

Improvements in Perimeter Thoracic Mobility on Patients with COPD after Pulmonary Rehabilitation: A Case Series

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ABSTRACT

Purpose: To evaluate if the perimeter thoracic mobility (PTM) improvements could be identified by measuring its perimeter during pulmonary rehabilitation (PR), searching for its correlations with standards clinical and functional assessments.

Design: A case series.

Methods: Twenty patients underwent a PR and accessed the arterial blood gas analyses, FVC, FEV1, FEV/FEV1, 6-minute walk test (6MWT), and the PTM measurement assessed at the angle of the Louis level and the xiphoid process level.

Results: PR improved PTM on the angle of Louis ($p=0.03$) but not on the xiphoid process. These improvements are negatively correlated with improvements in PaCO₂.

Conclusions: In COPD patients, a successful PR is accompanied by a reduction of the upper chest wall resting perimeter and by an improvement of the perimeter thoracic mobility.

Clinical relevance: The centimeter tape is a useful device able to identify PTM improvements in COPD patients.

Keywords: chronic obstructive pulmonary disease, exercise, pulmonary rehabilitation

INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by persistent respiratory symptoms, which is due to airway abnormalities, destruction of the lung parenchyma decreasing the lung elastic recoil [1]. The modification of the respiratory mechanics may cause progressive limitation of exercise capacity, resulting in a worsening of the clinical and functional status and quality of life [2].

It has been speculated that motion abnormalities, progressive stiffening and alteration in regional volumes of the chest wall [3] may play a role in the onset of breathlessness during exercise in COPD patients. These changes raise the question of whether pulmonary rehabilitation can reduce abnormal chest wall movement in COPD patients, thereby restoring exercise capacity and reducing dyspnea [4].

However, the assessment of perimeter thoracic mobility (PTM) in clinical practice requires reliable measures that do not consume time and economic resources. The measurement of the PTM by a centimeter tape measure is a technique already

described (also called cirtometry) both in healthy subjects [5] and in patients suffering from respiratory diseases [6]. The PTM consists of a set of standardized chest perimeter measurements during different respiratory capacities to evaluate the chest wall expansion during the respiration, and. Its reliability was confirmed by [7,8].

Cirtometry application in the field of pulmonary rehabilitation (PR) remains controversial [9], nevertheless more sophisticated instruments [10] to assess PTM in a COPD patient are not often available. So, it is important, for a respiratory physiotherapist, to use an easy technique to guide the clinical practice, permitting the possibility to assess the already known improvements in respiratory mechanics [11].

We designed this study to evaluate whether it is possible to identify the PTM improvements by measuring its perimeter during PR, searching for correlations between the PTM improvements with standard clinical and functional assessments.

METHODS

Study Design

This study is a prospective case series. Informed consent was obtained from all participants. The procedures were conducted according to the Declaration of Helsinki, respecting the Italian law regarding the privacy and utilization of the patients' data for research purposes. The protocol was approved by the Ethical Committee Comitato Etico Interaziendale A.O.U. San Luigi Gonzaga Di Orbassano, Protocol Number 005212.

Participants

We assessed 20 consecutive COPD patients (6 women) admitted at Casa di Cura Villa Serena, Piosasco (TO), Italy. All patients were older than 18 years and had been diagnosed with COPD, with severity determined according to the global initiative for chronic obstructive lung disease (GOLD) criteria. The exclusion criteria were: patients with tracheostomy, inability to perform Spirometry, hemodynamic instability, unstable angina or myocardial infarction, congestive heart failure, and any neurological or orthopedic condition that could inhibit patients from participating in the PR.

Protocol and Outcomes

All patients followed the same evaluation protocol on the first and last PR day. Vital signs, height, weight, and body mass index (BMI) were assessed. The patients were submitted to an arterial blood gas analysis (ABGA), 6-minute walking test (6MWT), and spirometry.

The thoracic perimeter measurements were performed by a trained physiotherapist that executed the evaluation protocol exclusively before and after the PR. The technique was performed according to previously described protocols [12] with patients in a sitting position with the arms hanging tightly to the thorax. An average tape measure was placed around the chest at the axillary level, just over the angle of Louis (ALL) and over the xiphoid process level (XPL). The measurements were taken when the patient inhaled: at the functional residual capacity (FRC), after a quiet expiration (rest position); at total lung capacity (TLC): (slow deep inspiration) and residual volume (RV) (slow deep expiration) [8]. After those measurements, the perimeter thoracic mobility (PTM) was determined by calculating the difference between the measurements made at TLC and the perimeter measured at RV (Δ TLC-RV).

Following this procedure, it was performed according to the ATS/ERS statements [13,14], the 6MWT and the spirometry, with a digital spirometer (Vmax, Viasys Healthcare Inc, USA). The PR followed the ATS/ERS guidelines [15]. The PR physical training consisted of a protocol that was comprised of upper and lower limb strength training. Cycloergometer continuous training (work rate target to find 60% to 70% of the theoretic maximal heart rate for each patient) for a total of 70 minutes a day (40 minutes for the aerobic endurance training, and the rest lower limb training according to the patients tolerance, reaching 60% of 1RM as workload), five days a week during 4±0.5 weeks. During the hospitalization, the patients received medication according to the medical clinic evaluation.

Table 1. Baseline demographics

Characteristics	Mean	SD
Age	76	±5
Female gender (n(%))	6 (30%)	
Smoking (Yes)	9 (45%)	
Time of recover (Days)	28	±3
Height (cm)	161.7	±10.5
Weight (kg)	69.9	±13.4
BMI	26.9	±5.8
pH	7.43	±0.04
PaO ₂ (mmHg)	62.0	±9.7
PaCO ₂ (mmHg)	46.1	±8.4
HCO ₃ (mmHg)	30.1	±4.8
PaO ₂ /FiO ₂	262.6	±58.7
SpO ₂ (%)	92.1	±3.7
FVC (%)	80.1	±30.7
FEV ₁ (%)	56.6	±28.1
FEV ₁ /FVC	54.4	±16.0

Note. BMI: Body mass index; SpO₂: Partial oxygen saturation; pH: Hydrogenionic potential; PaO₂: Partial arterial oxygen pressure; PaCO₂: Carbon dioxide partial pressure; HCO₃: Bicarbonate; mmHg: Millimeter of mercury; cm: Centimeters; kg: Kilograms; PaO₂/FiO₂: Partial arterial oxygen pressure/Inspiratory oxygen fraction ratio; FVC: Forced vital capacity; FEV₁: Forced expiratory volume on 1 second

Data Analysis

Data were analyzed using SPSS package version 25.0 (SPSS Inc, Chicago, IL, USA). We used the Kolmogorov-Smirnov test, the One-way analysis of variance (ANOVA) with repeated measurements, and Bonferroni was used as a posthoc test. Cohen's d coefficient is used to determine sample effect size. The Spearman's rank correlation coefficient (Rs) was used to evaluate the relationship between PTM with the other parameters, and p<0.05 was considered statistically significant.

RESULTS

The baseline characteristics are listed in **Table 1**.

The mobility at ALL (Δ TLC-RV) improved significantly (F=14.095, p=0.03), with improvements between pre vs. post-treatment (p=0.001). A small within-group effect size (d<0.2) was found between pre-treatment and post-treatment. The distance walked improved (F=9.179, p=0.008) as did the distance walked/ predicted distance ratio. A small within-group effect size (d<0.2) was found between pre-treatment and post-treatment (**Table 2**).

The HCO₃, PaO₂/FiO₂, and SpO₂ improved for time interaction (F=7.893; p=0.01, F=20.207; p=0.001, and F=10.415; p=0.005, respectively). The post hoc analysis revealed significant differences pre/post PR (all, p<0.01).

The PTM improvements at the ALL presented a moderate negative correlation to the pCO₂ and HCO₃ (Rs= -0.618 and -0.552, respectively, and all p<0.02) and positive correlation to the FVC and FEV₁ (Rs= 0.511 and 0.512, respectively, both p=0.02).

DISCUSSION

This study aimed to measure thoracic movement changes after pulmonary rehabilitation for chronic obstructive

Table 2. Mean (SD) for outcome at all study visits and mean (SD) difference within group

Outcome	Group		Effect size	Difference within group	
	Pre(n=20)	Post(n=20)	Cohen's d	Post minus pre (n=20)	
Cyrtometry	Angle Louis FRC	99.6(9.6)	96.9(8.8)	0.3	-2.7(-7.2; 1.8)
	Angle Louis TLC	101.3(9.6)	99.1(9.0)	0.2	-2.2(-6.6; 2.2)
	Angle Louis RV	98.7(9.4)	96.1(9.3)	0.3	-2.6(-7.0; 1.7)
	Angle Louis ΔTLC-RV	2.6(1.1)	3.0(1.1)	-0.4	0.4#(-0.04; 0.8)
	Xiphoid process FRC	97.7(11.7)	96.8(11.8)	0.04	-0.9(-2.5; 0.7)
	Xiphoid process TLC	99.1(11.4)	98.4(11.5)	0.06	-0.7(-2.2; 0.7)
	Xiphoid process RV	97.0(11.7)	96.0(11.6)	0.9	-1.0(-2.6; 0.6)
	Xiphoid process ΔTLC-RV	2.2 (1.3)	2.5(1.1)	-0.2	0.3(-0.4; 0.9)
6MWT	Distance (m)	233.1(109.5)	327.6(90.8)	-0.9	94.5#(28.7; 160.4)
	%/Predicted distance	73.6(8.4)	94.7(6.5)	-2.8	21.1*(9.7; 32.5)
ABGA	pH	7.43(0.04)	7.42(0.03)	0.3	0.01(-0.03; 0.02)
	PaO ₂ (mmHg)	62.0(9.9)	70.2(9.7)	-0.8	8.2(3.1; 13.3)
	PaCO ₂ (mmHg)	46.1(8.6)	43.5(8.0)	0.3	-2.6(-5.3; 0.09)
	HCO ₃ (mmHg)	30.1(4.9)	28.0(3.4)	0.5	-2.1*(-3.6; -0.5)
	PaO ₂ /FiO ₂	260.7(59.7)	309.3(56.0)	-0.8	48.5*(16.9; 80.1)
	SpO ₂ (%)	91.9(3.7)	94.8(2.4)	-0.9	2.9*(1.6; 4.3)

Significantly different within-group, P<0.05 (95% confidence interval); * Significantly different within-group, P<0.001 (95% confidence interval)

FRC: Functional residual capacity; TLC: Total lung capacity; RV: Residual volume; ΔTLC-RV: Difference between the total lung capacity and the residual volume; 6MWT: 6 minute walking test; ABGA: Arterial blood gases analyzes; pH: Hydrogenionic potential; PaO₂: Partial arterial oxygen pressure; PaCO₂: Carbon dioxide partial pressure of; HCO₃ : Bicarbonate; mmHg: Millimeter of mercury; cm: Centimeters; PaO₂/FiO₂: Partial arterial oxygen pressure/Inspiratory oxygen fraction ratio; SpO₂: Partial oxygen saturation; FVC: Forced vital capacity; FEV₁: Forced expiratory volume on 1 second

pulmonary disease. From this perspective, we showed that a simple centimeter tape could identify Perimeter thoracic mobility improvements in COPD patients. The chest wall seems to increase its mobility (at ALL), followed by improvements in the ABGA and functional performance. In addition, these improvements are followed by a hypercapnia, peripheral oxygen saturation, oxemia improvements. In moderate to severe COPD subjects, we found a mean 0.4 cm (0.0-0.8 cm) improvement in the PTM at the level of angle of Louis and 0.3 cm (-0.4 to 0.9 cm) at the xiphoid process level. However, the statistical significance of the PTM at xiphoid process level was not achieved in the present study.

Dynamic hyperinflation (DH) increases the thoracic-abdominal volume and is one of the main factors causing dyspnea and exercise limitation in COPD subjects DH [4]. Furthermore, hyperinflated patients are more likely to develop abnormalities in PTM, playing a role in breathlessness [16]. PR can reduce the degree of dynamic hyperinflation [17-20] and end-expiratory ribcage volume [4,14,21,22], partially restoring the upper and lower thoracic mobility restoring, dyspnea and exercise tolerance [4]. However, to determine variations of rib cage volume, the optoelectronic plethysmography is necessary.

Regarding PTM, it was demonstrated that a minimum of 0.6 cm of thoracic excursion should be considered to use this kind of assessment technique. But they demonstrated their results in healthy volunteers without demonstrating the mean circumferences values [8]. In [12], the authors, in another way, had correlated lung function and the measurement of the thoracic perimeter (they called cirtometry) in healthy subjects, and they found a positive weak but statistically relevant, the correlation between the thoracic circumference and FEV₁ and FVC. Besides, in this study, the mean thoracic circumference excursion at the angle of Louis was 6.3±2 cm, almost the double of our values in COPD subjects, and these differences may be explained by the known pulmonary hyperinflation and thoracic stiffness that COPD patients present. Both studies suggested the use of this technique in settings with different kinds of subjects as COPD patients.

We cannot state that the PTM improvements observed in our study (0.4 cm) are clinically relevant. We have not any other study to compare our results, because as far as we know, this is the only research that used the thoracic circumference measurement as a PR outcome. We also identified a moderate negative correlation between the PTM and the PaCO₂. The association between the hypercapnia, chest wall volume enhancement, and respiratory muscle activation is well documented. But the study presented a model with healthy individuals where the upper rib cage end-expiratory volume increased during increasing of end-tidal PCO₂ [23]. This model did not show any association between end-tidal PCO₂ levels and thoracic perimeter.

Our study has limitations related to its design. The control group was not planned, but this is in accordance with the explorative nature of the work. Moreover, regardless of the sample size effect determination, a study with a more significant, the sample may determine consistent results in the mean PTM improvements. In female patients, PTM at the xiphoid level may be more difficult due to morphological reasons.

In conclusion, this study provided an effective alternative method to evaluate thoracic mobility in COPD subjects because it is time saver, inexpensive, and easy to adopt in everyday clinical practice. Nevertheless, future randomized controlled trials should investigate the validity and reliability of PTM compared with more sophisticated motion capture systems and larger sample sizes.

We tried to determine a confident and straightforward way to identify thoracic movements, abnormalities, and improvements via the chest wall movements in the context of PR. The centimeter tape could be useful to add information when the standard lung functioning tests were not available. Further research with this technique might help in the interpretation of PTM, especially in the presence of mild-to-severe COPD. The sample size and lack of a control group were the main limitations.

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