers was used for the statistical analysis. Significant differences were assumed when $p < .05$.

Results

Table 1 summarizes general characteristics of participants. Both groups had a medium comparable age and Tanner's sexual development stage. SC group was heavier than TC with higher total and trunk fat. TC had a lower BMI as well. In addition SC group showed 14 points higher in % trunk fat, and 11 points higher in % body fat.

Table 1. Characteristics of participants

	Trained Children (n=60)		Sedentary Children (n=27)		<i>p value</i>
Age (y)	8.8667 \pm 0.9472	(8-13)	10.1852 \pm 1.6650	(7-13)	<.001
Height (cm)	137.1500 \pm 8.6570	(115-171)	144.1852 \pm 9.8020	(127-168)	<.001
Weight (kg)	32.6167 \pm 8.4635	(20-64)	50.4815 \pm 16.4021	(27-81)	<.001
BMI (kg/m ²)	17.0443 \pm 2.4652	(13.4-24.1)	22.3115 \pm 7.0698	(10.7-32.23)	<.001
Tanner stage	1.5500 \pm 0.5652	(1-3)	1.8889 \pm 0.5774	(1-3)	0.014
FEV1 (L)	2.1537 \pm 0.4318	(1.42-3.54)	2.5759 \pm 0.4593	(1.54-3.37)	<.001
FVC (L)	1.8703 \pm 0.3614	(1.25-3.04)	2.1563 \pm 0.3999	(1.47-2.97)	<.001
FVE1/FVC (%)	87.0600 \pm 5.3913	(75.5-98.2)	83.8370 \pm 6.4082	(71.6-97.4)	0.023
Total Fat mass (kg)	8.1510 \pm 4.4187	(3.26-30.37)	11.5596 \pm 4.1523	(3.97-19.13)	<.001
Total Fat mass (%)	25.3233 \pm 5.9399	(12.4-39)	36.1456 \pm 11.5205	(14.2-53.7)	<.001
Trunk Fat mass (kg)	2901.6670 \pm 2047.5500	(1085-13547)	8644.560 \pm 5173.6090	(1312-19138)	<.001
Trunk Fat mass (%)	20.8828 \pm 7.0737	(9.85-47.7)	34.9100 \pm 12.9632	(11.1-54.9)	<.001
Android Fat mass (kg)	543.3333 \pm 646.1360	(150-4560)	1371.9889 \pm 824.0379	(180-3411)	<.001
Android Fat mass (%)	21.6648 \pm 8.6973	(8.81-53.1)	40.1407 \pm 15.8282	(11.8-61.2)	<.001
Gynoid Fat mass (kg)	1550.7000 \pm 715.60540	(547-4740)	3314.6667 \pm 1667.5388	(677-6239)	<.001
Gynoid Fat mass (%)	30.6570 \pm 6.5023	(14.6-48.2)	42.5074 \pm 10.8015	(18.6-60.5)	<.001
Android/Gynoid rate	0.6928 \pm 0.1670	(0.44-1.12)	0.9104 \pm 0.1911	(0.5 -1.22)	<.001
Data are presented as mean \pm SD (range)					

Multiple regression analysis (Table 2) showed that physical activity, height and gender were the variables with significant predictive value for the FVE1, while height was for the FVC. Moreover, physical activity has a positive predictive value for the FVE1/FVC coefficient.

Table 2. Regression Model.

	FEV1	FVC	FEV1/FVC %
Physical Activity Practice	-0.171* (-2.371)	-0.037 (-0.558)	4.502** (2.755)
Gender	-0.135* (-2.299)	-0.075 (-1.386)	1.493 (1.117)
Age (y)	-0.027 (-1.059)	0.002 (0.073)	0.992 (1.695)
Height (cm)	0.040*** (10.218)	0.031*** (8.614)	-0.163 (-1.818)
BMI (kg/m2)	-0.003 (-0.408)	0.002 (0.370)	0.222 (1.362)
Total Fat Mass (kg)	0.007 (0.982)	0.005 (0.805)	-0.030 (-0.186)
Constant	-2.942*** (-6.427)	-2.442*** (-4.835)	92.151*** (8.858)
R-squared	0.750	0.690	0.140
F	39.926***	29.730***	2.169
Significance: *p<0.05; **p<0.01; ***p<0.001. T-values in parenthesis.			

Table 3 shows the relationship between forced expiratory volumes and parameters measured by dual-energy X-ray absorptiometry. Data were adjusted for age and height. We can observe in SC a positive association in SC between FEV1/FVC and BMI trunk fat mass, android-gynoid fat mass and android-gynoid rate.

Table 3. Relationship between forced expiratory volumes and variables measured by DXA.

	All Sample (n=87)			Trained Children (n=60)			Sedentary Children (n=27)		
	FEV1	FVC	FEV1/FVC	FEV1	FVC	FEV1/FVC	FEV1	FVC	FEV1/FVC
BMI (kg/m2)	0.021	0.054	0.064	0.012	0.038	0.048	-0.383	-0.032	0.437*
Total fat mass (kg)	0.136	0.110	-0.036	0.032	0.024	-0.023	0.222	0.327	0.222
Trunk fat mass (kg)	0.088	0.067	-0.011	0.027	0.027	0.001	-0.357	-0.033	0.437*
Android fat mass (kg)	0.033	0.085	0.102	0.041	0.081	0.079	-0.360	-0.006	0.469*
Gynoid fat mass (kg)	0.065	0.067	0.023	-0.013	0.008	0.007	-0.274	0.041	0.431*
Android gynoid rate	0.058	0.096	0.107	-0.026	-0.033	0.149	-0.207	0.141	0.514**
Data are presented as partial correlations for DXA-derived variables adjusted for age and height. Significance: *p<0.05; **p<0.01; ***p<0.001.									

Discussion

The main finding of the present study is that trained children and sedentary children did not show any association between forced respiratory volumes and the fat mass of whole body and trunk region. One of the causes that could explain our results is that the pre-puberty the lungs are still growing (Rosenthal, Cramer, Bain, Denison, Bush & Warner, 1993) and the fat mass maybe has not a direct effect on this development. Additionally lower BMI and fat mass were found in TC respect to SC.

Previously, the relationships between obesity and respiratory function have been described using a variety of body fat measures (Chen, Rennie, Cormier, & Dosman, 2007; Watson, Pride, Thomas, Ind, & Bell, 2012). The current study is one of the first to explore the relationships between fat mass and respiratory function using DXA scanning in otherwise healthy children with a wide range of BMI.

Moreover, results suggest weak evidence that physical activity affects positively the respiratory function. This has been shown in other studies where healthy populations have been trained during a short period of time (Fernández-Luna, Gallardo, Plaza-Carmona, García-Unanue, Sánchez-Sánchez, Felipe, Burillo & Ara, 2013) and over a year (Bottai, Pistelli, Di Pede, Carrozzi, Baldacci, Matteelli, Scognamiglio & Viegi, 2002). However, the physical activity could affect negatively to the FEV1/FVC ratio, as a main indicator of respiratory diseases (Mannino, Gagnon, Petty & Lydick, 2000). This could be associated to the hypothesis that some sports could affect the respiratory health (Carlsen, Anderson, Bjermer, Bonini, Brusasco, Canonica, Cummiskey, Delgado, Del Giacco, Drobic, Haahtela, Larsson, Palange, Popov & van Cauwenberge, 2008).

The BMI has been used in several studies to assess the effects of this variable in asthmatic (Bafadhel, Singapuri, Terry, Hargadon, Monteiro, Green, Bradding, Wardlaw, Pavord & Brightling, 2010) and healthy population (Luder, Ehrlich, Lou, Melnik & Kattan, 2004). The last longitudinal study showed that the gain of weight is associated with lung function, but heavy subjects had a less gain of lung volumes than thinner subjects. In the present study the BMI, trunk fat mass, android-gynoid fat mass and all the percentages of fat mass are positively associated with the FVE1/FVC percentage in sedentary children. For this reason, it could be interesting to carry out a longitudinal testing of all participants to contrast the results with other investigations.

As a main finding in our study, the percentages of whole body fat mass, trunk, gynoid and android fat mass have not relation with the forced expiratory volumes in the participants. According to this, recently other authors have directly compared the effect of both thoracic fat and abdominal fat on respiratory function and found them to be equivalent in a healthy population of adults (Sutherland et al., 2008). This supports the hypothesis that abdominal fat not only may impede diaphragmatic position and fluttering during inspiration (Gibson, 2000), but also that thoracic deposition of fat may alter chest wall recoil (Lazarus, Gore, Booth & Owen, 1998). In our case, we used the data of android and gynoid fat mass obtained from the DXA equipment and software, and we can observe that both had a positive association with the FVC/FEV1 ratio in sedentary group, even it is well known that gynoid fat mass only involves the abdominal region and hips where there are no muscles that work in the respiratory mechanics.

Some limitations of this study deserve comments. One of this is that the amount of physical activity has not been quantitatively (MET, minutes per week) measured and some participants make more than one sport (i.e. football and swimming) despite most of the sample were footballers. It would have been interesting to increase the number of subjects for each group, especially sedentary children. On the other hand, due to the cross-sectional design of this study we cannot assure the causality of the observations.

To our knowledge, the combination of sophisticated methods, such as DXA, to assess the fat mass in children, and the assessment of the different forced expiratory volumes could represent one of the biggest strengths of the present study. Despite of this, we have not confirmed that there is a significant effect of adiposity on respiratory function in children.

Conclusions

The current study provides weak evidence that the effect of adiposity on respiratory function is different in trained and sedentary children. While sedentary children have a negative association between lung volumes and some percentages of fat mass in trunk and total body fat mass, trained children did not show any association between these variables.

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