

CLINICAL SCIENCE

Strategy for respiratory exercise pattern associated with upper limb movements in COPD patients

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INTRODUCTION: Upper limb exercises are frequently used in respiratory physiotherapy, with UL elevation and controlled inspiratory timing. However, the use of expiration during upper limb elevation appears to be a strategy that could minimize the action of accessory muscles in patients with chronic obstructive pulmonary disease. In this context, little is known about the synchrony of upper limb (UL) movements associated with breathing. The aim of this study was to investigate the respiratory pattern of chronic obstructive pulmonary disease patients during different UL exercises associated with respiratory exercises.

METHODS: Fifteen chronic obstructive pulmonary disease patients participated in this study. Respiratory pattern analysis by inductance plethysmography was performed during four types of upper limb exercises, two shoulder flexion-extension (one associated with inspiratory time during the concentric phase and the other associated with expiratory time) and two shoulder abduction-adduction (same timing as above). Statistical analysis was performed by the Kolmogorov-Smirnov test and ANOVA with Tukey tests ($p \leq 0.05$).

RESULTS: The thoracoabdominal coordination measurements increased in the two exercises using both inspiration during shoulder flexion (PhRIB: 172%; PhREB: 131%; PhRTB: 142% and PhAng: 238%) as well as in shoulder horizontal abduction (PhRIB: 145%; PhREB: 109%; PhRTB: 130% and PhAng: 229%), differing from the exercises with expiration at the time of shoulder flexion and horizontal abduction.

CONCLUSION: The exercises performed with inverted respiratory time produced less asynchrony and can be used as important strategies during physical exercise programs in these patients.

KEYWORDS: Chronic obstructive pulmonary disease; Breathing exercises; Physiotherapy; Upper extremity; Plethysmography.

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INTRODUCTION

Reduced capacity to perform physical exercise is a common manifestation in chronic obstructive pulmonary disease (COPD), with patients presenting limitations in physical activities requiring normal exertion¹ and lower levels of physical activity when compared with healthy controls.² Frequently, the most severe patients relate major difficulty with activities that involve the upper limbs (UL) compared with lower limbs, particularly when using them without support.^{3,4} According to the most up-to-date guideline on pulmonary rehabilitation the new evidence provides additional support for the inclusion of upper limb

exercise training in pulmonary rehabilitation. Improvement has been demonstrated in upper limb exercise capacity and reduction in ventilation and oxygen uptake (VO_2) cost during arm activity after unsupported arm training.⁵ In this context, the inclusion of exercise training targeting the upper limbs muscles in pulmonary rehabilitation programs specifically for patients with COPD has been recommended.

Simple arm elevation modifies ventilatory and postural muscle recruitment, therefore, altering the mechanics of the ribcage and abdominal compartments. However, in COPD patients during exercise of UL, these muscles need to sustain the upper girdle and act as accessory respiratory muscles, playing a competitive role.⁶ These muscles, which are usually inactive during inspiration at rest in healthy people, vigorously act during physical effort^{7,8} in COPD patients.⁹ Thus, during activities that involve UL, respiration becomes ineffective because the accessory respiratory muscles operate to sustain the shoulder girdle. As a result, the functional overload of the diaphragm associated with

thoracoabdominal asynchrony trigger the premature appearance of dyspnea and fatigue, causing reduction of upper limbs endurance capacity in these patients.^{9,10}

The inclusion of UL exercises for COPD patients during a pulmonary rehabilitation program has been shown to increase the work capacity of the upper limbs, while there is a reduction of VO_2 . It is pointed out that the postulated mechanisms for this functional improvement in the upper limbs in COPD patients include desensitization to dyspnea, better muscle coordination and beneficial metabolic adaptations to the exercise.⁵

In this context, some strategies have been used in COPD patients aiming to improve exercise performance. Pursed-lip breathing is an intuitive technique that frequently many COPD adopt to reduce dyspnea during exertion and have been frequently used during, or after any physical activity as a breathing retraining form. This strategy relieves the dyspnea sensation almost immediately after beginning to use the technique¹¹ and encourages expiration time during the concentric phase of UL movements. Therefore it seems to be a form of physical exercise that could minimize the action of the accessory muscles. In contrast, inspiratory phase timing associated with concentric phase of the movements has been the incentive most frequently applied during a respiratory reeducation program. However, the effects of the inverse strategy on the respiratory pattern and thoracoabdominal synchrony have yet to be investigated. Another aspect that should be considered is whether different types of UL exercise (flexion-extension and horizontal adduction/abduction) also alter respiratory variables, which emphasizes the need for detailed exploration of the respiratory patterns under these circumstances.

Therefore, the aim of the present study was to investigate the respiratory pattern of COPD patients during different upper limbs exercises associated with respiratory exercises. The hypothesis of the present study was that there are marked differences in respiratory pattern during different upper limbs exercises due to different types of muscle recruitment related to accessory muscles.

MATERIALS AND METHODS

Subjects

A total of 30 subjects of both sexes were screened, including patients with stable COPD (diagnosed by accepted criteria,¹² among whom fifteen subjects (08 men and 07 women) were selected for inclusion in the study. For all COPD patients the exclusion criteria were: age over 80 years old; history of recent exacerbation; uncontrolled arterial hypertension and need for long-term oxygen therapy. The selected subjects had a documented medical history of COPD, were receiving medical therapy with pulmonary drugs, and all of them were smokers or former smokers, and none had any clinical or physiological features of bronchial asthma. The study was approved by the Research Ethics Committee of the University (Protocol 073/2009) and informed consent was obtained from each participant.

Study design

The respiratory pattern of COPD patients was investigated in the present study during four upper limbs exercises that consisted of shoulder movements described as follows:

- 1) Shoulder flexion from 0° to 180° (upper limbs elevation) during inspiratory time, and return to the initial position during expiratory time (shoulder extension: 180° to 0°).
- 2) Shoulder flexion from 0° to 180° (upper limbs elevation) during expiratory time, and return to the initial position during inspiratory time (shoulder extension: 180° to 0°).
- 3) Shoulder horizontal abduction (initial position: shoulder flexion at 90°) during inspiratory time, and return to the initial position during expiratory time (shoulder horizontal adduction).
- 4) Shoulder horizontal abduction (initial position: shoulder flexion at 90°) during expiratory time, and return to the initial position during inspiratory time (shoulder horizontal adduction).

Initially, the exercises performed in this study were taught to participants by the physiotherapist (learning phase). After this patients were asked to perform each of the four exercises during a maximum time of two minutes, in order to retain their effectiveness. The exercises were interrupted if the individual felt dyspnea and/or muscle fatigue. After the learning phase and a period of 10 minutes rest in the seated position, the respiratory pattern was recorded (in the standing position) during the exercises (1, 2, 3 and 4) as described above (Figure 1).

For the shoulder flexion-extension exercises (1 and 2) the individual held a long stick (weighing 120g) and for the shoulder horizontal abduction-adduction exercises (3 and 4) the individual held a small tennis ball (58g), which were alternated between their hands in each movement.

During the upper limbs exercises, patients were instructed to inspire through the nose and expire through the mouth with pursed-lip breathing. The four exercises were performed for one minute each, with a time interval of two minutes between them, and no speed at which to perform the exercises was imposed on them. The inspiratory and expiratory times were not standardized; that is, the volunteers were free to perform the exercises at their own pace. The respiratory pattern (described below) was assessed during all experimental procedure and further analyses were done with data collected during the four exercises performed.

Respiratory pattern assessment and analysis

The respiratory pattern was assessed by respiratory inductive plethysmography (RIP) (LifeShirt System; Vivometrics Inc., Ventura, CA, USA) and was monitored using the thoracic and abdominal inductance plethysmography bands integrated in the LifeShirt garment, located at the levels of the nipples and umbilicus, respectively. Data were recorded with a portable device, stored on a flash memory card inserted in the LifeShirt recorder and then downloaded to a computer into the VivoLogic analysis software (Vivometrics, Ventura CA, USA) accompanying the LifeShirt in order to perform respiratory data analyses.

For the volumetric adjustment procedure with RIP, the participants were asked to breathe in and out of an 800 ml plastic-bag attached to a mouthpiece tube, seven times, with the nose clipped, filling and emptying the bag completely with each breath. This procedure was conducted in the sitting and standing posture after appropriate pauses, twice

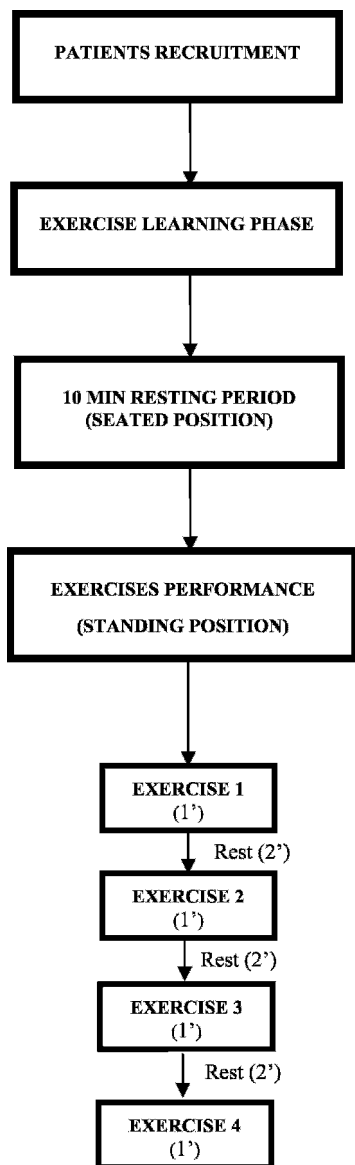


Figure 1 - Experimental protocol.

for each posture, and repeated if participants did not adhere to instructions, until it was successfully performed.

In the respiratory pattern analyses, the following variables were used: inspiratory tidal volume (ViVol); expiratory tidal volume (VeVol); minute ventilation (VE); inspiratory time (Ti); expiratory time (Te); total breath time (Tt); phase relation during inspiration (PhRIB); phase relation during expiration (PhREB); phase relation of the entire breath (PhRTB) and phase angle (PhAng). To obtain the respiratory inductive plethysmographic sum signal for absolute volume in ml, a quantitative calibration was carried out (fixed volume least squares calibration) before the analysis of respiratory variables. The respiratory pattern was collected during one minute of each exercise but the breath-by-breath analysis was done during a 30-second period each one (which was chosen according to the most stable strength signal) and converted to mean values for later comparisons by statistical analysis.

Statistical analysis

Data were submitted to a frequency distribution analysis by Kolmogorov-Smirnov’s test and as data presented normality, repeated measures ANOVA with Tukey post-Hoc for the intragroup analyses were performed. A P value of 0.05 was considered statistically significant. The Prism 3.0® software was used. For calculating the sample size the GraphPad StatMate 1.01i (San Diego, CA, USA) software was used.

RESULTS

The results were showed by mean ± standard deviation and the sample size (n=15) was reached by power calculation.

The baseline characteristics of the study population are shown in Table 1. The mean age was 65 years. The participants were current (n=06) or former (n=09) smokers. The mean FEV1 was 1.41±0.45 liters with 06 moderate and 09 severe COPD.

Figure 2 illustrates volume measures of COPD patients during the five studied conditions. An increase of ViVol and VeVol values can be observed during exercises 2 and 4, represented by 424.1% and 179.1% in the ViVol; 441.7% and 218.9% in the VeVol respectively, when compared with rest condition. Comparisons among the four types of exercises showed higher volume values during exercise 2, when compared with exercises 1, 3 and 4.

The VE also increased (p<0.001) to 354.9% and 254% during exercises 2 and 4 (2: 51.4±27.5 / 4: 40.0±22.7) when compared with rest (11.3±4.8); and during exercise 2 (p<0.01) when compared with exercises 1 (27.0±16.4) and 3 (25.0±9.3).

Table 2 shows the alterations in time measurements in exercise 1 (decrease of 29% in Te), exercise 3 (decrease of 46% in Te and 31% in Tt) and exercise 4 (decrease of 37% in Te and 27% in Tt), when compared with rest condition. Higher values of Ti, Te and Tt variables were also observed

Table 1 - Baseline characteristics of the study population.

| Characteristic | N = 15 |
|---|--------------|
| Age, mean (SD), years | 65.3 (7.3) |
| Male/Female, N | 08/07 |
| Height, mean (SD), cm | 1.65 (0.11) |
| Weight, mean (SD), kg | 63.3 (10.9) |
| Body Mass Index, mean (SD), kg/m ² | 24.6 (4.8) |
| Smoking status, N | |
| Never | 0 |
| Former | 09 |
| Current | 06 |
| Pulmonary Function, mean (SD) | |
| FVC (%predicted) | 70.2 (16.2) |
| FEV1 (%predicted) | 47.7 (11.8) |
| FEV1/FVC ratio (% predicted) | 69.8 (12.7) |
| Moderate COPD (n) | 06 |
| Severe COPD (n) | 09 |
| Respiratory muscle strength, mean (SD) | |
| MIP (cmH ₂ O) | -64.7 (27.2) |
| MEP (cmH ₂ O) | 81.4 (28.6) |
| Associated chronic conditions, N | |
| Hypertension | 05 |
| Diabetes Mellitus | 01 |

SD: standard deviation. N= number. BMI = body mass index; FVC= forced vital capacity; FEV1 = forced expiratory volume in 1 second; MIP: maximal inspiratory pressure; MEP: maximal expiratory pressure

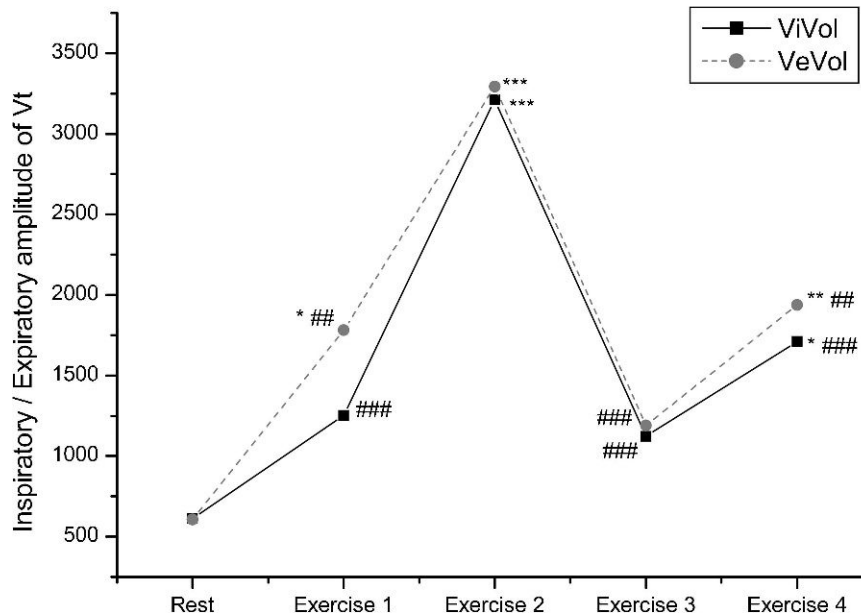


Figure 2 - Inspiratory tidal volume (ViVol) and expiratory tidal volume (VeVol) under conditions of rest and respiratory exercises associated with upper limbs (1, 2, 3 and 4) of COPD group (n = 15).
Explanatory legend: * p<0.05; ** p<0.01; *** p<0.001 compared with rest condition; ## p<0.01; ### p<0.001 compared with exercise 2.

during exercise 2 when compared with exercise 3; and Ti and Tt when compared with exercises 4 (Table 2).

Thoracoabdominal coordination measurements (PhRIB, PhREB, PhRTB) and PhAng increased during exercises 1 and 3 when compared with rest condition, as observed in Figure 3 (PhRIB = 1: 172%; 3: 145% / PhREB = 1: 131%; 3: 109%) / PhRTB = 1: 142%; 3: 130% and PhAng 1: 238% / 3: 229%). Exercises 1 and 3 showed higher values of PhRIB (1: 89%; 3: 70%) and PhAng (1: 199%; 3: 191%) when compared with exercise 2. The same exercises (1 and 3) also showed higher values in comparison with exercise 4, considering the same variables PhRIB (1: 83%; 3: 65%) and PhAng (1: 158%; 3: 152%). Exercise 1 presented higher PhREB and PhRTB values when compared with exercises 2 (PhREB: 64%; PhRTB: 79%) and 4 (PhREB: 55%; PhRTB: 60%), while exercise 3 presented higher PhRTB values (70%) in comparison with exercise 2 (Figure 3).

DISCUSSION

The main finding of the present study was the better thoracoabdominal synchronism during the UL exercises associated with inverted breathing (expiration during concentric phase of UL movement) when compared with the results of exercises frequently applied in clinical practice, with a specific exercise (arm elevation). These

results can demonstrate the best respiratory pattern of these COPD patients. In addition, amongst the studied exercises, exercise 2 showed the highest tidal volumes.

In 2007, Rabe et al.¹² observed that COPD could be the third most common cause of death worldwide by 2020. In 2009, Donner and Bjermer¹³ observed that “although COPD is a major disease worldwide there is a perplexing current uncertainty about the nature of this disease” and that “COPD begins as a local inflammation in the lungs, and through differentiated pathways still to be clarified, this leads to systemic consequences”.

In this direction, some studies have also related that although COPD is a respiratory disease affecting the lungs, it is known that its effects are not exclusively limited to the respiratory system. Consequently, there are non-respiratory manifestations, including skeletal muscle dysfunction with atrophy and weakness, systemic inflammation, nutritional depletion and malnutrition, which can contribute to exercise limitation and affect patients’ function and mobility.¹⁴⁻¹⁸ In their study, Papaioannou et al. observed that higher systemic levels of oxidative stress in COPD patients may contribute to a reduction in the body mass and fat-free mass indexes, thereby contributing to impaired exercise capacity.¹⁹

From this aspect, studies have shown that in COPD patients, the peripheral muscles are frequently affected,

Table 2 - Time measurements of respiratory inductance plethysmography under conditions of rest and respiratory exercises associated with upper limbs of COPD group (n = 15).

| | Rest | Exercise 1 | Exercise 2 | Exercise 3 | Exercise 4 |
|----|-------------|----------------|-------------|--------------------|-----------------|
| Ti | 1.30 ± 0.22 | 1.60 ± 0.59 | 1.75 ± 0.58 | 1.26 ± 0.42 # | 1.17 ± 0.36 ## |
| Te | 2.35 ± 0.44 | 1.66 ± 0.58 ** | 1.96 ± 0.60 | 1.27 ± 0.39 *** ## | 1.47 ± 0.67 *** |
| Tt | 3.65 ± 0.52 | 3.26 ± 1.08 | 3.70 ± 1.11 | 2.53 ± 0.74 ** ## | 2.65 ± 0.90 * # |

Ti: inspiratory time; Te: expiratory time; Tt: total breath time

*p<0.05; ** p<0.01; *** p<0.001 compared with rest condition; # p<0.05; ## p<0.01 compared with exercise 2

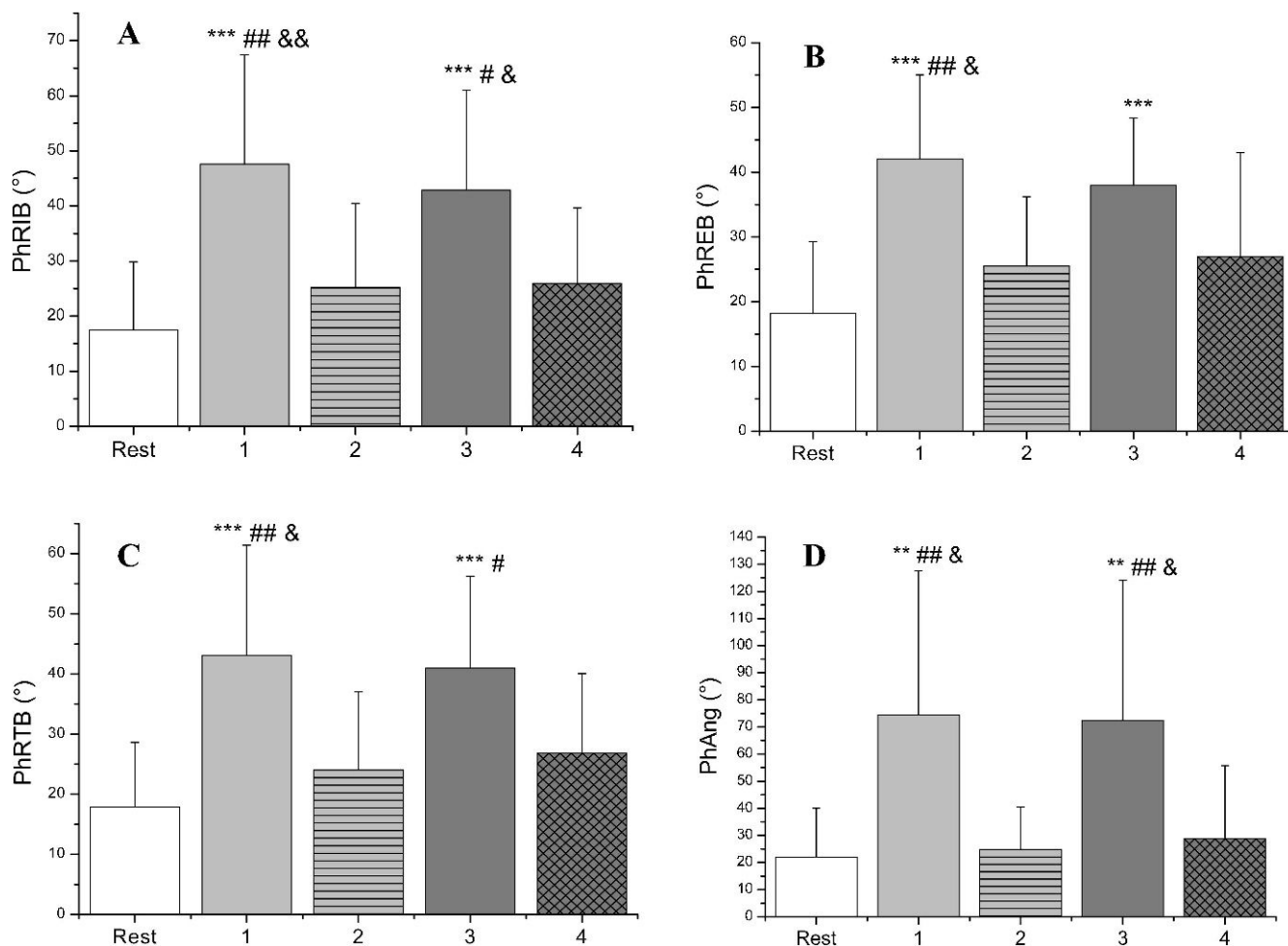


Figure 3 - Thoracoabdominal coordination measurements PhRIB (A), PhREB (B) and PhRTB (C) and PhAng (D) under conditions of rest and respiratory exercises associated with upper limbs (1, 2, 3 and 4) of COPD group (n = 15). Explanatory legend: PhRIB: phase relation during inspiration; PhREB: phase relation during expiration; PhRTB: phase relation of entire breath; PhAng: phase angle. *** p<0.001 compared with rest condition; # p<0.05; ## p<0.01 compared with exercise 2; & p<0.05; && p<0.01 compared with exercise 4.

involving respiratory as well as upper and lower limbs muscles. According to Levine et al.²⁰ and Gosker et al.,²¹ patients with COPD present a higher ratio of type I fibers in the diaphragm muscle and this process can contribute to the reduction in force generation. In contrast, peripheral muscles dysfunction is characterized by a reduction in the percentage of oxidative fibers (type I) in relation to glycolytic fibers, thus contributing to reduction in the oxidative capacity of these muscles.^{22,23} Due to dysfunction and atrophy in the striated skeletal muscles, COPD patients may show reduced exercise capacity in addition to impaired quality of life and an increased mortality rate.^{24,25}

As a corollary, activities such as combing hair, brushing teeth or shaving involve UL movements and shoulder muscles without support²⁶, in which the accessory muscles of inspiration assist the positioning of the trunk and upper limbs. This activities contributes to increased demand on these muscles and diaphragm overload, resulting in inspiratory movements with thoracoabdominal asynchrony and the premature appearance of dyspnea and leg fatigue, limiting the endurance of the upper limbs.¹⁰ According to Casaburi and Petty, the low tolerance of COPD patients during UL exercises is due to the fact that the shoulder and

thorax muscles participate in the respiratory processes and shoulder movements.²⁷

In clinical practice, UL exercises can be performed with and without support. Among those without support are the exercises used in this study, specifically shoulder flexion and horizontal abduction-adduction, which can be associated with the respiratory pattern, considering expiration during concentric phase of the movements. This technique is adopted in some pulmonary rehabilitation programs, however, without any studies related to respiratory pattern having been conducted, specifically during the different respiratory patterns associated with these exercises performed with inverted movements by patients with COPD.

Exercises 1 and 3 showed greater thoracoabdominal asynchrony, when compared with the rest condition. This result can be explained by the activity of the accessory muscles of respiration during UL movements. Hussain et al. reported that the ribcage muscles are recruited for multiple activities, such as breathing, postural support, and stabilization during the tasks performed with UL and their positioning.²⁸ When there is an increase in ventilatory necessity, such as in physical exercise, the accessory and expiratory muscles are recruited. When the asynchrony or

coordination of these muscles with the primary motor muscles of inspiration is altered, it can cause airway obstruction, thoracic wall distortion and inefficient muscle actions, and all these alterations cause disadvantage in respiratory work.¹⁰

Celli et al. also studied the ventilatory and metabolic responses during UL exercises without support in COPD patients and showed that this exercise promoted thoracoabdominal asynchrony, followed by dyspnea.¹⁰ In 1992, Couser et al. observed that arm elevation in normal subjects promoted an increase in ventilatory and metabolic demands similar to mild exercise with changes in ribcage and/or abdominal mechanics.²⁹ This can help to explain the limitation in exercise tolerance observed in unsupported UL activities in these subjects and this could be more relevant in COPD patients whose diaphragm muscles are less effective.

However, in exercises 2 and 4, in which the respiratory movement was inverted, there was no increase in thoracoabdominal asynchrony, when compared with the rest condition and the other exercises. These physical exercises being performed by COPD patients in clinical practice are based on this aspect, not only when there is shoulder flexion (upper limbs elevation), but also shoulder horizontal abduction-adduction exercises, specifically exercise 2. A possible explanation for this is that during inspiration, when the UL are turned down, it decreases the double action of accessory muscles; differently from exercise 1, in which the accessory muscles assist the UL during the rising movement.

This also could explain the high values in volume measurements (V_{iVol} , V_{eVol} and V_E) during exercise 2, when compared with the others. This could be the result of better performance and intensification of breathing that was being achieved only by the muscles responsible for the action, without interference by the accessory muscles in the movement, probably without overloading the diaphragm. Although exercise 2 showed higher values than the other exercises (1, 3 and 4), exercise 4, also with an inverted respiratory pattern, presented an increase in the V_{iVol} , V_{eVol} and V_E values when compared with the rest condition, corroborating the idea that inversion of the respiratory pattern intensifies the volume measurements during respiration.

Considering exercises 3 and 4, shoulder horizontal abduction-adduction, in which the patients's UL were supported in the shoulder flexion position at 90°, it could be seen that during the horizontal abduction associated with inspiration (exercise 3), there was increased asynchrony, when compared with the opposite movement (exercise 4). In exercise 3, the increased asynchrony can be explained by the combined movement of shoulder flexion, shoulder abduction and assistance with breathing, while in exercise 4, the inversion of breathing helped to inhibit the accessory muscles of respiration, restricting them to only their main action during the shoulder exercise, in which the shoulders were sustained flexion at 90°.

During exercises 3 and 4, it is important to emphasize the inversion of respiratory movements associated with the intense use of accessory muscles of respiration related to the ribcage expansion movement. In the horizontal abduction movement with inspiration, the muscles assist in inspiration and also in ribcage expansion, in this context, operating in the two functions, while during the horizontal adduction

with inspiration, the ribcage expansion is more restricted, which could minimize action of the accessory muscles. This could explain why there was less asynchrony in this type of exercise, with the reduced function of the accessory muscles of respiration.

Some muscles of the superior part of the thorax and scapular girdle, which serve for respiratory and postural functions, have thoracic and extrathoracic attachment points, such as the inferior/superior trapezius, latissimus dorsi, serratus anterior, subclavius and pectoralis major and minor. In COPD patients with pulmonary hyperinflation, which frequently occurs, the diaphragm lowers and loses its capacity to generate force, so that the ribcage muscles become more important to generate the inspiratory pressures.³⁰ In this sense, and based on the results of the present study, it is suggested that exercises that minimize the action of accessory muscles of inspiration are more appropriate for COPD patients, because they direct the inspiratory movement to the muscles suitable for the movement, especially the diaphragm muscle.

The limitations of this study are related to the scarcity of studies about the issue, and to the methodology used, especially the inductance plethysmography. Therefore, it is suggested that studies of this nature should be conducted with different evaluation methodologies (electromyography or optoelectronic plethysmography) with the intention of leading to better understanding of the results of the present study.

CONCLUSIONS

In view of the results of this study, it could be concluded that the inversion of inspiration/expiration could probably be an interesting strategy for performing respiratory exercises associated with the upper limbs to minimize thoracoabdominal asynchrony in COPD patients. Future studies could relate this strategy to the breathing retraining during upper limbs exercises, which are also part of pulmonary rehabilitation and daily life activities.

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