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Sternocleidomastoid muscle activation following inspiratory muscle training in patients with chronic obstructive pulmonary disease: a randomized clinical trial

Ativação do músculo esternocleidomastoideo após treinamento muscular inspiratório em pacientes com doença pulmonar obstrutiva crônica: ensaio clínico randomizado

Activación del músculo esternocleidomastoideo tras el entrenamiento muscular inspiratorio de pacientes con enfermedad pulmonar obstructiva crónica: un ensayo clínico aleatorizado

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ABSTRACT | This study aims to assess the effect of short-time low frequency inspiratory muscle trainer (Threshold IMT) on inspiratory muscle strength and electromyographic activity of the sternocleidomastoid (SCM) muscle in people with chronic obstructive pulmonary disease (COPD). People with COPD participating in a lung rehabilitation program were allocated to a control or inspiratory muscle training (IMT) group. The control group participated in the usual rehabilitation, whereas the other group received IMT (performed with a load of 50% maximal inspiratory pressure (MIP) adjusted weekly). Both interventions lasted for 2 months. Outcomes included electromyographic analysis of the SCM and MIP. In total, ten participants were allocated to each group. The IMT group presented an increase in absolute (p<0.001) and predicted (p<0.001) values of MIP and also in pre- and post-intervention variation between groups (p=0.003 and p=0.008, respectively). Such differences were not found in the control group. The SCM muscle activity decreased in the IMT post intragroup evaluation (p=0.008). IMT provided a reduction of the electromyographic activity of SCM in COPD patients, also increasing inspiratory muscle strength in the study participants.

Keywords | Electromyography; Respiratory Muscles; Pulmonary Disease, Chronic Obstructive; Respiratory Terapy.

RESUMO | O objetivo deste estudo foi avaliar o efeito do treinamento muscular inspiratório de baixa frequência de curta duração (Threshold TMI) na força muscular inspiratória e na atividade eletromiográfica do músculo esternocleidomastoideo (ME) em pessoas com doença pulmonar obstrutiva crônica (DPOC). Pessoas com DPOC que participam de um programa de reabilitação pulmonar foram alocadas em um grupo controle ou de treinamento muscular inspiratório (TMI). O grupo controle participou da reabilitação habitual, enquanto o grupo TMI também recebeu TMI, com carga de 50% da pressão inspiratória máxima (PImáx) ajustada semanalmente. Ambas as intervenções duraram 2 meses. Os resultados incluíram análise eletromiográfica do SCM e PImáx. Dez participantes foram alocados para o grupo controle e 10 para o grupo TMI. O grupo com TMI apresentou um aumento na PImáx nos valores absoluto (p<0,001) e previsto (p<0,001) e na variação pré e pós-intervenção entre os grupos

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(p=0,003 e p=0,008, respectivamente). Tais diferenças não foram encontradas no grupo controle. A atividade muscular do ME diminuiu no TMI após avaliação intragrupo (p=0,008). O TMI proporcionou redução da atividade eletromiográfica do ME em pacientes com DPOC, além de aumentar a força muscular inspiratória nos participantes do estudo.
Descritores | Eletromiografia; Músculos Respiratórios; Doença Pulmonar Obstrutiva Crônica; Terapia Respiratória.

RESUMEN | El presente estudio tuvo como objetivo evaluar el efecto del entrenamiento muscular inspiratorio de baja frecuencia a corto plazo (Threshold TMI) sobre la fuerza muscular inspiratoria y la actividad electromiográfica del músculo esternocleidomastoideo (ME) en personas con enfermedad pulmonar obstructiva crónica (EPOC). Las personas con EPOC que participan en un programa de rehabilitación pulmonar se asignaron a un grupo control o de entrenamiento muscular inspiratorio (EMI). El grupo control participó en la rehabilitación habitual, mientras que el grupo de EMI también recibió EMI, con una carga del 50% de la presión inspiratoria máxima (PImáx) ajustada semanalmente. Ambas intervenciones tuvieron 2 meses de duración. Los resultados incluyeron el análisis electromiográfico de SCM y PImáx. Se asignaron 10 participantes al grupo control y 10 al grupo de EMI. El grupo de EMI tuvo un aumento de la PImáx en los valores absoluto (p<0,001) y predicho (p<0,001) y en la variación pre y posintervención entre grupos (p=0,003 y p=0,008, respectivamente). No se encontraron estas diferencias en el grupo control. La actividad muscular del ME disminuyó en el EMI después de la evaluación intragrupal (p=0,008). El EMI redujo la actividad electromiográfica del ME de pacientes con EPOC, además aumentó la fuerza muscular inspiratoria en los participantes del estudio.
Palabras clave | Electromiografía; Músculos Respiratorios; Enfermedad Pulmonar Obstructiva Crónica; Terapia Respiratoria.

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a systemic condition characterized by airflow limitation, being not fully reversible[1]. Pulmonary hyperinflation, which is an abnormal increase on functional residual capacity (i.e., lung volume at the end of tidal expiration), induces the recruitment of inspiratory accessory muscle, which can fatigue the muscles involved[2]. The diaphragm is the most affected muscle, as it becomes flattened, reducing its motion and efficiency to contract. Structural changes in the thoracic cage caused by the overload of diaphragm increase the resistance to fatigue[3-5]. However, it does not increase inspiratory pressure, leading to accessory muscle activation to compensate the increase in ventilation demand[3], including the activation of the scalene and sternocleidomastoid (SCM) muscles[3].

The diagnosis of respiratory muscles disorders is commonly confirmed by respiratory muscle strength tests, using maximal respiratory pressure[6]. However, this method only enables a global assessment, without differentiating the muscle groups involved[6]. Surface electromyography (EMG) is a non-invasive technique that allows differentiation of muscle activity generated in different muscle groups, assessing muscle activation by electric signals, and it has been used under different conditions[4-7].

Inspiratory muscle training (IMT) enables effective increments in respiratory muscle loading, and it can be conducted by spring-loaded valves such as the threshold inspiratory muscle trainer (Threshold IMT)[8], or by incentive spirometers or other devices[9]. Although spring-loaded valve devices are superior for inspiratory muscle training—as it produces a linear pressure load enabling gradual pressure increments, so that strength gains are proportional to the resistance applied[10]–, there is no consensus on the amount of necessary resistance to increase strength in people with COPD[11-13]. López-García et al.[14] and Elmorsi et al.[15] suggested a load of 30 to 60% of the maximal inspiratory pressure (MIP) that should be adjusted according to patients' tolerance.

Previous studies demonstrated that the short-time low frequency IMT in COPD patients increases respiratory muscle[11,12]. However, its effects on reducing accessory inspiratory muscle activity remains unclear. Thus, this study aims to assess the effect of short inspiratory muscle training of low frequency on inspiratory muscle strength and electromyography activity of the SCM muscle in people with COPD attending a pulmonary rehabilitation program.

METHODOLOGY

This was a randomized controlled trial with blinded outcome rater. The trial was registered a priori at

ClinicalTrials.gov (NCT02014155). The study was conducted at the lung rehabilitation program of the Santa Cruz do Sul Hospital, Brazil.

COPD patients at the stages II to IV, according to the Global Initiative for Chronic Obstructive Lung Disease (GOLD) classification[1], participating in a lung rehabilitation program for at least 2 months, participant that were clinically stable and signed the informed consent were eligible to participate in the study. Individuals with asthma, and/or cardiovascular disease and individuals with cognitive and/or behavioral impairments were excluded.

Eligible participants were randomly allocated to intervention (IMT group) or control (control group) using a sealed opaque envelop. Participants allocated to the control group did not receive any additional intervention apart from participating in the lung rehabilitation program. Participants allocated to the IMT group participated in the same lung rehabilitation program, also receiving inspiratory muscle training using Threshold IMT® (Respironics®, USA). The primary outcome was electromyography activity of the SCM muscle and the secondary outcome was inspiratory muscle strength in people with COPD attending a pulmonary rehabilitation program. Outcomes were measured in both groups in the pre and post short inspiratory muscle training of low frequency.

The intervention protocol for the IMT group was performed in three phases: (1) Pre-training assessment of maximal inspiratory pressure and pulmonary volumes, and electromyographic activity of the ECM muscle; (2) Education and training, participants received 3 sessions (20 minutes each) of training for familiarization with the Threshold IMT device without resistance for one week, followed by inspiratory muscle training 3 times a week for 20 minutes over 4 weeks, which was increased to 25 minutes on weeks 5 and 6, and to 30 minutes on weeks 7 and 8. Participants received a total of 24 sessions conducted by blinded personnel for the study objectives, and all sessions were supervised by a registered physiotherapist. (3) Post-training: reassessment of maximal inspiratory pressure and electromyographic activity of the SCM muscles[16]. Threshold IMT was set at 50% of maximal inspiratory pressure (assessed at baseline using a manometer). The device was adjusted weekly to increase the resistance for incremental strengthening training[16].

The lung rehabilitation program included 30 minutes of cycling exercise on a vertical cycle ergometer for lower limbs (Movement®, BM 2700, Brazil) set at 60% of the maximal heart rate determined using the Karvonen method modified for the reserve heart rate[17]. Participants also preformed strengthening exercises for major muscles of the upper and lower limbs, with the intensity of 50-80% of the one repetition maximum test (1RM). Furthermore, a Borg scale was used to quantify the levels of dyspnea perceived by COPD patients.

Spirometry was used to classify disease stage according to the GOLD classification[1]. A spirometer (EasyOne®, Modelo 2001, Switzerland) was used to assess forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), forced expiratory flow between 25 and 75% of the FVC ($FEF_{25-75\%}$) and FEV_1/FVC ratio expressed as the predicted values[18]. Spirometry values were compared to previously published and validated values[19].

The assessment of inspiratory muscle strength followed the American Thoracic and European Respiratory Society protocol[6]. Participants were in sitting position and instructed to exhale, reaching the residual volume and inhale reaching the total lung capacity, to measure maximal inspiratory pressure. A total of five measurements were obtained, the two first were for learning purposes and the highest value from the following three was selected.

For the electromyography assessment, surface electrodes were used (MIOTEC®, miotool400, Brazil) with a sample frequency of 2000Hz per channel by circular bipolar electrodes (Meditrace 100 pediatric – Ag/AgCl – solid gel sticker and conduction; Tyco Healthcare Group Canada Inc, Pointe Claire, Canada) at 15mm, pre-amplified and connected to a surface differential sensor (SDS500 model; Miotec Equipamentos Biomédicos Ltda., Brazil) with 30mm distance between the electrodes center. The sensors were calibrated and the area was shaved and disinfected, before the assessment, with alcohol to remove dead skin-cells and reduce skin resistance to the electromyographic signal, as recommended by the International Society of Electrophysiology and Kinesiology[20].

Participants were asked to laterally rotate the neck to the left during the evaluation of the SCM muscle, so that the muscle belly was better exposed, then, two electrodes were positioned 3cm above the muscle belly. The percentage of root mean square (%RMS) was obtained with the participant in sitting position assessing SCM muscle activation in two moments: (1) mean RMS% of five respiratory incursions, and (2) the best of three maximal voluntary ventilation through the nose[3]. Then, data were exported to SAD 32 program (Laboratory of Mechanical Measures of the Universidade Federal do Rio Grande do Sul) for digital filtering.

SAMPLE SIZE ESTIMATION AND STATISTICAL ANALYSES

The sample size estimation was based on data obtained from the first five participants using the G*Power software (version 3.1.9.2)[21,22]. A total of ten participants were required in each group to detect a mean statistical difference of 22.4% on RMS electromyographic activity of SCM between groups with 10.8% RMS standard deviation, 80% power and 5% significance level, and allowing for a 20% loss to follow-up.

Data analyses were performed using the software SPSS (version 20.0). Means and standard deviations (SD) or medians and interquartile ranges (IQR) are presented according to data normality. Shapiro-Wilk test was used to verify data distribution. Chi-squared test was used to compare gender proportions between groups. For intra group comparisons, paired Student's t test or Mann-Whitney U test for the non-parametric data, were used. Moreover, analysis of covariance (ANCOVA) was used as a supportive analysis, to compare differences between groups after the intervention, adjusting for values of the respective outcomes at baseline[23]. A significance level of 5% was set for all analyses.

RESULTS

A total of 22 participants were randomly allocated to IMT group (n=12) and control group (n=10). Recruitment occurred between March and September 2014. Follow-up assessments were completed on October 2014. Two participants from the IMT group were lost to follow-up due to an acute worsening of the condition and lack of treatment adherence (Figure 1). No between-group difference was presented for the anthropometric characteristics or lung function at baseline (Table 1). Participants in both groups presented obstructive and restrictive patterns of lung function values. Participants from both groups did not present resting dyspnea.

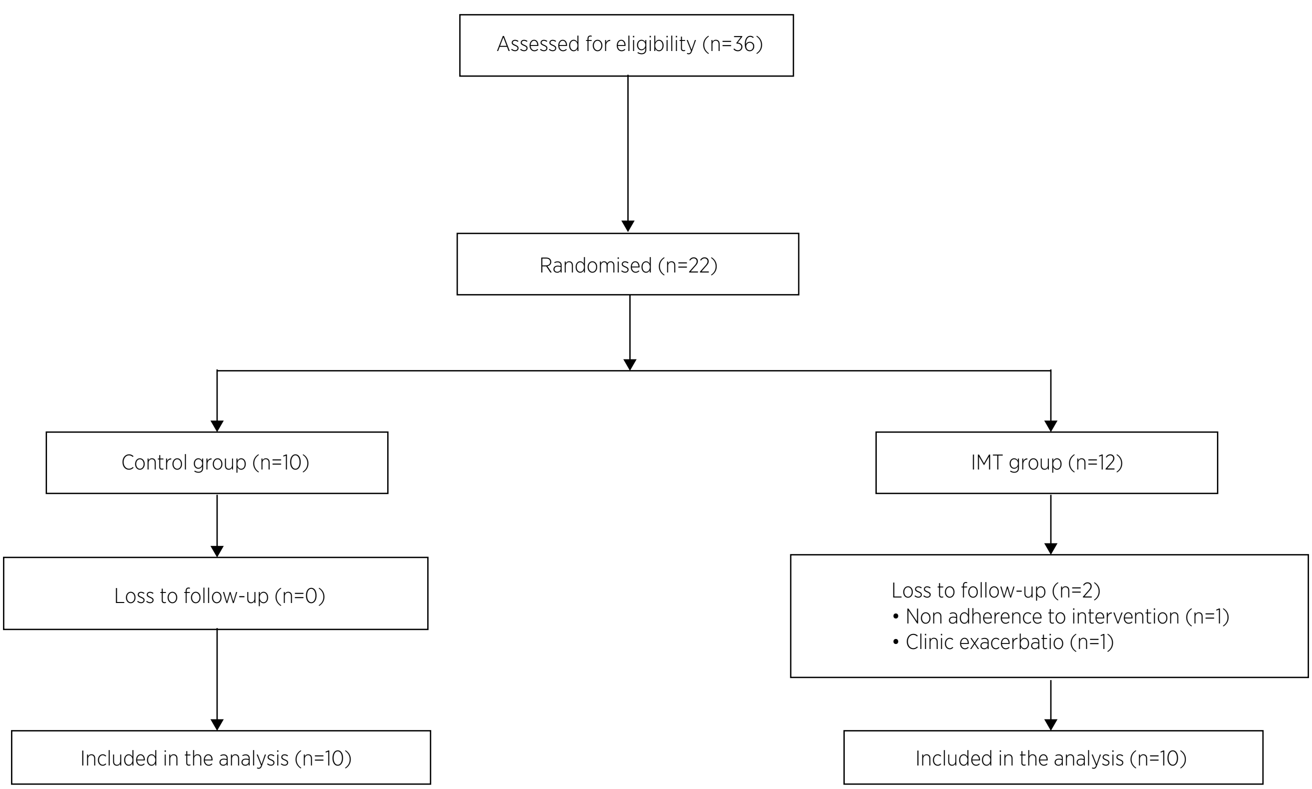

Figure 1. Study flow chart

Table 1. Baseline characteristics of the included participants presented in means (standard deviation), unless otherwise stated

Characteristic	Control group (n=10)	IMT group (n=10)
Age (years)	66.2 (9.2)	63.2 (5.7)
Sex, n female/male	4/6	5/5
Weight (Kg)	63.4 (15.3)	64.5 (12.8)
Height (m)	1.5 (0.1)	1.6 (0.1)
BMI (Kg/m^2)	25.4 (5.8)	25.3 (5.1)
FVC, %predicted	60 (19)	58 (19.9)
FEV_1, %predicted	36 (18.7)	41 (22.4)
FEV_1/FVC, %predicted	59 (20.4)	68 (22.9)
$FEV_{25-75\%}$, %predicted	13 (9-22)	23.3 (8-35)
MIP (cmH_2O)¥	70 (24.2)	77.8 (21.2)
Female	72.3 (3)	72.2 (16.8)
Male	84.8 (19.7)	93.3 (14.9)
MIP (%predicted)¥	71 (24)	87.6 (18.1)
Female	85.6 (11.9)	82.7 (7)
Male	85.9 (18.3)	98.7 (11.7)

BMI: body mass index; FVC: forced vital capacity; FEV_1: forced expiratory volume during the first second; $FEV_{25-75\%}$: forced expiratory volume between 25 and 75% of the FVC; MIP: maximal inspiratory pressure. Data expressed as mean (standard deviation) and median (interquartile range). ¥: mean and standard deviation of MIP of both sexes.

After the intervention with Threshold IMT, maximal inspiratory pressure was significantly higher for absolute (p<0.001) and predicted values (p<0.001) in the IMT group. The same effect was not observed on the control group (p=0.710 for absolute and p=0.162 for predicted values). Furthermore, MIP increase is demonstrated when comparing pre and post intervention variation (Δ) between control and IMT Group for absolute (p=0.001) and predicted values (p=0.011) (Table 2).

At pre-training phase, IMT group presented a median (interquartile range) of 22.02 %RMS (10.58 to 32.09) and the control group presented a median of 26.74 %RMS (18.77 to 34.38), considering SCM muscle assessment. At post-training phase, for the SCM muscle assessment, IMT group presented a median of 6.38 %RMS (4.14 to 8.91) and the control group 34.08 %RMS (3.13 to 62.43). A significant decrease occurred in the activity of SCM muscles for the IMT group (p=0.008), whereas the same effect was not observed in the control group. Regarding the SCM muscle, a difference between groups was observed, also favoring IMT group (mean difference between groups: −16.6 %RMS, 95% confidence interval: −31 to −2.1) (p=0.021) (Figure 2).

Table 2. Inspiratory muscle strength before and after intervention in control and IMT groups.

Characteristic	Control group			IMT group			Difference between groups (95% CI) p-value*
	Before	After	Difference between groups p-value	Before	After	Difference between groups p-value	
MIP (cmH_2O)	70 (24.2)	70.7 (24.0)	0.710	77.8 (21.2)	95.12 (20.5)	<0.001	−16.6 (−25.8 to −7.4) 0.001
MIP (% predicted)	71 (24)	87.4 (42)	0.162	87.6 (18.1)	132.7 (43.7)	<0.001	−21.6 (−37.6 to −5.7) 0.011

MIP: maximal inspiratory pressure; IMT: inspiratory muscle training. Data presented as means (standard deviation). CI: confidence interval. *: comparison between groups. p<0.05 was considered to be significant. Intragroup comparison: paired Student t test, or Mann-Whitney U test for the non-parametric data. Comparison between group: ANCOVA.

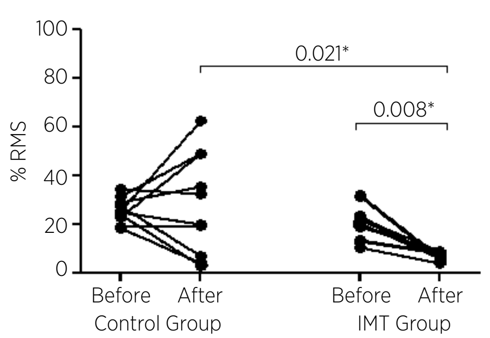

Figure 2. Medians and interquartile ranges of the percentage root mean square (%RMS) on sternocleidomastoid muscle before and after intervention on control and IMT groups (p<0.05)

DISCUSSION

This study showed that inspiratory muscle training at 50% of the maximal inspiratory pressure with weekly adjustments of short-time low frequency training significantly increased maximal inspiratory pressure. The increase was observed on the pre-post changes and between-group variation of the IMT group. Furthermore, a reduction of the electromyography activity of the SCM muscle was verified. At the end of the study, the IMT group presented a mean of 95.12cmH_2O, exceeding the maximum load of 41cmH_2O of the Threshold IMT as 50% of load (Table 2), which occurred only in the last week of training.

The beneficial effects of Threshold IMT on strength gains of inspiratory muscles in people with COPD have been reported previously in the literature[14,24]. It has been suggested that people with COPD should undergo training with IMT using loads between 40 and 50% of the maximal inspiratory pressure for 30 minutes a day, 5 days per week[15]. Moreover, it has been recommended weekly readjust of load to account for the changes on the inspiratory pressures[15]. Although there is no consensus on the optimal frequency or length of treatment, many specialists recommend a high frequency of training, usually performed daily[25,26].

Despite the fact that Threshold IMT is widely used in COPD patients with inspiratory muscle weakness[14,24], patients evaluated in the present study, regardless of gender, did not present such impairment, considering inspiratory muscle weakness as the reduction of absolute MIP lower than 50% of predicted value[25]. We chose this population because the primary focus to observe whether the short-term inspiratory muscle training would be able to reduce sternocleidomastoid muscle activation in individuals without inspiratory muscle weakness.

The present study showed an increase in the maximal inspiratory pressure and a significant reduction in SCM muscle activation in the IMT group after treatment, also when comparing the variation between groups. In healthy individuals, SCM is recruited only after 70% of the tidal volume has been reached, when the inspiratory capacity is increased by hypercapnia[27] or hyperpnoea[28]. Our study demonstrated a considerable SCM muscle activation in eupnea for both groups, with significant reduction in its activation following the intervention in the IMT group. Gama et al.[29] have also shown a reduction on SCM muscle activation, however the effects were only observed immediately after the IMT and on healthy individuals.

The loss in inspiratory muscle strength observed in people with COPD occurs mainly for lung hyperinflation, which leads to changes in the thoracic cage and diaphragm, lowering the hemidiaphragm and shortening its muscle fiber, leading the diaphragm to work in a disadvantaged area of the length-tension curve[30].

Regarding the reduced SCM muscle activation observed at post intervention in the IMT group, it could be possibly explained by an improvement on the inspiratory muscle synergy, reducing the activation load of the muscles who are highly required in people with COPD[3]. A previous study has shown a significant change in the external intercostal muscle fibers following intervention with Threshold IMT at 40 to 50% load of MIP[31]. Such response suggest that other muscles, apart from the SCM, also benefit from the increase in strength following training with Threshold IMT.

Some limitations of this study include the difficulty to maintain the orientation of the electrodes in relation to the muscle fibers and to control the interference of factors existing between the muscle assessed and the positioning of the electrode (i.e., variations in the amount of subcutaneous fat[32] and cross-captures of the activation of adjacent muscles[33]). Furthermore, the degree of hyperinflation was not assessed in the study participants. Also, it was not possible to perform intention-to-treat analysis with two patients allocated to the IMT group, who were excluded from the study, since they presented clinical exacerbation and non-adherence to the study protocol, prior to the initiation of inspiratory muscle training proper.

CONCLUSIONS

As far as we know, this is the first study to demonstrate that a short-time training with low frequency Threshold IMT seems to be an efficient method to increase inspiratory muscle strength as well as to detect SCM muscle activation on electromyography in people with COPD. This study results demonstrate that this simple technique can be replicable in COPD patients attending a lung rehabilitation program.

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