

Effects of noninvasive ventilation on dynamic hyperinflation of patients with COPD during activities of daily living with upper limbs

Efeitos da ventilação não-invasiva sobre a hiperinsuflação dinâmica de pacientes com DPOC durante atividade da vida diária com os membros superiores

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Abstract

Background: Patients with chronic obstructive pulmonary disease (COPD) complain of dyspnea on activities of daily living (ADLs) with the upper limbs. Dynamic hyperinflation (DH) is one of the ventilatory mechanisms that may contribute towards dyspnea. To minimize the DH it is indicated the use of noninvasive ventilation (NIV). **Objectives:** To verify whether there is DH and dyspnea during the performance of ADL with the upper limbs with and without the use of NIV. **Methods:** 32 patients with moderate-to-severe COPD, aged 54 to 87 years (mean 69.4, SD 7.4) were evaluated. The subjects lift up containers weighing between 0.5 and 5.0 kg over a five-minute period, starting from the waist level and putting them onto a shelf located above head height, with and without the use of NIV (BiPAP[®]; IPAP 10cmH₂O; EPAP 4 cmH₂O). The inspiratory capacity (IC) and dyspnea (Borg scale) were evaluated on all the patients. The IC was measured before and after simulation of the ADL. In order to analyze the data, Student's t test for dependent samples and the Wilcoxon test were used. **Results:** There were statistically significant reductions in IC after the ADL with and without NIV ($p=0.01$). The dyspnea increased after the ADL with and without the NIV, however between both interventional procedures protocols no between-group difference was observed. **Conclusions:** The simulation of an ADL with the upper limbs resulted in an increase in DH and dyspnea. The NIV supplied with pre-established pressure was not enough to prevent the DH and dyspnea.

Keywords: physical therapy; dynamic hyperinflation; noninvasive ventilation; chronic obstructive pulmonary disease; activities of daily living.

Resumo

Contextualização: Pacientes com doença pulmonar obstrutiva crônica (DPOC) queixam-se de dispneia nas atividades de vida diária (AVD) com os membros superiores (MMSS). A hiperinsuflação dinâmica (HD) é um dos mecanismos ventilatórios que contribuem para a dispneia. Para minimizar a HD, propõe-se a utilização de sistemas de ventilação não-invasiva (VNI). **Objetivos:** Verificar se existe HD e dispneia durante a realização de uma AVD com os MMSS com e sem o uso da VNI. **Métodos:** Participaram 32 pacientes com DPOC de moderada a muito grave, com idades entre 54 a 87 anos (69,4±7,4). Os pacientes elevaram potes com pesos de 0,5 a 5 kg durante 5 minutos, iniciando a elevação a partir da cintura pélvica em direção a uma prateleira localizada acima da cabeça, com e sem o uso da VNI (BiPAP[®]; IPAP 10 cmH₂O; EPAP 4 cmH₂O). Foram avaliadas a capacidade inspiratória (CI) e a dispneia (Escala de Borg). A CI foi mensurada antes e após a simulação da AVD. Na análise dos dados foram utilizados o teste *t* de Student para amostras dependentes e o teste de Wilcoxon. **Resultados:** Houve redução significativa da CI após a AVD com e sem VNI ($p=0,01$). A dispneia aumentou após a AVD com e sem a VNI, mas entre ambos os protocolos não houve diferença. **Conclusões:** A simulação da AVD com os MMSS resultou em aumento da HD e dispneia. A VNI ofertada com pressões preestabelecidas não foi suficiente para evitar a HD e a dispneia.

Palavras-chave: fisioterapia; hiperinsuflação dinâmica; ventilação não-invasiva; doença pulmonar obstrutiva crônica; AVD.

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Introduction

Chronic obstructive pulmonary disease (COPD) is characterized by a progressive airflow obstruction and dyspnea and is the main complaint reported by patients¹. Dyspnea is a common complaint in patients with chronic lung disease during physical activities, which lead to a chronic physical inactivity and sedentary lifestyle. Paradoxically, this lifestyle induces increased ventilatory demand for the same activity, feeding the dyspnea-inactivity-dyspnea cycle¹.

The upper limbs (ULs) are used extensively in daily life for carrying out activities of daily living (ADLs). As the disease progresses, patients have thoracoabdominal asynchrony, increase the oxygen consumption and increase the minute ventilation (VE) during efforts using of the ULs without support^{2,3}. According to Tangri and Woolf⁴, patients with COPD present an irregular, superficial and rapid breathing pattern followed by dyspnea during activities such as tying their shoes.

According to McKeough, Alison and Bye⁵ there are changes in static lung volumes of patients with moderate-to-severe COPD when the ULs are raised without support above 90° of flexion. There is an increase in functional residual capacity (FRC) and a reduction in inspiratory capacity (IC), which characterizes the dynamic pulmonary hyperinflation (DH)⁶.

In the DH occurs an increase in ventilatory demand contributing to the severe dyspnea reported by the patients⁷. According to Porto et al.⁸ exercises performed with the ULs lead to a greater DH compared with exercise performed with the lower limbs (LL). A therapeutic approach aimed to reduce DH during exercises and to interrupt the dyspnea-inactivity-dyspnea cycle is the use of noninvasive ventilation (NIV)^{9,10}. The NIV has been used more recently associated with the training of LL in order to increase the exercise tolerance^{10,11}. This therapy provides a reduction of dyspnea by decreasing the burden on the respiratory muscles as a result of DH; resulting therefore, in a greater amount of blood flow to peripheral muscles, which allows the patient to achieve higher intensities during the exercise¹².

Therefore, the objective of this study was to determine whether there are dynamic pulmonary hyperinflation and dyspnea during the performance of an activity with the upper limbs, simulating activities of daily living, with and without the use of noninvasive ventilation in COPD patients.

Methods

Sample

This study was conducted in a Pulmonary Function Laboratory, where 32 patients with COPD were evaluated.

The participants were recruited from a school clinic of an academic institution and from the local community. The sample size calculation was based on the inspiratory capacity variable analyzed in the study of Marin et al.⁷, which had an effect of moderate magnitude ($d=0.71$), a statistical power of 0.80 and significance level $\alpha=0.05$. Considering an inferential analysis with non-directional test, significance level $\alpha=0.05$ and the sample size needed to detect the desired effect was 22 patients.

The following inclusion criteria were established: patients with COPD stages II to IV according to the criteria of the Global Initiative for Chronic Obstructive Pulmonary Disease¹, presenting lung hyperinflation with values of total lung capacity (TLC) >120% of predicted¹³ and/or the ratio between the forced expiratory volume in one second and the forced vital capacity (FEV_1/FVC) <70% and FEV_1 <80%; air trapping represented by the increase in residual volume (RV) and the ratio RV/TLC >140% and >40% of predicted¹³; in stable clinical conditions, without pulmonary infection four weeks prior the tests and reporting dyspnea during ADL the with the ULs.

Patients presenting asthma, heart failure, orthopedic impairments of the shoulder girdle, recent surgery, history of thoracic fractures, pneumothorax, and claustrophobia were excluded from the study.

This study was approved by the Ethics Committee of the Universidade Metodista de Piracicaba (UNIMEP), Piracicaba, SP, Brazil, number 75/05. All participants signed a consent form.

Instruments and measures

Static and dynamic spirometry analysis

To perform spirometry and to measure the static lung volumes, a whole-body plethysmograph (Vmax22 Autobox, SensorMedics Corporation, Yorba Linda, CA)¹⁴ was used. The evaluations of the TLC, IC, FRC and RV were performed with the patient sitting in the plethysmograph chamber with constant volume and variable pressure. The pulmonary function tests were performed according to the recommendations of the American Thoracic Society¹⁵. In order to evaluate the pulmonary function under optimized ventilatory conditions, the patients performed the pulmonary function tests 20 minutes after the inhalation of 400 mg of salbutamol via nebulizer⁷, in the same day of the procedures described below.

Inspiratory capacity (IC) analysis

To measure the IC, patients breathed through a mouthpiece wearing a nose-clip. Each respiratory cycle was measured using an automated metabolic and ventilatory measurement system (Vmax229d Cardiopulmonary Exercise Testing Instrument

SensorMedics, Yorba Linda, CA). The equipment was calibrated prior to the beginning of the data collection. The evaluation of this variable is based on the analysis of the inspiratory and expiratory flow-volume loops. The DH is demonstrated by the shift of the inspiratory and expiratory loops to the left, as a result of the reduction in IC and the increase of FRC. As the TLC does not change during exercise in patients with COPD, the change in the capacities mentioned above demonstrated the occurrence of the DH^{16,17}.

Firstly, the patient performed the spirometric FVC maneuvers. This maneuver was chosen based on its acceptability and reproducibility¹⁴. After four to six respiratory cycles, in the FRC level, patients were instructed to breathe in until the TLC, with the command "take a deep breath" and at the end they returned to basal breathing in order to establish the basal IC. The greater maneuver from two reproducible IC maneuvers was selected for analysis before the beginning of the ADL simulation⁷. After the intervention, the patients were asked immediately to perform two IC maneuvers following the same verbal command. Due to the proximity of the end of the procedures the first maneuver was chosen for analysis.

Analysis of respiratory distress

In order to describe the sample, the modified Medical Research Council scale¹⁸ (MRC) was used, which includes five situations of physical activity that lead to dyspnea. This scale ranges from 0 to 4, where 0 = no dyspnea, except during strenuous exercise and 4 = dyspnea prevents you from leaving the house or dyspnea occurs while you dress or undress your clothes. To evaluate the effect of the intervention on dyspnea, the modified Borg scale¹⁹ was used, where 0 represents the absence of respiratory fatigue and 10 the greatest feeling of respiratory fatigue, on a scale ranging from 0 to 10.

Intervention

The patients underwent into two different interventional procedures, named Protocol 1 and 2: Protocol 1: ADL - simulation of an ADL that involves elevation of the upper limbs; Protocol 2: ADL + NIV - simulation of an ADL that involves elevation of the upper limbs associated to NIV, performed with positive airway pressure ventilator (BiPAP[®], Respironics[®] - Auto Trak Sensitivity, Murrysville, Pennsylvania, USA). The interventional procedures order was randomized by drawing lots.

Protocol 1 – ADL

The following ADL were simulated by the participants: lift containers with weights of 0.5, 1, 2, 3, 4 and 5 kg, during a period of five minutes, with both arms extended, picking up the containers from a waist high surface and positioning them on

a shelf located above the head³. The activity started by lifting the lightest container and continued progressively with the heaviest ones, until the completion the entire series. The series were repeated as often as necessary, within the total time of 5 minutes, and the number of completed series was not taken into consideration.

Protocol 2 - ADL ± NIV

The interventional procedure was the same that the one performed in the protocol 1, however the performance of the activity was associated with the NIV, using the BiPAP[®]. The inspiratory pressure (IPAP) was set at 10 cmH₂O and the expiratory pressure (EPAP), at 4 cmH₂O. All patients used a face mask (Respironics Cpap Mask Comfortfull 2w Premium, Sao Paulo). Prior to the performance of the activity associated with NIV, the patients underwent to a brief period of adaptation and orientation, which consisted in increasing the pressure gradually until the preset pressure level that was established during the dyspnea analysis and the changes in vital signs: respiratory rate (RR), heart rate (HR - Polar[®]) and peripheral saturation of hemoglobin (SpO₂ - Nonim[®], USA).

Whenever it was observed a decrease in SpO₂ below 90% during the performance of both interventional procedures protocols, the activities were stopped and oxygen was given by nasal cannula (protocol 1) and by face mask (protocol 2) in order to maintain SpO₂ above 90%.

Study design and procedures

Figure 1 presents the study design and the procedures performed during this study. At the end of the first interventional protocol, the patient rested long enough for the SpO₂, HR and RR returned to baseline values and then they performed of the second interventional protocol. These variables were measured 15 minutes after the performance of the first protocol. If the return to baseline value was not reached, a new evaluation was performed every 15 minutes, establishing a maximum period of 60 minutes to return to baseline values.

Statistical analysis

Data are shown as mean ± standard deviation. The distribution of variables was tested using the Shapiro-Wilk tests. All variables were normally distributed with the exception of the fatigue sensation variable. Statistical analysis was performed using the Student t test for paired samples. The analysis of the fatigue sensation variable, the Wilcoxon test was used. The significance level of 5% was established. The analyses were performed by using the statistical package SAS[®] - Statistical Analysis System, 12.0, Cary, NC, USA.

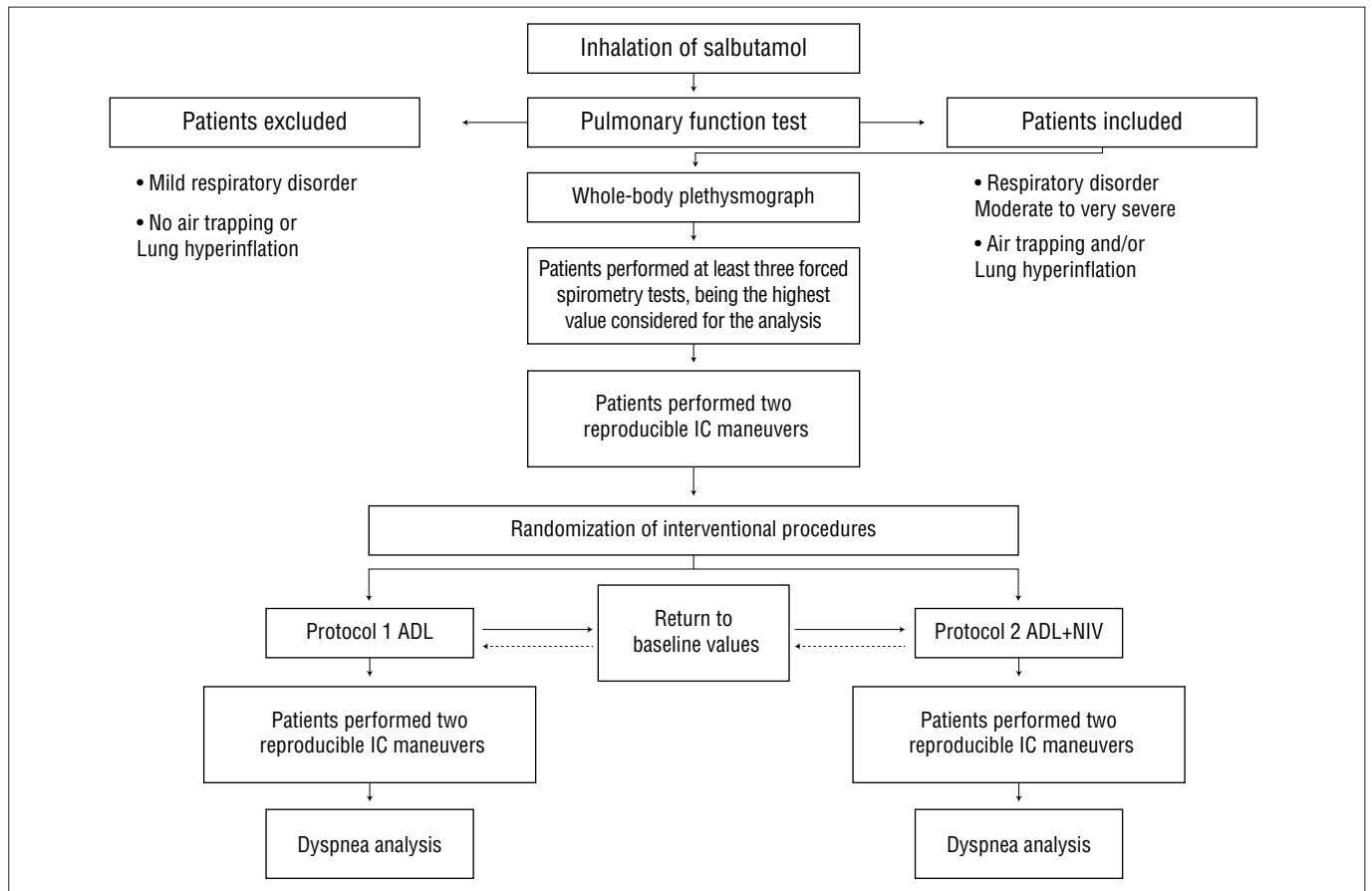


Figure 1. Study design and procedures.

Results

Initially, 33 patients were evaluated, of whom 1 participant had an obstruction stage II, however without pulmonary hyperinflation and air-trapping, being excluded from the study. Therefore, 32 patients underwent both interventional protocols on the same day, as the variables IC, SpO₂ and HR returned to baseline values within 45 minutes.

Table 1 shows the characteristics of patients according to gender, age, body mass index (BMI), years/pack of cigarettes and pulmonary function test. The patients presented FEV₁ between 22% and 64% of predicted. All participants presented air-trapping (n=32) being only 12 of them with pulmonary hyperinflation. Thirteen patients had a score of 4 on MRC scale; 15 had a score of 3 and four patients had a score of 2. All patients reported dyspnea while performing weight-bearing ADLs with the ULs elevated.

Table 2 shows the results for the IC before and after the completion of the two interventional protocols. There was a statistically significant decrease in IC after the completion of both interventional protocols.

Figure 2 shows the data related to the IC after the completion of the two interventional protocols. There was no statistically significant difference between the IC maneuvers after the completion of ADL with and without the association of NIV.

Table 1. Characteristics of patients with COPD.

Characteristics	Patients with COPD (mean±SD) (n=32)
Gender: M/F	24/8
Age (yr)	69.38±7.36
Body Mass (kg)	65.04±13.76
Height (cm)	147.53±50.08
Pack-years (smoke)	78.03±42.51
FEV ₁ -L (% predicted)	1.03±0.36 (42±13)
FVC-L (% predicted)	2.73±0.84 (89±23)
FEV ₁ /FVC %	42±12
TLC-L (% predicted)	7.03±1.46 (120±31)
FRC-L (% predicted)	5.19±1.37 (160±52)
VR-L (% predicted)	4.27±1.35 (228±124)
RV/TLC%	61±10
IC % predicted	67±15
IC/TLC %	26±7

Data are presented as mean±Standard Deviation. COPD=chronic obstructive pulmonary disease; M=Male; F=Female; FEV₁=forced expiratory volume in one s; FVC=forced vital capacity; FEV₁/FVC=Tiffeneau; TLC=total lung capacity; FRC=functional residual capacity; RV=residual volume; IC=inspiratory capacity and IC/TLC=inspiratory fraction.

Figure 3 shows the data related to the evaluation of dyspnea after the completion of both interventional protocols. It was observed that the performance of the interventional procedures promoted a significant increase in dyspnea after the completion of both protocols, with no difference between them.

Table 2. Inspiratory capacity in patients with COPD (n=32) before and after ADL with or without NIV.

Interventional Procedures Protocol	Before	After	p Value
ADL	2.06±0.60 L	1.69±0.60 L	0.0001*
ADL+ NIV	2.05±0.62 L	1.73±0.57 L	0.0001*

Data are presented as mean±Standard Deviation; IC=inspiratory capacity; COPD=chronic obstructive pulmonary disease; ADL=activity of daily living; NIV=noninvasive positive pressure ventilation and *p<0.05.

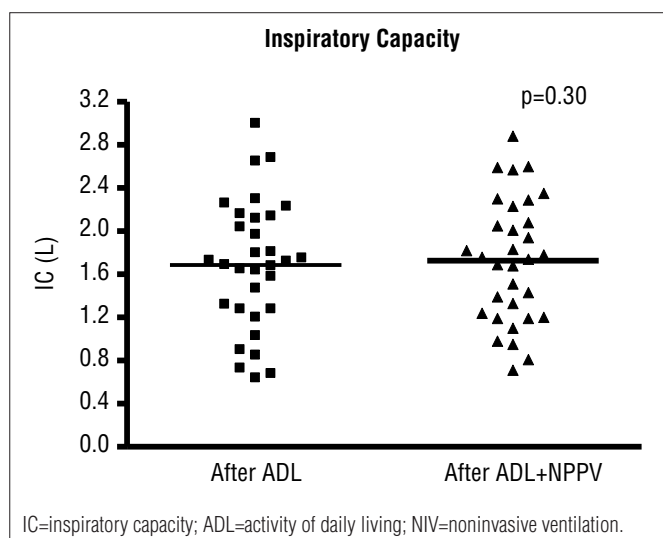


Figure 2. Data are presented as absolute values and means.

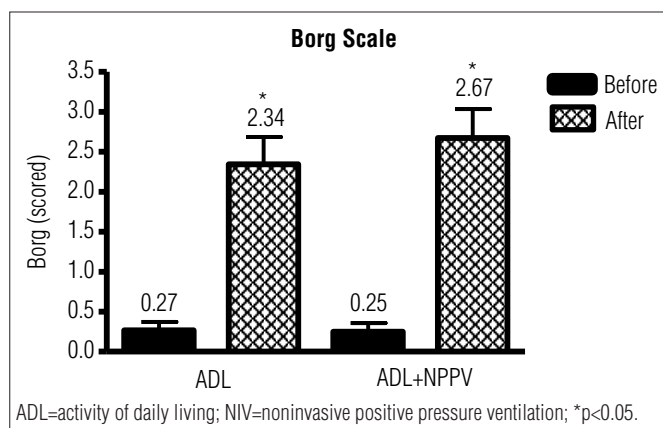


Figure 3. Data are presented as median.

Discussion

The main results observed in this study were: 1) there was a statistically significant decrease in IC with the simulation of an ADL, associated or not with noninvasive ventilation, demonstrating DH; 2) a statistically significant difference was not observed in the comparison of the IC after the completion of both protocols and 3) there was a significant increase in dyspnea after the completion of both protocols, with no difference between them.

The DH observed in patients with COPD leads to dyspnea and limits the capacity to perform physical exercises². The hypothesis of this study was that NIV performed with two levels of positive pressure (IPAP of 10 cmH₂O and EPAP of 4 cmH₂O) would decrease dyspnea and pulmonary intrinsic pressure (PEEPi), and consequently would decrease the DH.

The ventilatory pattern during activities with the elevation of the ULs influences the onset of DH in patients with COPD who have difficulty to optimize the VE by the increase in the Tidal Volume (Vt)^{5,20-22}. In a recently study, Colucci et al.²³ verified the association between different intensities of exercises with the ULs (50, 65 and 80% of maximum load during a ergometer cycle exercises) and the DH in patients with severe COPD. These authors observed that higher loads of exercise were associated with DH and a lower tolerance to exercise and 80% of the maximum load represented lower work efficiency (measured by the ratio VO₂ (ml/kg)/exercise duration).

The ventilatory strategy of these patients to increase the VE is to increase the RR, since the TLC does not change with exercise^{16,17}. The premature end of exhalation increases even more the air-trapping, decreasing therefore the IC⁶. In the present study, the use of NIV with pre-determined and not individualized values (IPAP 10 cmH₂O and EPAP 4 cmH₂O) aimed to standardizing the intervention, and the choice of the used pressures was based on several studies^{9,24,26-28} which have demonstrated the benefits of using these pressures during exercises with the LLs. To our knowledge there are no studies that have associated the simulation of an ADL with NIV.

Nava et al.²⁴ found a reduction in the activity of the diaphragm muscle measured by the decrease in transdiaphragmatic pressure as well as a significant decrease in RR and a parallel increase in the Vt when an IPAP of 10 cmH₂O or 20 cmH₂O, associated with an EPAP of 5 cm H₂O, was applied in stable and hypercapnic patients with severe COPD during basal respiration.

The artificial ventilation support may improve exercise tolerance and may help patients with severe COPD to achieve higher level of training²⁵⁻²⁷. Van't Hul et al.²⁶ evaluated the effects of exercise training with only pressure support ventilation (PSV of 10 or 5 cmH₂O) in patients with moderate to very severe COPD. These authors found that in the assistance level of 10 cmH₂O, there was a reduction in the VE by the reduction in the RR. The authors suggested that the changes in the respiratory pattern may have reduced the DH, which justified the increased tolerance to high-intensity training in these patients.

Maltais, Reissmann and Gottfried⁹ evaluated the respiratory pattern, dyspnea and inspiratory effort in patients with moderate-to-severe COPD, performing a constant load test on the ergometer cycle, associated with the use of SP of 10 cmH₂O. These authors found an increase in the VE by the increase in

RR and Vt, however with a significant decrease in the inspiratory effort and dyspnea.

Poggi et al.²⁷ investigated the effects of two types of artificial ventilation (PAV and PSV - both with IPAP, established according to patients comfort, and EPAP of 4 cmH₂O) during elevation of the ULs in patients with severe COPD. In both modes of ventilation, there was a reduction of the PEEPi greater than 30% compared with the control group, however this difference was not statistically significant. It should be noted, however, that the group that used the PAV method reported lower inspiratory effort during the elevation of the ULs.

O'Donnell, Sanii and Younes²⁸, in an innovative study, evaluated the impact of the use of CPAP of 4 to 5 cmH₂O in patients with moderate-to-severe COPD and observed a reduction of dyspnea during the performance of submaximal exercise on the treadmill, suggesting that positive pressure promoted the reduction of DH.

With regards to the IPAP established in order to provide support to the inspiratory muscles, especially to the diaphragm muscle, it is possible that the selected pressure of 10 cmH₂O was not adequate to achieve this goal when the simulation of a ADLs was performed. There was a significant increase in dyspnea, which indicates indirectly an overload of the inspiratory muscles. According to the findings of the present study, it appears that the EPAP of 4 cmH₂O was insufficient to counterbalance the PEEPi and, therefore, to reduce the overload of the inspiratory muscles in these patients. Studies show that patients with COPD usually complain of a more intense dyspnea when performing prolonged tasks involving the upper limbs in elevated positions and without support compared to tasks with LLs^{3,4,8,29}. This fact demonstrates the possibility of ULs exercises to generate greater impact on DH compared with LLs exercises.

This study has some limitations. Firstly the RR, the transdiaphragmatic pressure and the PEEPi, which could explain the absence of a reduction in the elastic and resistive work of the respiratory muscles, were not measured after the

interventional procedures protocols. Therefore, the pre-established pressures may have been inadequate for some patients. Secondly, studies show that other forms of artificial ventilation, such as proportional assisted ventilation, PAV, may provide better results compared to the two fixed pressure levels established in this study, since the PAV suit better to the patient's ventilatory demand³⁰.

The main purpose of using NIV during the exercise is to reduce dyspnea by reducing the overload imposed on the respiratory muscles as a result of DH, allowing patients to achieve higher intensity during exercise³⁰. The reduction in the overload of respiratory muscles during exercise reduces blood flow competition between these muscles and the peripheral muscles, contributing to an increased of blood supply to the muscles¹². In the Velloso et al.³ study, in patients with COPD performing four ADLs involving the ULs (sweeping the floor, clearing a whiteboard, lifting containers of different weights and changing light bulbs), was observed an increase in the ratio VE on the maximum voluntary ventilation, justifying the intense dyspnea reported by these patients, although the DH has not been evaluated. Our results showed that the addition of NIV was not able to significantly reduce dyspnea during a simulation of ADL, which may be due to the use of pressures (IPAP and EPAP) beyond the requirements of the patients.

Therefore, our results suggest that the bi-level pressure modality, with IPAP and EPAP of 10 and 4 cmH₂O, respectively, was not sufficient to prevent the DH and dyspnea during ADL with the ULs in patients with moderate-to-severe COPD. The search for therapeutic strategies to improve the functionality of the patient with COPD during the performance of ADLs is extremely important, considering that 80% of the functionality is performed by ULs tasks⁸.

We suggest future studies to examine the effects of NIV during ADL with the ULs using other pressures or modalities of NIV, since the functional independence during ADL is a major goal of respiratory physical therapy in the treatment of patients with COPD.

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