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Efectos de un entrenamiento de la musculatura respiratoria sobre la función pulmonar en adolescentes con sobrepeso y obesidad

Effects of respiratory muscle training on lung function in adolescents with overweight and obesity

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Abstract. The prevalence of overweight and obesity in adolescents has reached alarming rates globally, with significant implications for health, including compromised lung function. This study investigated the effects of progressive respiratory muscle training (RMT) on lung function in overweight and obese adolescents. A quasi-experimental design was employed with 28 participants, randomly assigned to RMT or control groups. Lung function was assessed using spirometry and pymometry before and after an 8-week intervention. Results revealed significant improvements in spirometry variables (FEV1, FVC, PEF, FEF25, FEF50, FEF75, FEF25-75) and pymometry variables (MIP, MEP) in the RMT group compared to controls. However, no significant changes were observed in the restrictive ventilatory pattern. The findings suggest that isolated RMT enhances lung function and respiratory muscle strength in overweight and obese adolescents. Future interventions should consider combining RMT with strategies to reduce BMI for comprehensive improvements in respiratory health in this population.

Keywords: Respiratory muscle training; lung function; spirometry; overweight; obesity; adolescents.

Resumen. La prevalencia del sobrepeso y la obesidad en adolescentes ha alcanzado tasas alarmantes a nivel mundial, con implicaciones significativas para la salud, incluido el deterioro de la función pulmonar. Este estudio investigó los efectos del entrenamiento de la musculatura respiratoria (EMR) sobre la función pulmonar en adolescentes con sobrepeso y obesidad. Se empleó un diseño cuasiexperimental con 28 participantes, asignados aleatoriamente a grupos de EMR y control. La función pulmonar se evaluó mediante espirometría y pimometría antes y después de una intervención de 8 semanas. Los resultados revelaron mejoras significativas en las variables de espirometría (FEV1, FVC, PEF, FEF25, FEF50, FEF75, FEF25-75) y las variables de pimometría (PIM, PEM) en el grupo de EMR en comparación con los controles. Sin embargo, no se observaron cambios significativos en el patrón ventilatorio restrictivo. Los hallazgos sugieren que el EMR aislado mejora la función pulmonar y la fuerza de los músculos respiratorios en adolescentes con sobrepeso y obesidad. Las intervenciones futuras deben considerar la combinación de EMR con estrategias de reducción del IMC para lograr mejoras integrales en la salud respiratoria en esta población.

Palabras clave: Entrenamiento de la musculatura respiratoria; función pulmonar; espirometría; sobrepeso; obesidad; adolescentes.

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Introduction

Overweight and obesity are defined as abnormal and excessive accumulations of fat mass manifested as excess weight and body volume, which can be detrimental to health (Ng et al., 2014). The prevalence of overweight and obesity in children and adolescents (aged 5 to 19 years) has experienced an alarming increase, from 4% in 1975 to more than 18% in 2016, with similar rates in both sexes (World Health Organization, 2021). This increase in adolescent obesity is worrying since, according to projections, approximately 80% of obese adolescents will still be obese in adulthood, and around 70% will be obese over age 30 (Simmonds et al., 2016). Furthermore, it has been reported that in this age group, unhealthy lifestyles promote the development of obesity and associated changes to physical health such as deterioration of cardiorespiratory capacity (Concha et al., 2024; Rodriguez-Canales et al., 2022).

On the other hand, obese adolescents have a higher risk of developing chronic conditions such as type 2 diabetes, hypertension, dyslipidemia, and cardiovascular diseases (Kansra et al., 2021; Cardoso et al., 2022). Also, Obesity in adolescents can have negative effects on pulmonary function. Obesity causes mechanical compression of the diaphragm, lungs, and chest cavity, which can lead to restrictive pulmonary damage (Mafort et al., 2016; Salome et al., 2010). Fat deposition on the chest wall, abdomen, and upper airway can also cause direct mechanical changes (Mafort et al., 2016). Along the same line, the accumulation of fat in individuals with obesity causes chronic systemic inflammation (Guzmán-Muñoz et al., 2024). This may have a detrimental effect on skeletal muscle by promoting muscle protein breakdown, which can impair muscle function (Guzmán-Muñoz et al., 2024; Straight et al., 2021). Therefore, it is proposed that in the respiratory system, there would be an alteration in the contraction of the diaphragm muscle.

In this sense, a systematic review revealed that individuals with obesity exhibit diminished lung volume and capacity, with notable reductions in functional residual capacity (FRC), expiratory reserve volume (ERV), and residual volume (RV) (Winck et al., 2016). Also, it has been seen that in people with obesity, there is reduced forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and forced expiratory flow between 25% and 75% of FVC (FEF25–75%) (Winck et al., 2016). Particularly in adolescents with excess weight and obesity, few studies isolated respiratory muscle training and its effect on lung function. A study incorporated 3 weeks of respiratory muscle training

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into a weight reduction program for a group of obese adolescents, resulting in a significant increase in FVC, FEV1, and peak expiratory flow (PEF) (Salvadego et al., 2022).

However, previous studies showed that isolated respiratory muscle training did not significantly modify the spirometric variables evaluated and only a significant increase in maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) was reported (Kaeotawee et al., 2022; Villiot-Danger et al., 2011). Kaeotawee et al. (2022), highlighted that a potential reason for the lack of significant changes in the spirometric variables could be because they did not increase the intensity of the training during the 8 weeks it was applied. Therefore, this study aimed to analyze the effects of progressive respiratory muscle training on lung function in overweight and obese adolescents

Material y methods

This study was quantitative with a quasi-experimental design. All participants voluntarily read and signed an informed assent, while their legal guardians authorized participation by signing an informed consent. The research was approved by the ethics committee of the Universidad Santo Tomás, Chile (N°22-63) and was based on the Declaration of Helsinki.

Participants

A sample size calculation was done with the G*POWER software version 3.1, obtaining a minimum of 12 participants per group. For this calculation, a power of 0.95, an error probability of 0.05, and a loss percentage of 20% were considered. Data from a previous study that considered respiratory muscle training were used, from which a mean difference of 1.3 and standard deviation of 0.2 was established to obtain significant changes in lung function from the variable minute volume (l·min-1) (Segizbaeva & Aleksandrova, 2014). Therefore, the sample was non-probabilistic for convenience, composed of 28 overweight and obese adolescents belonging to a public school in Santiago City (Chile). Fourteen of them were assigned to 8 weeks of isolated respiratory muscle training and another 14 participants were assigned to a control group who did not train for 8 weeks. The inclusion criteria were: (i) ages between 16 and 17 years; (ii) belong to a third-year high school class; (iii) both sexes. Adolescents who presented the following characteristics were excluded: (i) diagnosed cardiac or respiratory pathologies; (ii) acute respiratory symptoms; (iii) general pain or discomfort at the time of the evaluation; (iv) inability to perform pulmonary function tests.

Lung function

Lung function was assessed by spirometry and pymometry before and after 8 weeks of intervention. Spirometry was measured with the Microlab™ brand spirometer (36ML3500MK8). FEV1, FVC, FEV1/FVC, FEF25, FEF50, FEF75 and FEF25-75 were collected and recorded. The strength of the respiratory muscles was assessed by pymometry, performed with a Micromedical-Carefusion brand pymometer Microlab™ RPM model, using the MIP from residual volume to total lung capacity and PEM during forced expiration from total lung capacity to residual volume. The mean of three acceptable maneuvers (without gas leaks and at least 1 second) was considered. The results were expressed according to the reference equations (Mora-Romero et al., 2014). The control group was subjected to these same assessments.

Respiratory muscle training

Respiratory muscle training was carried out over 8 weeks, with a frequency of 2 times per week (total 16 sessions), 20 minutes each session. To begin each session, breathing control exercises were performed at tidal volume. Subsequently, diaphragmatic exercises were performed with a 3-second inhalation and a 6-second pursed-lip exhalation until the residual volume was reached. Also, lung expansion exercises were performed working at vital capacity, and hypopressive exercises controlling breathing and abdominal contraction. The initial intensity was set at 30%, which was adjusted every two weeks by adding 10% resistance, this being progressive training increasing the intensity with inspiratory and expiratory resistance valves and apneas. The density was adapted according to progression, reducing rest times from 1 minute to 30 and 20 seconds between exercises. The volume progressed with the exercise series of 1, 2 to 3 series. All exercises were guided and supervised.

Statistical analysis

GraphPad Prism version 9.0 statistical software was employed for the analysis of both descriptive and inferential data. The descriptive statistics included the calculation of the mean and standard deviation. The Shapiro-Wilk was applied to determine the data distribution. Subsequently, a two-factor mixed ANOVA model with repeated measures was performed to measure the group×time effect of pulmonary function variables. When the time×group interaction was significant, a Bonferroni multiple comparisons test (post hoc) was performed to establish intra-group (pre vs. post) and inter-group (RMT vs. CG) differences. To determine the effect size of the time×group interaction, the partial eta squared (ηp^2) was calculated, which was interpreted considering the ηp^2 values of 0.01, 0.06, and 0.14, which correspond to small effect sizes, medium and large, respectively. For multiple comparisons, the effect size was calculated with Cohen's d, considering a small (≥0.2), moderate (≥0.5), or strong (≥0.8) effect. For all analyses, an α value of 0.05 was considered.

Results

The sample analyzed in this study was made up of 14 participants in the control group (9 female and 5 male) and 14 in the experimental group (10 female and 4 male). There were no dropouts or deviations in the intervention in both groups. Table 1 shows the mean and standard deviation of the general characteristics of the participants. There were no significant differences in these variables between the groups ($p > 0.05$).

Table 1.
Baseline characteristics of the sample

	Control Group (n=14)		Experimental group (n=14)	
	Mean	SD	Mean	SD
Age (years)	16.62	0.65	16.46	0.52
Weight (kg)	77.25	9.21	74.87	7.46
Height (m)	1.62	0.06	1.67	0.08
BMI (kg/m²)	28.08	2.25	26.95	1.50

BMI: body mass index; SD: standar desviation.

Table 2 shows the pre-and post-intervention results of the variables assessed for EG and CG. Concerning the variables evaluated with spirometry, The two-way mixed ANOVA test revealed a significant time×group interaction for FEF1 ($F = 7.59$; $p = 0.017$; $\eta p^2 = 0.883$), FVC ($F=7.96$; $p = 0.015$; $\eta p^2= 0.398$), PEF ($F = 9.74$; $p = 0.008$; $\eta p^2 = 0.448$), FEF25 ($F = 16.87$; $p = 0.001$; $\eta p^2 = 0.584$), FEF50 ($F =11.11$; $p = 0.006$; $\eta p^2 = 0.917$), FEF75 ($F = 9.37$; $p = 0.009$; $\eta p^2 = 0.903$), and FEF25-75 ($F = 22.90$; $p = 0.001$; $\eta p^2 = 0.958$). For its part, for FEV1/FVC there was no significant interaction ($F = 2.59$; $p = 0.133$; $\eta p^2 = 0.017$). For the variables measured with pymometry, there was a significant interaction for both MIP ($F = 8.77$; $p = 0.011$; $\eta p^2 = 0.422$) and MEP ($F = 9.25$; $p = 0.010$; $\eta p^2 = 0.435$) Multiple comparisons are shown in Figures 1 and 2 for the variables that had significant interaction in spirometry and pymometry, respectively.

Table 2.
Time x group interaction in variables of spirometry and pymometry.

Variables	Group	Pre-Interventions	Post-Interventions	Time x Group p value	Time x Group F value	ηp^2
FEV1	CG	2.75 (0.74)	2.88 (0.824)	0.017	7.59	0.883
	EG	2.71 (0.73)	4.05 (0.64)			
FVC	CG	3.76 (0.76)	3.67 (0.78)	0.015	7.96	0.398
	EG	3.51 (0.71)	3.99 (0,80)			
PEF	CG	225.60 (92.54)	234.78 (112.98)	0.008	9.74	0.448
	EG	213.60 (78.84)	328.67 (102.11)			
FEV1/FVC	CG	74.76 (17.31)	76.82 (13.16)	0.133	2.59	0.017
	EG	78.99 (15.92	88.36 (11.09)			
$FEF_{25\%}$	CG	3.48 (1.52)	3.34 (1.46)	0.001	16.87	0.584
	EG	3.40 (1.30)	5.21 (1.48)			
$FEF_{50\%}$	CG	2.80 (0.88)	2.82 (1.08)	0.006	11.11	0.917
	EG	3.02 (1.03)	4.39 (0.87)			
$FEF_{75\%}$	CG	1.92 (0.59)	2.04 (0,51)	0.009	9.37	0.903
	EG	2.04 (0.62)	3.68 (0.62)			
$FEF_{25-75\%}$	CG	3.06 (1.52)	2.44 (0.85)	0.001	22.90	0.958
	EG	2.82 (0.91)	3.83 (0.91)			

Data presented as mean and 95% confidence intervals. Partial eta square (ηp^2); CG= control group; EG= experimental group.

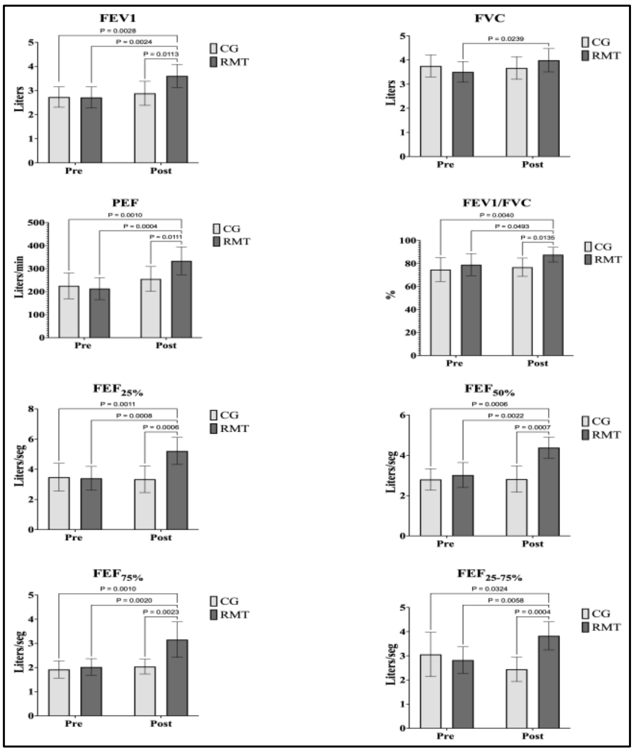

Figure 1. Multiple comparations of spirometry variables.

Discussion

The main result of this research indicates that eight-week respiratory isolated muscle training (inspiratory and expiratory) in overweight and obese adolescents favors lung function by increasing the variables of spirometry and pymometry. Previous studies of isolated respiratory muscle training in obese people have reported similar results mainly in the pymometry variables (MIP and MEP) (Kaeotawee et al., 2022). When respiratory muscle training has been complemented with aerobic exercises (30 minutes 5 days a week) together with a calorie-restricted diet, favorable effects have been seen on lung function evaluated with spirometry, without observing important changes in the respiratory pattern (Kaeotawee et al., 2022; Salvadego et al., 2022).

Specifically, respiratory muscle training improved the spirometry variables of FEV1, FVC, PEF, FEF25, FEF50, FEF75, and FEF25-75 and pymometry variables of MIP and MEP. These changes could be explained because respiratory muscle training stimulates an increase in the proportion and size of type II muscle fibers, which favors the development of muscle strength and endurance, optimizing neuromuscular recruitment and generating faster contractions (Kaeotawee et al., 2022; Polla et al., 2004). Also, respiratory muscle training promotes muscle oxygenation and reduces lactate production by the respiratory muscles, preventing fatigue (Álvarez-Herms et al., 2018; Girardi et al., 2020). Therefore, activating the respiratory muscles improves the expansion of the rib cage, which is reflected in the effective mobilization of lung volumes. The FEV1/FVC variable did not present significant changes, which explains that the training increases the volumes but does not modify the respiratory pattern, evidencing that the subjects maintained the restrictive ventilatory alteration that people with obesity present. One of the main causes of this result could be excess fat mass in the chest wall and increased resistance in the airways in overweight and obese people (Mafort et al., 2016; Melo et al., 2014; Poulain et al., 2006). The excess fat mass that covers the thorax and abdomen restricts diaphragmatic and rib cage mobility, which promotes changes in ventilatory dynamics and decreases its functionality, increasing respiratory work and generating a restrictive pattern (due to increased elastic resistance of the lung and rib cage and decreased compliance) (Mafort et al., 2016; Melo et al., 2014; Winck et al., 2016). On the other hand, adipose tissue also acts as an endocrine and paracrine organ that produces cytokines and bioactive mediators, promoting a pro-inflammatory state that may be associated with pulmonary hypoplasia, atopy, bronchial hyperreactivity and a greater risk of asthma in obese individuals (Mandal & Hart, 2012; Rodríguez Valdés et al., 2019; Svartengren et al., 2020). It has been shown that the decrease in fat mass alters the metabolic demands of the body. Studies even indicate that moderate weight loss of 8% contributes to the optimal function of respiratory muscles by reducing airway resistance, thus improving cardiorespiratory function (Carpio et al., 2014). Therefore, isolated respiratory muscle training for 8 weeks is not enough to generate changes in the restrictive pattern in overweight and obese people. Kaeotawee et al. (2022) indicate that reducing excess fat in the chest wall and abdomen favors the function of the respiratory muscles (diaphragm), which improves lung volume, lung mechanics, and physical condition. Salvadego et al. (2022) carried out respiratory muscle training plus a multidisciplinary program to reduce body weight in young people with obesity, where he showed that after completing the 3-week training, lung function and exercise tolerance improved. Therefore, according to our findings, it is possible to assume that isolated training of the respiratory muscles is crucial to promote volume changes; however, to modify the respiratory pattern of obese individuals, it is necessary to complement it with a program of reduction of body fat.

In this study, the training of the respiratory muscles favored MIP and MEP assessed with pymometry, which means that lung function improved by mobilizing a greater volume of air. These results are in line with what was reported in another study that demonstrated a favorable effect on lung function in people with COPD, asthma, muscular dystrophy, myasthenia gravis, and even athletes (after performing training of the respiratory muscles (inspiratory and expiratory) from 8 to 13 weeks, improving strength and endurance (Cabrita et al., 2022; Chen et al., 2023; Mackała et al., 2019; Vázquez-Gandullo et al., 2022; Xiang et al., 2024). However, there is little evidence of this effect in overweight adolescents and obesity. Our study demonstrates that the strength of the respiratory muscles is improved in adolescents with obesity, mainly the diaphragm (which presents 75% to 80% of the activation during inspiration) and the accessory muscles of inspiration (external intercostals, scalene, sternocleidomastoid, and spinal extensors) (Girardi et al., 2020), which are muscles that were activated during the training carried out. Also, it is demonstrated that respiratory muscles training improves the strength of the expiratory muscles in this population since during the training forced expiration exercises with resistance were performed to strengthen the accessory expiratory muscles.

In our study, the only variable that showed favorable changes in the CG was the PEF, corresponding to the maximum expiratory flow obtained during forced expiration from maximum inspiration. This may be because all adolescents in both groups maintained their curricular and extraprogrammatic physical activities, which increased physical activity in both the control group and the experimental group.

Among the limitations of this study is the choice of participants through non-probabilistic sampling, which may limit the external representativeness. On the other hand, the participants were not analyzed separately by sex, which could affect the interpretation of the results. Despite these limitations, this study provides knowledge to fill a gap about the effect of respiratory muscles in overweight and obese adolescents. One of the main strengths of this study is that it only performs respiratory muscle training to demonstrate an effect on lung function isolated from another type of intervention, considering the minimum number of weeks indicated in other studies. Also, our study used gold-standard instruments for lung function (spirometry and pymometry). Another strength is that this study presents a control group.

Conclusion

This study indicates that an 8-week isolated respiratory muscle training significantly improved the variables of lung function and respiratory muscle strength but not the restrictive respiratory pattern of overweight and obese adolescents. Because body fat is one of the main causes of lung function alterations, it is suggested to implement this type of training associated with interventions to reduce BMI, considering a multidisciplinary approach for a greater impact on the quality of life in overweight and obese adolescents.

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