UNIVERSIDADE FEDERAL DE MINAS GERAIS

CINEMÁTICA VENTILATÓRIA E ATIVIDADE DE MÚSCULOS RESPIRATÓRIOS DE INDIVÍDUOS COM DPOC DURANTE SOBRECARGA DE MÚSCULOS INSPIRATÓRIOS: ESTUDO DESCRITIVO

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Belo Horizonte

2010

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Trabalho de Conclusão de Curso apresentado - no formato opcional de artigo segundo as normas de publicação da Revista Respirology - ao Programa de Graduação em Fisioterapia do Departamento de Fisioterapia da Escola de Educação Física, Fisioterapia e Terapia Ocupacional – UFMG, como requisito parcial para a obtenção do título de graduado em fisioterapia.

Orientadora: Prof. Dra. Raquel Rodrigues Britto

Belo Horizonte

2010

DEDICATÓRIA

Dedico este trabalho...

A meus pais (Verli e Pedro), que são capazes de retirar todas as pedras que cruzam o meu caminho, que facilitaram esta jornada e que me ensinaram que com respeito, humildade e sabedoria, sou capaz de realizar meus sonhos e conquistar a felicidade.

Ao Léo, por simplificar os mais complexos de meus problemas.

AGRADECIMENTOS

Agradeço a Deus por ter me iluminado e guiado meus passos durante estes cinco anos e por ter colocado pessoas tão especiais em minha vida que fizeram com que esta jornada fosse mais agradável e prazerosa.

A minha orientadora Prof. Dra. Raquel Rodrigues Britto pelas oportunidades que me foram dadas, pelos conhecimentos repassados, por ter me transmitido tanta tranquilidade nos momentos de minhas dificuldades.

A Prof. Dra. Verônica Franco Parreira por acreditar em meu potencial, por sempre estar disposta a me ajudar e por me ensinar que “fundamental mesmo é o amor”.

A Karolime Simões Moraes por me permitir participar de todas as coletas, pelo apoio e ensinamentos.

A Susan Martins Lage por ter sido meu “anjo da guarda acadêmico” desde o primeiro ao último período, pela paciência diante de minhas eternas dúvidas e aflições, pelos ótimos momentos de risada e de descontração.

A toda equipe LabCare por ter me acolhido tão bem ao longo destes dois anos, por ter despertado em mim o interesse científico e acadêmico, e por me proporcionar grande crescimento pessoal e profissional.

A todos os voluntários pela disponibilidade em contribuir para o estudo, pela compreensão e colaboração.

A meus pais, por serem meus maiores mestres, por serem responsáveis por eu ser quem sou, pelos inúmeros sacrifícios e renúncias para que eu chegasse até aqui, por terem me dado a melhor herança: o conhecimento.

Ao Léo pelo amor presente ao longo desta jornada, por ter me encorajado diante de cada desafio, por ter comemorado cada pequena vitória, por ter perdoado meus momentos de nervosismo e pelo apoio diante de minhas decisões.

APRESENTAÇÃO

Esta monografia foi desenvolvida a partir dos dados obtidos por meio do trabalho de Iniciação Científica (bolsa CNPq), sendo subprojeto do estudo "Avaliação da cinemática da parede torácica e da dispneia durante a respiração diafragmática e a respiração com freno-labial em pacientes com doença pulmonar obstrutiva crônica", desenvolvido por uma aluna de mestrado em Ciências da Reabilitação do programa de pós-graduação da UFMG, o qual foi avaliado e aprovado pelo Comitê de Ética em Pesquisa da UFMG (Parecer ETIC 557/08).

Para apresentação da monografia foi escolhido o formato de artigo científico de acordo com as normas da Revista Respirology, em anexo.

RESUMO

Introdução: Pacientes com DPOC apresentam disfunção da musculatura inspiratória e prejuízo do movimento toracoabdominal. O treinamento muscular inspiratório (TMI) por meio da sobrecarga de músculos inspiratórios (SMI) é indicado a estes pacientes, estando seus benefícios bem descritos. Entender a cinemática ventilatória e a atividade dos músculos respiratórios durante SMI contribuirá para melhores protocolos de TMI. **Objetivo:** Avaliar a cinemática ventilatória e a atividade de músculos respiratórios de indivíduos com DPOC durante SMI. **Método:** Estudo observacional, tipo transversal. 13 indivíduos com DPOC foram avaliados durante repouso e durante SMI por meio do *Threshold*® a 30% da pressão inspiratória máxima. A cinemática ventilatória foi avaliada por meio da pletismografia optoeletrônica e a atividade dos músculos esternocleidomastóideo (ECM) e abdominais pela eletromiografia de superfície. **Resultados:** Do repouso para a SMI observou-se aumento significativo ($p<0,05$) do volume (V) da parede torácica (V_{pt}), da caixa torácica pulmonar (V_{ctp}), do abdômen (V_{ab}), do volume expiratório final da caixa torácica abdominal (Vef_{cta}), do volume inspiratório final da parede torácica e da caixa torácica abdominal (CTA), do tempo inspiratório e da ventilação minuto. Não foi encontrada diferença significativa no V_{cta}. Observou-se aumento significativo da ativação do ECM durante a SMI em comparação com o repouso. Apenas a correlação entre V_{pt} ($r=0,558$; $p=0,005$), V_{ab} ($r=0,425$; $p=0,038$) e a atividade do ECM foi positiva e de moderada magnitude. **Conclusão:** Os resultados sugerem que indivíduos com DPOC aumentam V_{ctp}, V_{ab} e a atividade do ECM para responder à SMI. O comportamento do V_{cta} e do Vef_{cta} pode relacionar-se à hiperinsuflação dinâmica.

Palavras-chave: doença pulmonar obstrutiva crônica, exercícios para os músculos respiratórios, cinemática ventilatória, eletromiografia

ABSTRACT

Background: Patients with COPD demonstrate respiratory muscular weakness and impairment in the toracoabdominal movement. Inspiratory muscle training (IMT) with inspiratory threshold loading (ITL) is indicated for these patients and its benefits are well described. Understanding chest wall kinematics and respiratory muscular activity during ITL can contribute for better ITL protocols. **Objective:** To assess the chest wall kinematics and the respiratory muscular activity during ITL in patients with COPD. **Method**: cross-sectional, observational study. Thirteen male patients with COPD were investigated at rest and during ITL with a *Threshold*®. Inspiratory load was fixed at 30% of the maximal inspiratory pressure. The chest wall kinematics was evaluated by the optoelectronic plethysmography and the activity of the muscles sternocleidomastoid (SMM) and abdominals by electromyography. **Results:** From rest to ITL, these were observed increases ($p<0.05$) in volumes (V) of the chest wall (V_{cw}), pulmonary rib cage (V_{rcp}), abdomen (V_{ab}), end-expiratory volume of abdominal rib cage (Vee_{rca}), end-inpiratory volume of chest wall, pulmonary and abdominal rib cage, inspiratory time and minute ventilation. No significant changes were found in V_{rca}. It was observed a significant increase in SMM activity during ITL in comparison with rest. Only the correlation between V_{cw} (r=0,558; p=0,005), V_{ab} (r=0,425; p=0,038) and the SMM's activity were positive and with a moderate magnitude. **Conclusions:** The results suggest that patients with COPD increase V_{rcp}, V_{ab} and SMM activities to support the load . The behavior on V_{rca} and Vee_{rca} may be related to dynamic pulmonary hyperinflation.

Key words: Chest wall, chronic obstructive pulmonary disease, electromyography, rehabilitation, respiratory muscle exercise.

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LISTA DE ABREVIATURAS E SIGLAS

AB: abdomen

ABD: abdominal muscles

BMI: Body Mass Index

COPD: chronic obstructive pulmonary disease

EMG: electromyography

FEV_1 Forced expiratory volume in 1 second

FVC: forced vital capacity

HF(beats/min): heart rate

ITL: inspiratory threshold loading

MIP (cmH_2O): Maximal Inspiratory Pressure

MRC: Medical Research Council Scale

OEP: optoelectronic plethysmography

RCA: abdominal rib cage

RCP: pulmonary rib cage

RF (min^{-1}): respiratory frequency

RMS: *Root Mean Square*

SBPT: Sociedade Brasileira de Pneumologia e Tisiologia

SD: standard desviation

SMM: sternocledomastoid

SpO_2 (%): transcutaneous oxygen saturation

Te (s): expiratory time

Ti (s): inspiratory time

Ttot (s): total time of the respiratory cycle

V_{ab} (L): abdominal volume

V_{cw} (L): chest wall volume

VE ($Lmin^{-1}$): minute ventilation

Vee_{ab} (L): abdomen end-expiratory volume

Vee_{cw} (L): chest wall end-expiratory volume

Vee_{rca} (L): abdominal rib cage end-expiratory volume

Vee_{rcp} (L): pulmonary rib cage end-expiratory volume

Vei_{cw} (L): chest wall end-inspiratory volume

Vei_{rca} (L): abdomen end-inspiratory volume

Vei_{rca} (L): abdominal rib cage end-inspiratory volume

Vei_{rcp} (L): pulmonary rib cage end-inspiratory volume

V_{rca} (L): abdominal rib cage volume

V_{rcp} (L): pulmonary rib cage volume

SUMÁRIO

ORIGINAL ARTICLE

CHANGES IN CHEST WALL KINEMATICS AND RESPIRATORY MUSCULAR ACTIVITY IN PATIENTS WITH COPD DURING INSPIRATORY THRESHOLD LOADING: DESRIPTIVE STUDY

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Short Title:

- Kinematics and muscle activity in COPD

SUMMARY AT A GLANCE

This study evaluated the chest wall kinematics and the activity of the sternocleidomastoid and abdominal muscles in 13 COPD patients during inspiratory threshold loading at 30% of maximal inspiratory pressure. The comprehension of chest wall compartments and respiratory muscular activity during this exercise could improve the use of this technique.

ABSTRACT

Background: Patients with COPD demonstrate respiratory muscular weakness and impairment in the toracoabdominal movement. Inspiratory muscle training (IMT) with inspiratory threshold loading (ITL) is indicated for these patients and its benefits are well described. Understanding chest wall kinematics and respiratory muscular activity during ITL can contribute for better ITL protocols. **Objective:** To assess the chest wall kinematics and the respiratory muscular activity during ITL in patients with COPD. **Method**: cross-sectional, observational study. Thirteen male patients with COPD were investigated at rest and during ITL with a *Threshold*®. Inspiratory load was fixed at 30% of the maximal inspiratory pressure. The chest wall kinematics was evaluated by the optoelectronic plethysmography and the activity of the muscles sternocleidomastoid (SMM) and abdominals by electromyography. **Results:** From rest to ITL, these were observed increases ($p<0.05$) in volumes (V) of the chest wall (V_{cw}), pulmonary rib cage (V_{rcp}), abdomen (V_{ab}), end-expiratory volume of abdominal rib cage (Vee_{rca}), end-inpiratory volume of chest wall, pulmonary and abdominal rib cage, inspiratory time and minute ventilation. No significant changes were found in V_{rca}. It was observed a significant increase in SMM activity during ITL in comparison with rest. Only the correlation between V_{cw} (r=0,558; p=0,005), V_{ab} (r=0,425; p=0,038) and the SMM's activity were positive and with a moderate magnitude. **Conclusions:** The results suggest that patients with COPD increase V_{rcp}, V_{ab} and SMM activities to support the load . The behavior on V_{rca} and Vee_{rca} may be related to dynamic pulmonary hyperinflation.

Key words: Chest wall, chronic obstructive pulmonary disease, electromyography, rehabilitation, respiratory muscle exercise.

INTRODUCTION

In patients with COPD, pulmonary hyperinflation affects the respiratory muscles, particularly the diaphragm, by changing the shape and geometry of the chest wall, reducing its zone of apposition, which increases the movement of the upper rib cage and reduces the movement of the lower rib cage.[2,3] The flattening of the diaphragm reduces the length of its fibers,[4,5] changing the optimal length-tension relationship for contractions,[3,6,7] impairing its ability to generate force[7,8], resulting in dyspnea and in reduction of exercise tolerance.[9] Thus, the diaphragm works with mechanical overload[4,5] and COPD patients demonstrate thoracic breathing pattern[10-12]predominantly with increased use of accessory respiratory muscles, such as sternocleidomastoid (SMM) and abdominal (ABD).[13]

In 1997, the Joint American College of Chest Physicians/American Association of Cardiovascular and Pulmonary Rehabilitation concluded that there was enough evidence to recommend inspiratory muscle training with inspiratory threshold loading (ITL) as part of rehabilitation programs.[14] There are evidences that the ITL increases strength and endurance of inspiratory muscles, reduces dyspnea and fatigue, increases exercise tolerance, and the distance walked during the 6-minute walk test, improves the performance in daily activities and quality of life,[9,15-18] provided that it is applied a load of at least 30% of the maximal inspiratory pressure (MIP) is applied.[17]

The airflow obstruction and the mechanical disadvantage of the inspiratory muscles contribute to changes in breathing pattern and thoracoabdominal motion in COPD patients.[2,3,10-12] To identify the chest wall kinematics during the ITL in COPD patients may help to understand the physiological responses of this intervention and it will help to establish more effective training protocols with ITL.

We hypothesized that COPD patients have less thoracoabdominal motion due to dysfunction of the diaphragm and, therefore, they would use accessory respiratory muscles during ITL. Thefore, the aim of this study was to evaluate the chest wall kinematics and the activity of SMM and ABD muscles in COPD patients during ITL.

METHODS

Design

This was cross-sectional study, was approved by the institutional ethical committee board and all participants gave written informed consent. Participants were recruited from the Special Department for Diagnosis and Treatment of Pulmonology and Thoracic Surgery of the University Hospital. The chest wall kinematics and the activity of respiratory muscles in COPD patients during ITL were assessed at a fixed load of 30% of MIP.

Participants

Participants were eligible if they were male between the ages of 45 and 75 years, had BMI between 18 and 30kg/m^2, had clinical diagnosis of moderate to very severe COPD (FEV_1<50%),[4] were clinically stable with no exacerbation in the last four weeks, had smoking history, had no respiratory diseases witch could contribute to dyspnea, had no cardiovascular, neurological or psychiatric disorders and did not participate in a pulmonary rehabilitation program. Participants were excluded if they were not able to understand and follow the study precedures.

Procedures

The procedures were performed in two days with a maximum interval of one week. On the first day, muscle strength was evaluated according to Neder et al.[19] and pulmonary function following the guidelines of the Sociedade Brasileira de Pneumologia e Tisiologia (SBPT).[20] The normal values of pulmonary function volumes were those proposed by Pereira et al.[21] On the second day, the chest wall kinematics and the activity of the respiratory muscles were assessed.

After electromyography (EMG) calibration, the skin was cleaned with alcohol in the region where the surface electrodes would be placed. For SMM, a pair of electrodes were fastened to the lower third part of the muscle belly, identified by palpation during the manually resisted flexion of the neck.[22] To obtain the activity of the ABD, the electrodes were placed 2cm apart of the umbilicus.[23,24] The ground electrode was fixed on the ulnar styloid process. All electrodes were fixed on the right. For all procedures, the capture and analyze of the EMG signals were carried out as recommend by the International Society for Electrophysiology and Kinesiology (ISEK).[25]

During the procedures, the participants remained sat on a backless bench with their feet flat on the floor and their upper limps abducted, externally rotated and flexed (Figure 1), for visualization of the lateral markers.[26] They were comfortably supported by an apparatus to minimize the activity of the accessory respiratory muscles, so the palpation of these muscles was carried out to identify the best placement. The participants were instructed to look forward during all the data collection procedures.

The respiratory muscular activity was simultaneously collected with the chest wall kinematic during two moments: 1- quiet breathing (rest) during three sets of two minutes with intervals between sets: one-minute, totaling six minutes; 2 – ITL at 30% of MIP, without orientation from specific breathing patterns for five minutes.

To allow the cameras to capture the lateral chest wall markers, the examiner held the inspiratory threshold device at the right side, since the participant had to maintain his arms abducted for the assessment of chest wall kinematics. The examiner provided the same instruction to all participants during ITL: "pull the air strongly and exhale." The participants were asked to quantify their sensation of dyspnea at rest and immediately after ITL.

Outcome measures

The chest wall kinematics was evaluated by analyzing the volumes of the chest wall and its compartments: pulmonary rib cage (RCP), abdominal rib cage (RCA), abdomen (AB) and the activity of respiratory muscles by the Root Mean Squares (RMS).

Primary outcome variable

The volume (V) of the chest wall (V_{cw}), end-inspiratory volume (Vei) of the chest wall (Vei_{cw}) and each of its three compartments (Vei_{rcp}, Vei_{cta}, Vei_{ab}), end-expiratory volume (Vee) of the chest wall (Vee_{cw}) and each of its three compartments (Vee_{rcp}, Vef_{rca}; Vee_{ab}), dyspnea, muscle activity of SMM and of ABD (RMS).

Secondary outcomes variables

Volume (V) of the chest wall compartments: V_{rcp}, V_{rca} and V_{ab}, respiratory frequency (RF), minute ventilation (VE), inspiratory time (Ti), expiratory time (Te), total time of the respiratory cycle (Ttot), ratio Ti/Ttot, V_{cw}/Ti and V_{cw}/Te.

Pulmonary Function

Pulmonary function was assessed using a spirometer (Vitalograph 2120, Buckingham, England). The criteria of acceptability, reproducibility and gradation of quality, followed the standards recommended by SBPT.[20] The results were compared with the predicted values for the Brazilian population.[21]

Inspiratory muscles strength

Maximal Inspiratory Pressure (MIP) was evaluated using an analog manovacuometer (GERAR® Class B - SP/Brazil) with the operational range of ±300cmH_2O with 10 in

10cmH_2O divisions, which was connected to a plastic corrugated tube (30x2cm) and plastic, flat mouthpiece, without drain hole.

Medical Research Council Scale (MRC)

Indices of dyspnea were assessed by the British Medical Institute Scale, graduated from 1 to 5.[27]

Inspiratory threshold loading (ITL)

ITL was performed with a threshold device (Threshold Inspiratory Muscle Trainer, HealthScan Products, Cedar Grove, New Jersey, USA), which consists of a plastic cylinder, 1.5cm internal diameter, with an internal pressure regulator, calibrated in cmH_2O (from 7 to 41), and imposes a workload on the inspiratory muscles. This device maintains a constant load during inspiration, is flow-independent, with no resistance during expiration.

Chest wall kinematics

Chest wall kinematics was measured by the Optoelectronic Plethysmography (OEP-BTS, Milan - Italy) with a sampling frequency of 60Hz. This is a non-invasive technique which measures minutely, cycle to cycle, changes in volume of chest wall compartments[26,28-30] in different situations and positions (standing, sitting, supine, or prone).[31,32] Eight-nine reflecting markers[33] were placed over the front and back of the trunk along pre-defined horizontal and vertical lines.[32,34] The landmark coordinates were measured with a system configuration of six infrared cameras, three in the front of the participant and three behind.[33] Using the Gauss's theorem, these points were transformed into a 3D geometric model to define the chest wall.[26,28,33] The boundaries between the three portions were represented by a transverse section placed at the level of the xiphoid process (between RCP and RCA) and another surface positioned at the level of the lower costal margin (between RCA e AB).[32,33,35]The total volume of the chest wall was calculated as the sum of its compartments: CTP, CTA and AB [30,33] and the volume of each compartment was calculated by the difference between Vei and Vee (V=Vei-Vee).[29]

Respiratory muscular activity

EMG was used to record the activity of the SMM and ABD muscles. For data acquisition, it was employed an electromyography (EMG System do Brazil Ltda, São Paulo, Brazil) that had acquisition module of biological signals of eight channels, an amplifier gain of 1000x and a common mode rejection ratio > 120db. The data was processed using specific software for acquisition and analyze (WinDaq®Software Acquisition), a converting plate for A/D 12 bits signal to convert analog to digital signals with a sampling frequency of anti-aliasing 2000Hz for each channel and an input range of 5mV. Active bipolar superficial electrodes consisted of two rectangular parallel bars of Ag/AgCl (1cm in length, 0.78cm^2 of contact area) with an internal amplifier to reduce the effects of electromagnetic interference and other noises.

Dyspnea

The participants were asked to measure the sensation of dyspnea at rest and immediately after ITL by pointing a score on the Modified Borg Scale.[36,37]

Statistical Analyses

Sample size calculation

Based on a pilot study, considering the significance level α =0.05, a statistical power of 0.80, it would be necessary about 10 individuals to be able to find a difference of 390ml in chest wall volume. Thus, 15 individuals were selected, considering the possibility of losses.

Data analyses

Analyses of the chest wall kinematics of each series of two minutes during rest and two minutes during ITL (90-210sec) were carried out by specific software (DIAMOV®). The mean rest values were compared to those during ITL by Student's t-test or Wilcoxon's test, depending upon data distributions.

EMG signal processing was achieved by the time-domain, so the signals generated by the muscles represented their activity, as a function of time. From the results of the program, the RMS (the square root sum of all signals in a given period divided by the number of signs considered) was used to evaluate the intensity of the muscular contractions.[38] It was analyzed a minute (30 to 90seg) in the second serie of rest and a minute in the ITL (120 to 180s). For comparative analyses between the muscles in the two situations, the signal normalization was calculated by the RMS and its absolute value was converted to relative value. A reference value of 100% was calculated as the absolute rest value. Values during ITL resulted from the mathematical ratio between the absolute values of the loading period and those at rest, and then multiplied by 100. Thus, values greater than 100 indicated increases in muscular activity, while those lower than 100, decreases in muscle activity. [39]

Person’s or Sperman’s correlation coefficients were employed to investigate the relationships between the chest wall volumes and the activity of SMM and ABD muscles. All statistical procedures were carried out using the Statistical Package for Social Science (SPSS, Chicago, IL, USA), version 15.0. The level of significance was set at $p < 0.05$.

RESULTS

Participants

Fifteen COPD patients were evaluated, but two were excluded because they were not able to complete five minutes of ITL. During the processing analyses of the EMG signal, there were artifacts that precluded analysis of a participant. Therefore, the correlations between the chest wall volumes and muscular activity was conducted with 12 participantsas shown in the flowchart of the study (Figure 2). The anthropometric characteristics, pulmonary function and inspiratory muscular strength were described as means and standard deviations (SD), as shown in Table 1.

Chest wall kinematics

Table 2 shows the effects of the ITL in the breathing patterns and chest wall kinematics. In relation to breathing pattern, from rest to ITL, V_{cw}, V_{rcp}, V_{ab}, Ti, Ti/Ttot, V_{cw}/Te and VE increased ($p<0.05$), although V_{rca}, Te, V_{cw}/Ti and RF did not change. The analysis of the chest wall kinematics showed that with ITL, Vee_{rca}, Vei_{cw}, Vei_{rcp}, Vei_{rca} all increased ($p<0.05$) without changes in Vee_{cw}, Vee_{rcp}, Vee_{ab}, Vei_{ab} (Table 2 and Figure 3). Figure 3 shows the results in the form of Δ in the volume compartments of chest wall, that it is the difference between Vei and Vee of the same condition ($\Delta V_{cw} = Vei_{cw}$ Rest - Vee_{cw} Rest), which results in correspondent tidal volume. For a Δ of Vee was posted the difference between the Vee in ITL and the Vee in Rest ($\Delta Vee_{cw} = Vee_{cw}$ ITL - Vee_{cw} Rest), considering as reference the functional residual capacity (V=0).

Dyspnea

As expected, the sensation of dyspnea increased after ITL, from 0.37 to 1.12 ($p=0.010$).

Muscle activity

From rest to ITL, only the activity of SMM muscle increased significantly (p=0.007) (Figure 4). Only the correlation between activity of SMM and V_{cw}, V_{ab} was positive and had moderate magnitude (Table 3).

DISCUSSION

The present study showed that patients with COPD, to overcome the inspiratory load, increased V_{rcp} and V_{ab} during ITL with 30% of MIP, without changes in the V_{rca}. The highest activity of the SMM mescle during ITL was related to increases in V_{cw} and in V_{ab}.

The increases in V_{cw} and in V_{rcp} resulted from an increased in Vei, without changing the Vee. As there was no significant difference in Vee_{cw}, there was no dynamic hyperinflation during ITL, although Vee_{rca} has significantly increased, suggesting diaphragm impairment. The increases in Ti, without increases in V_{cw}/Ti also contributed to increase in V_{cw}. As no difference was found in Te, but there was an increase in V_{cw}, ocurred an increase in V_{cw}/Te. It was observed an increase of Ti/Ttot during ITL, which indicates a greater work of inspiratory muscles.[7]

Two participants did not finish five minutes of ITL, even having preserved inspiratory muscle strength. This may be explained by the low value of FEV_1 of these participants (21.69 and 16.59% Pred). These participants reported no breathless during ITL, but justified their difficulty to continue due a discomfort caused by the nose clip.

This was the first study to describe the chest wall kinematics in patients with COPD during ITL, using OEP. Although this equipment requires substantial technical preparation, it provides a direct measurement of the absolute volumes and the variation of chest wall compartments, which is not possible to obtain with other equipments. Unlike magnetometers or respiratory inductance plethysmography, it requires neither calibration on the participant, nor depends on the degrees of freedom, nor yet does it require particular respiratory maneuvers involving the participants cooperation. Moreover, it is non-invasive and does not require a mouthpiece,[40] which could change the breathing patterns of the participants.

The inspiratory muscular strength (MIP) may be reduced in COPD patients. Many authors explained this change to pulmonary hyperinflation, which leads to mechanical disadvantage of the diaphragm and weakness.[2] According to Rochester, the MIP in these patients should be corrected according to changes in lung volumes only when MIP values indicates weakness. From this correction, it is possible to determine if the low values found for the MIP are the result of weakness or caused by limited air flow.[2] In this study, this correction was not performed, since the participants showed preserved muscle strength, although the values were below the predicted ones.[19] Furthermore, this correction is not used in clinical practice.

There may be three explanations for the strength to be preserved in these patients: 1 - chronic adaptations of COPD, reducing the length of the sarcomeres and increasing the oxidative capacity of mitochondria;[3,13,41] 2 – adaptation of the accessory respiratory muscles to overcome the load during the respiratory cycle due to the weakness of the diaphragm, maintaining adequate levels of ventilation;[24] 3 – the manovacuometer assesses global inspiratory muscles, not differentiating which muscle would be weak. Thus, there may be weakness of the diaphragm with compensation of the accessory muscles.[42]

Dos Santos Yamaguti et al. (2008) evaluated the diaphragmatic mobility in 54 patients with COPD and 20 healthy individuals with ultrasound and found that COPD patients had less diaphragm mobility and this reduction was associated with air trapping, airway resistance, and pulmonary ventilatory capacity, but not with respiratory muscle strength or hyperinflation. There were no correlation between diaphragm mobility and respiratory muscular strength, suggesting that although diaphragm strength can be restored by a process of adaptation, its mobility continues to be impaired as a result of muscular shortening.[41]

The present study suggests that although the COPD patients did not show inspiratory muscular weakness, their diaphragm's have impairments in mobility during the ITL, since increases in V_{rca} were not observed.

Impairments caused by pulmonary hyperinflation can be compensated by adaptations of the chest wall and shape of the diaphragm to accommodate the increase in lung volume and adaptations of muscular fibers to preserve strength and endurance.[13] Chronic hyperinflation generates adaptation in the diaphragm length-tension curve due to a reduction of sarcomeres in series which can restore its ability to generate force.[8]

It is well established that during the sensation of respiratory efforts, as observed in this study, there is greater contribution of inspiratory rib cage muscles and a smaller work of diaphragm.[1] In this study, the increases in V_{cw} resulted from the increase in V_{rcp} and V_{ab}, but not from the increases in V_{rca}. These results suggest that in these patients, there may be an activity of the upper rib cage muscles and an impairment in diaphragm contraction, since this muscle is primarily responsible for CTA movement.[26,30,43] This can be explained by changes in strength and/or diaphragm mobility.

EMG was used because it is a non-invasive method and reflects the activity of superficial muscles in time and space, capturing signals from motor units.[3,39,44] However, its signal can be influenced by the distance between the muscle and the electrode, being easily confused with non-physiological signals orcross-talk. The absolute values of the EMG signals suffer effects of individual constitution and of adjacent muscles, complicating the comparison of the values.[38,39] To compensate this constraint, the EMG amplitudes were normalized, considering the study of individual differences. This technique consists in setting the absolute values using a reference EMG considered at 100%.[39]

De Andrade. (2005) evaluated the EMG activity of SMM and diaphragm muscles in patients with COPD and the correlations between the activity of SMM, MIP and FEV_1 during ITL with Threshold® IMT (30% MIP). They observed that for the COPD group, the RMS increased 28% during the ITL (p=0.04), while the RMS of the diaphragm remained constant, which can be explained by its mechanical disadvantage.[39] Duiverman et al.[24] evaluated the reproducibility and sensitivity of surface EMG in respiratory muscles during ITL and concluded that EMG was reproducible and sensitive to assess the breathing patterns of healthy subjects and patients with COPD.

The present findings suggested that patients with COPD, to overcome the load, activated the SMM, which was associated with changes in V_{cw} and V_{ab}. Thus, the SMM activation seems to be able to ensure the AB ventilation. Due to the difficulty in placing electrodes in the diaphragm region, as markers of OEP were fixed in the same place, it was not possible to evaluate the electromyography activity of this muscle. The SMM electromyography activity may have been influenced by the participant head movement toward the examiner who held inspiratory threshold device on the right side.

In this study, a specific breathing pattern was not required to be followed during ITL, so the participant was free to choose the most comfortable way to perform the inspiratory threshold device. Future studies should assess participants with inspiratory muscuular weaknesses and orient diaphragmatic breathing during ITL, to have greater CTA movements and more activity of the diaphragm.

CONCLUSIONS

The results of this study suggested that patients with COPD to overcome the inspiratory load, increased the pulmonary rib cage volume and the abdominal volume. In addition, significant relationships were found between the activation of sternocledomastoid and those variables. The behavior of the abdominal rib cage and its end-expiratory volume may be related to dynamic hyperinflation due to mechanical diaphragm disadvantage.

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Ref Type: Catalog

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FIGURE 1: Position of the participant for data collection

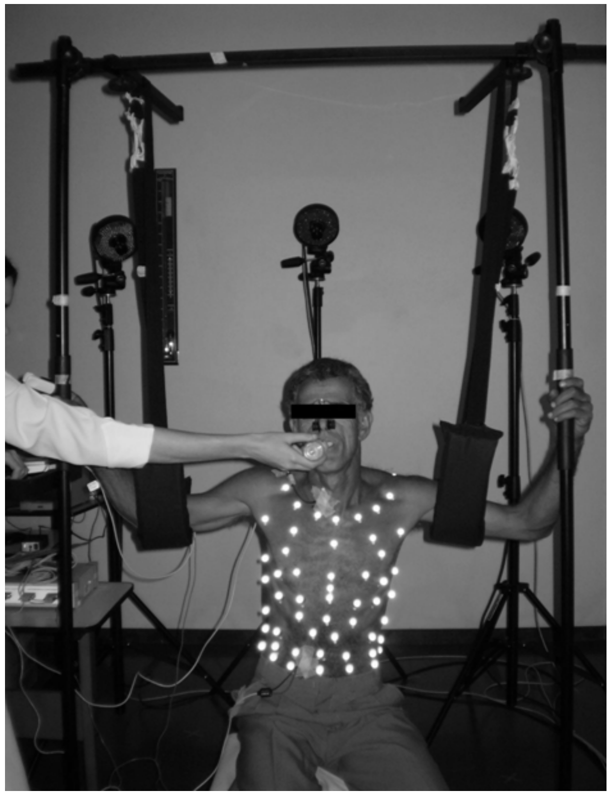
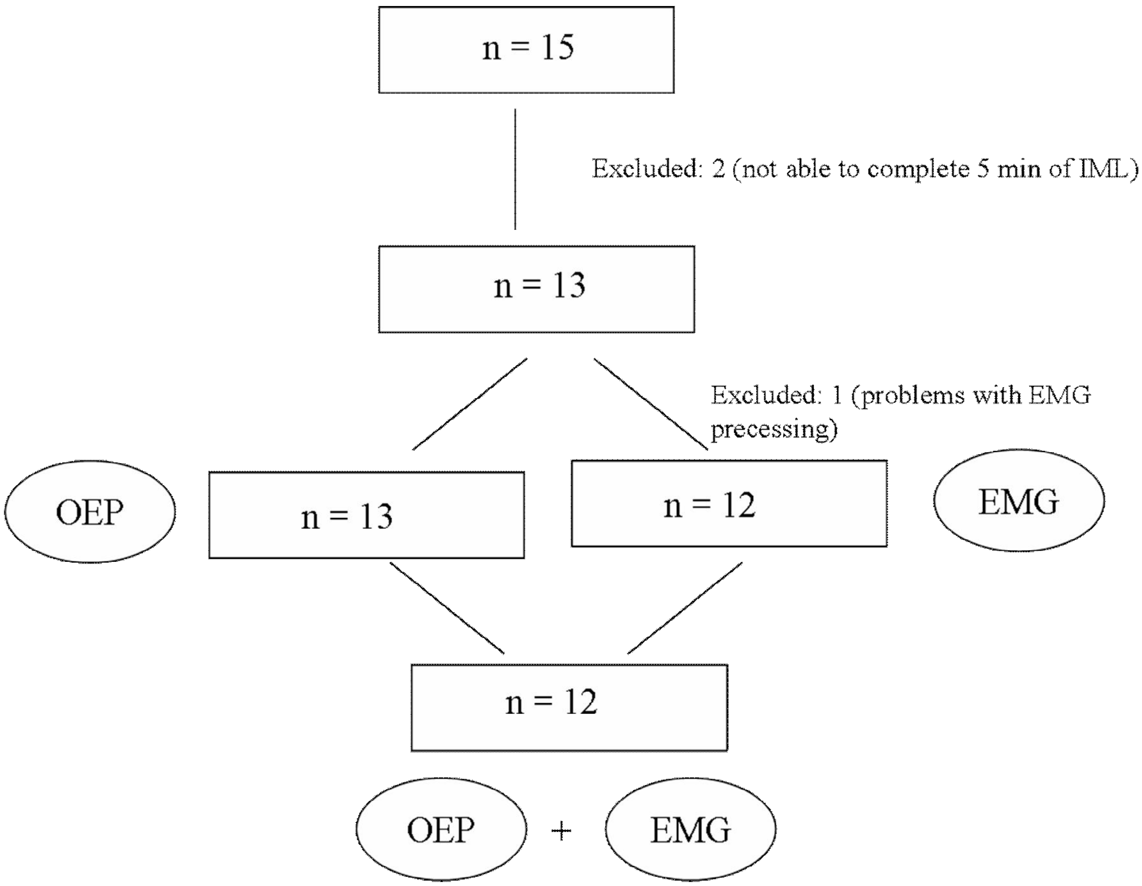
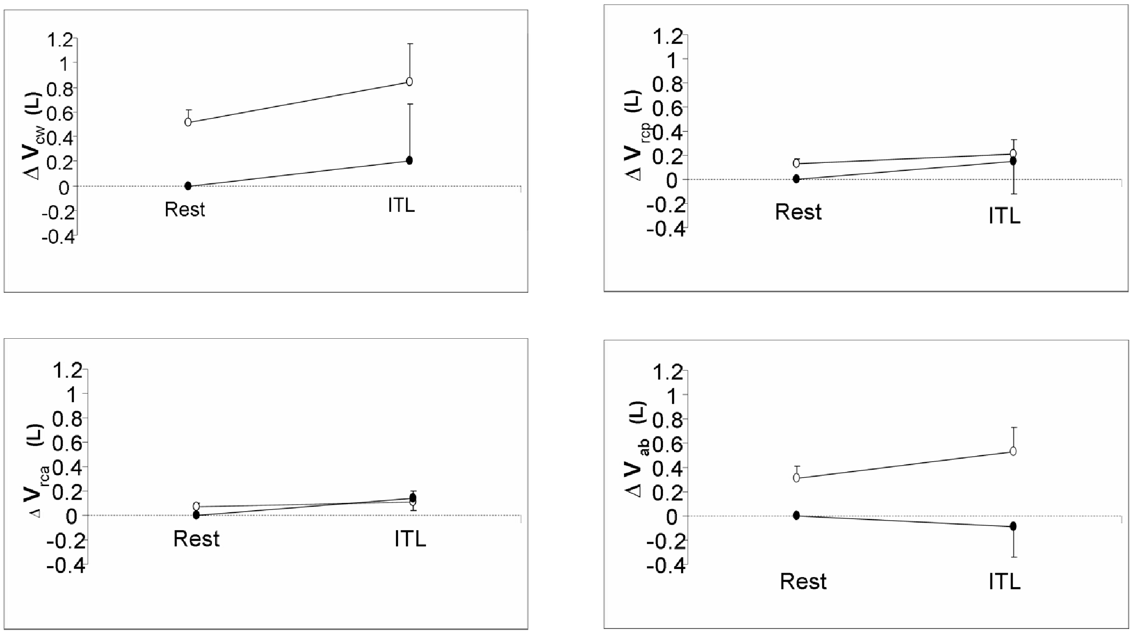


FIGURE 2: Flowchart of the participants



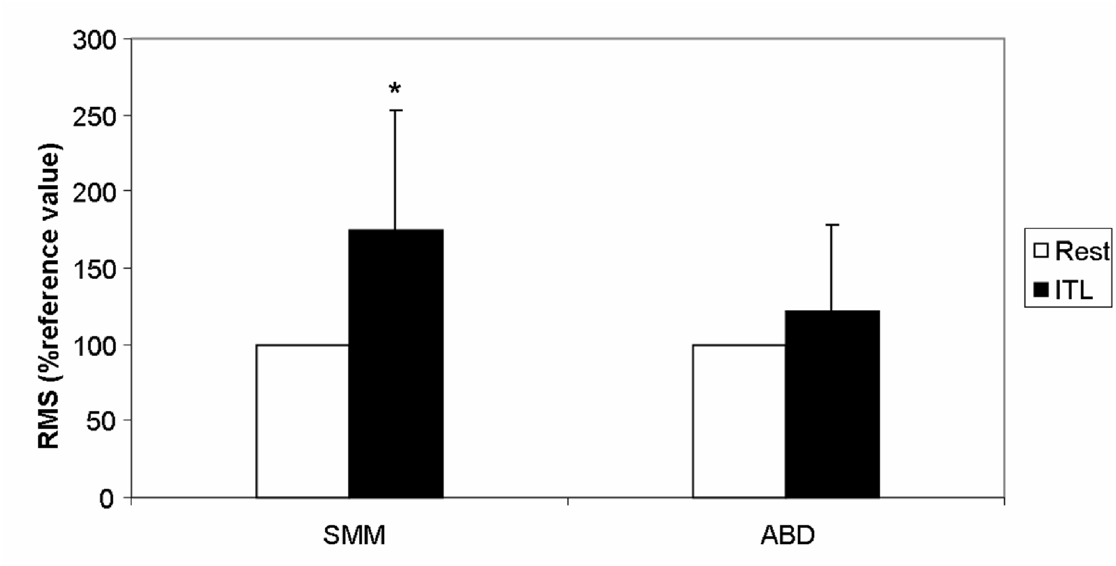
ITL: inspiratory threshold loading, EMG: electromyography, OEP: optoelectronic plethysmography.

FIGURE 3: Changes in the chest wall volumes and their compartments during inspiratory threshold loading



CW: chest wall, RCP: pulmonary rib cage, RCA: abdominal rib cage, AB: abdomen, ITL: inspiratory threshold loading, closed symbols: end-expiratory volume, open symbols: end-inspiratory volume. The dotted line: functional respiratory capacity. Bars are means ± SD.

FIGURE 4: RMS values of the Sternocleidomastoid (SMM) and abdominal (ABD) activity during rest and during inspiratory threshold loading (ITL)



*p<0.05

TABLE 1: Descriptive data (means ± SD) of the characteristics of the paricipants

Characteristic	(n = 13)
Age (*yr)*, mean (SD)	65.15 (7.09)
Weight *(kg)*, mean (SD)	62.88 (8.59)
Height *(m)*, mean (SD)	1.64 (0.06)
BMI *(kg/m^2)*	23.37 (2.61)
MIP *(cmH_2O)*	86.92 (29.97)
MIP *(% Pred)*	81.13 (28.03)
FEV_1 *(L)*	1.07 (0.44)
FEV_1 *(%pred)*	33.18 (10.91)
FEV_1/FVC	0.46 (0.07)
MRC*(a.u..)*	2.31 (0.75)

MIP: Maximal Inspiratory Pressure, MRC: Medical Research Council, a.u.: arbitrary unit.

TABLE 2: Effects of the inspiratory threshold loading on volumes of the chest wall compartments, breathing patterns and Modified Borg Scale (means±SD) n=13

	Rest	ITL	ITL - Rest	95% CI	*p*
V_{cw} (L)	0.51±0.11	0.84±0.31	0.34	0.16 a 0.51	0.002[a]
V_{rcp} (L)	0.13±0.04	0.21±0.12	0.08	0.01 a 0.15	0.028[a]
V_{rca} (L)	0.07±0.03	0.11±0.09	0.04	-0.01 a 0.08	0.137
V_{ab} (L)	0.31±0.10	0.53±0.20	0.22	0.14 a 0.31	<0.001
Ti (s)	1.36±0.20	2.09±0.74	0.73	0.23 a 1.23	0.001[a]
Te (s)	2.14±0.48	2.25±0.83	0.11	-0.43 a 0.66	0.653
Ttot (s)	3.49±0.64	4.34±1.40	0.85	-0.09 a 1.78	0.071
Ti/Ttot	0.40±0.28	0.48±0.08	0.09	0.03 a 0.14	0.005
R_f (min^{-1})	18.55±3.26	15.53±4.66	-3.02	-6.92 a 0.88	0.117
V_E ($Lmin^{-1}$)	8.85±1.69	12.30±3.94	3.46	0.79 a 6.13	0.015
V_{cw}/Ti(L/s)	0.37±0.06	0.44±0.16	0.07	-0.03 a 0.17	0.173
V_{cw}/Te(L/s)	0.25±0.06	0.42±0.18	0.17	0.04 a 0.29	0.001[a]
Vee_{cw} (L)	22.53±3.76	22.74±3.80	20	-0.08 a 0.48	0.144
Vee_{rcp} (L)	13.26±1.92	13.41±1.94	0.15	-0.01 a 0.31	0.067
Vee_{rca} (L)	3.29±0.57	3.43±0.57	0.14	0.08 a 0.20	<0.001
Vee_{ab} (L)	5.99±1.55	5.90±1.60	-0.09	-0.24 a 0.06	0.228
Vei_{cw} (L)	23.04±3.79	23.58±3.93	0.54	0.14 a 0.93	0.011
Vei_{rcp} (L)	13.39±1.91	13.61±1.97	0.23	0.02 a 0.43	0.032
Vei_{cta} (L)	3.36±0.58	3.53±0.58	0.17	0.09 a 0.26	0.009
Vei_{ab} (L)	6.29±1.60	6.43±1.73	0.13	-0.06 a 0.33	0,156

ITL: inspiratory threshold loading, CI: confidence interval, V_{cw}: chest wall volume, V_{rcp}: pulmonary rib cage volume, V_{rca}: abdominal rib cage volume, V_{ab}: abdominal volume, Ti: inspiratory time, Te: expiratory time, T_{tot}: total time of the respiratory cycle, R_f: respiratory frequency, VE: minute ventilation, Vee_{cw}: chest wall end-expiratory volume, Vee_{rcp}: pulmonary rib cage end-expiratory volume, Vee_{rca}: abdominal rib cage end-expiratory volume, Vee_{ab}: abdomen end-expiratory volume, Vei_{cw}: chest wall end-inspiratory volume, Vei_{rcp}: pulmonary rib cage end-inspiratory volume, Vei_{rca}: abdominal rib cage end-inspiratory volume, Vei_{rca}: abdomen end-inspiratory volume. [a]: non-parametric variables.

TABLE 3: Coefficients and p-values between pulmonary volumes and muscular activity

Correlation	V_{cw} [a]	V_{rcp} [a]	V_{rca} [b]	V_{ab} [b]
SMM	r=0.558; p=0.005*	r=0.303; p=0.150	r=0.162; p=0.449	r=0.425; p=0.038*
ABD	r=0.094; p=0.663	r=0.142; p=0.509	r=0.107; p=0.617	r=0.070; p=0.747

SMM: sternocledomastoid, ABD: abdominals, V_{cw}: chest wall volume, V_{rcp}: pulmonary rib cage volume, V_{rca}: abdominal rib cage volume, V_{ab}: abdomen volume, [a:] Sperman's correlation, [b]: Pearson Correlation.

ANEXO 1

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1 Lahita R, Kluger J, Drayer DE, *et al.* Antibodies to nuclear antigens in patients treated with procainamide or acetylprocainamide. *N. Engl. J. Med.* 1979; **301**: 1382–5.

Books and other monographs
2 Cade JF, Pain MCF. *Essentials of Respiratory Medicine.* Blackwell Science, Oxford, 1988.

Chapter in a book
3 Colby VT, Carrington CB. Infiltrative lung disease. In: Thurlbeck WM (ed.) *Pathology of the Lung.* Thieme Medical Publishers, New York, 1988; 198–213.

Electronic material
4 World Health Organisation, 3 July 2003. Update 94: Preparing for the Next Influenza Season in a World Altered by SARS. http://www.who.International/csr/disease/ inﬂuenza/sars. Accessed: 15 September 2003.

Online Article not yet published in an issue
An online article that has not yet been published in an issue (therefore has no volume, issue or page numbers) can be cited by its Digital Object Identifier (DOI). The DOI will remain valid and allow an article to be tracked even after its allocation to an issue.

5. Walker J, Kelly PT and Beckart L.Airline policy for passengers requiring supplemental in-flight oxygen. Respirology 2009 doi 10.1111/j.1440-1843.2009.01521.x

References should be cited in the text, tables and legends, using superscript Arabic numerals (after punctuation marks where appropriate), in the order in which they first appear in the text. References should be typed double-spaced and numbered consecutively. Titles of journals should be abbreviated in the reference list according to the style used in *Index Medicus.*

Unpublished observations and personal communications should not be listed as references, but may be incorporated in the text and stated as such in parentheses. References to articles in a language other than English that do not have an English abstract should not be used.

Tables

Tables should be supplied in the manuscript file, on separate pages with one table per page, and each table accompanied by an explanatory caption at the top. Each table should be referred to in the text and numbered in the order of mention. Explanatory material should be placed in footnotes below the Table and not included in the heading. All non-standard abbreviations should be defined in the footnotes. Footnotes should be indicated by *, †, ‡, §. Statistical terms such as SD or SEM should be identified in headings. Use of the word-processing 'Table' function for creating tables is encouraged; otherwise, use only one Tab (not spaces) to separate each column in a table. Vertical and horizontal lines between entries should be omitted.

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Accepted Abbreviations for *Respirology*

Abbreviation	Full Name	Units
6MWD	6 minute walk distance	m
A-aO_2 gradient	alveolar-arterial oxygen gradient	
AHI	apnoea/hypopnoea index	
AIDS	acquired immune deficiency syndrome	
ARDS	acute respiratory distress syndrome	
BAL	bronchoalveolar lavage	
bd	twice daily	
BHR	bronchial hyperresponsiveness	
BMI	body mass index	kg/m^2
BSA	bovine serum albumin	
cAMP	cyclic AMP	
cDNA	complementary DNA	
CI	confidence interval	
CPAP	continuous positive airway pressure	
CRP	C-reactive protein	mg/L
COPD	chronic obstructive pulmonary disease	
CT	computed tomography	
CXR	chest X-ray	
DLCO	diffusing capacity of carbon monoxide	mL/min/mm Hg
DNA	deoxyribonucleic acid	
ECG	electrocardiogram	
ELISA	enzyme-linked immunosorbent assay	

ESR	erythrocyte sedimentation rate	mm/h
FACS	fluorescence-activated cell sorter	
$FEF_{25–75\%}$	forced mid-expiratory flow	L/s
FEV_1	forced expiratory volume in 1 second	L
$FEV_1\%$	percent of predicted forced expiratory volume in 1 second	
FRC	function residual capacity (method of measurement to be specified)	L
FVC	forced vital capacity	L
FVC%	percent of predicted forced vital capacity	
h	hour	
Hb	haemoglobin	g/L
HIV	human immunodeficiency virus	
HPLC	high performance liquid chromatography	
HRCT	high resolution computed tomography	
Hz	hertz	
Ig	immunoglobulin	
IL	interleukin	
IPF	idiopathic pulmonary fibrosis	
IU	international unit	
i.v.	intravenous	
kg	kilogram	
kPa	kilopascals	
L	litre	
LDH	lactate dehydrogenase	
LPS	lipopolysaccharide	
m	metre	
mAb	monoclonal antibody	
MHC	major histocompatibility complex	
min	minute	
mm	millimetre	
mm Hg	millimetre of mercury	
MRI	magnetic resonance imaging	
mRNA	messenger RNA	
MW	molecular weight	
n	number in study group	
OR	odds ratio	
OSA	obstructive sleep apnoea	
P	probability	
PaO_2	partial pressure of arterial oxygen	mm Hg
$PaCO_2$	partial pressure of arterial carbon dioxide	mm Hg
PBS	phosphate-buffered saline	
PC_{20}	concentration of an agent causing a 20% fall in FEV_1	
PCR	polymerase chain reaction	
PD_{20}	dose of an agent causing a 20% fall in FEV_1	
PEEP	positive end expiratory pressure	kPa
PEF	peak expiratory flow	L/min
PET	positron emission tomography	
PET FDG	positron emission tomography with fluorodeoxyglucose	
RNA	ribonucleic acid	
RV	residual volume (method should be specified)	L

s	second	
SaO_2	arterial oxygen saturation	%
SD	standard deviation	
SEM	standard error of the mean	
SPECT	single photon emission computed tomography	
$t_{1/2}$	half life	
tds	thrice daily	
TLC	total lung capacity (method should be specified)	
TNF- **α**	tumour necrosis factor alpha	
UV	ultraviolet	
VA	alveolar volume	L
VATS	video-assisted thoracoscopic surgery	
V/Q	ventilation perfusion	
VC	vital capacity	L
WCC	white cell count	$x10^9/L$
µg	microgram	

AFTER A MANUSCRIPT HAS BEEN ACCEPTED

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SUPPLEMENTS

Guidelines for supplements to be published by *Respirology* can be obtained either from the Editorial Office or from the Business Medical Sales Supplement Executive of the publisher.

ANEXO 2

TERMO DE CONSENTIMENTO LIVRE E ESCLARECIDO

Obrigada pelo seu interesse em participar do projeto "AVALIAÇÃO DA CINEMÁTICA DA PAREDE TORÁCICA E DA DISPNÉIA DURANTE A RESPIRAÇÃO DIAFRAGMÁTICA E A RESPIRAÇÃO COM FRENO-LABIAL EM PACIENTES COM DOENÇA PULMONAR OBSTRUTIVA CRÔNICA"

Objetivo da pesquisa

Esta é uma pesquisa importante para as pessoas com doenças pulmonares, pois tem como objetivo avaliar o movimento do tórax e a sensação de falta de ar durante a realização de dois exercícios respiratórios muito utilizados por pacientes com doenças respiratórias.

Responsáveis

- Profa. Dra. Verônica Franco Parreira do Departamento de Fisioterapia / Universidade Federal de Minas Gerais (UFMG).
- Karoline Simões Moraes, aluna do Programa de Pós-Graduação em Ciências da Reabilitação da UFMG, nível mestrado.

Antes de autorizar sua participação neste Projeto de Pesquisa é necessário que o Sr. compreenda as explicações sobre os procedimentos, benefícios, riscos e informações adicionais sobre a pesquisa.

Caso o Sr. aceite participar desta pesquisa, irá submeter-se aos seguintes **PROCEDIMENTOS**:

Primeiro dia:

O Sr. receberá informações sobre o projeto de pesquisa, depois seu peso e sua altura serão medidos, utilizando uma balança, e sua circunferência abdominal será medida com uma fita métrica. Depois disto, o Sr. realizará duas avaliações, uma para avaliar a quantidade de ar que entra e sai de seus pulmões (análise de volumes e capacidades pulmonares) e outra para avaliar a força dos seus músculos respiratórios. Para a realização destas duas avaliações, o Sr. fará algumas respirações profundas e rápidas. O Sr. aprenderá então a realizar os 2 (dois) exercícios respiratórios: respiração diafragmática (respiração movimentando predominantemente o abdome) e respiração com freno-labial (respiração com os lábios parcialmente cerrados).

Segundo dia:

Serão posicionados marcadores na superfície do seu tórax por meio de adesivos, que parecem com uma fita "durex". O Sr. ficará sentado em um banco, com os braços apoiados e realizará cada exercício respiratório por um período de 6 minutos, com um intervalo de descanso entre eles.

Não será utilizado nenhum instrumento invasivo durante a realização das medidas, ou seja, não haverá elementos pérfuro-cortantes, como agulhas.

Riscos e desconfortos

O estudo não oferece riscos significativos, já que não há nenhum procedimento invasivo ou desgastante para os participantes. Se o Sr. perceber qualquer sintoma diferente do habitual, como por exemplo cansaço, o Sr. poderá interromper o teste.

Benefícios esperados

O Sr. terá sua função pulmonar avaliada e os resultados obtidos contribuirão para um maior conhecimento científico na área e para melhorar a avaliação e o tratamento dos pacientes com doenças pulmonares.

Além dessas explicações, o Sr. tem o direito de solicitar outros esclarecimentos e, como voluntário, o Sr. poderá interromper a sua participação a qualquer momento, durante a coleta de dados, sem qualquer penalização ou prejuízo.

A PESQUISA NÃO REVELARÁ A IDENTIDADE DOS PARTICIPANTES.

O Sr. não terá qualquer tipo de despesa e não receberá nenhuma remuneração por sua participação na pesquisa. As despesas com seu deslocamento serão de responsabilidade das pesquisadoras.

Li e entendi as informações acima. Desta forma, eu ___________________________, concordo em participar deste estudo.Belo Horizonte, _______de __________________de 20____.

___

Assinatura do voluntário

___

Assinatura do pesquisador

Telefones e endereços para contato:

- Professora Verônica Franco Parreira
Endereço: Av. Antônio Carlos, 6627 – Pampulha . Belo Horizonte.
Escola de Educação Física, Fisioterapia e Terapia Ocupacional.
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- COEP – Comitê de Ética em Pesquisa
Endereço: Av. Antônio Carlos, 6627 - Unidade Administrativa II - 2º andar - Sala 2005 – Pampulha. Belo Horizonte.
Telefone: 3409 4592

ANEXO 3

UNIVERSIDADE FEDERAL DE MINAS GERAIS
COMITÊ DE ÉTICA EM PESQUISA - COEP

Parecer nº. ETIC 557/08

Interessado(a): Profa. Verônica Franco Parreira
Departamento de Fisioterapia
EEFFTO - UFMG

DECISÃO

O Comitê de Ética em Pesquisa da UFMG – COEP aprovou, no dia 03 de dezembro de 2008, o projeto de pesquisa intitulado **"Avaliação da cinemática da parede torácica e da dispnéia durante a respiração diafragmática e a respiração com freno-labial em pacientes com doença pulmonar obstrutiva crônica"** bem como o Termo de Consentimento Livre e Esclarecido.

O relatório final ou parcial deverá ser encaminhado ao COEP um ano após o início do projeto.

Profa. Maria Teresa Marques Amaral
Coordenadora do COEP-UFMG

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