

Correlation between Maximal Expiratory Pressure and Electromyographic Activity of the Abdominal Muscles during Forced Expiration in COPD individuals

Saulo Fabrin^{1,3,4*}, Regueiro EMG⁵, Verri ED^{1,4}, Silva GP^{1,3}, Fioco EM^{1,4}, Siéssere S¹, Gomes GGC¹, Sobrani E², Martinez JAB² and Regalo SCH¹

¹Faculty of Dentistry of Ribeirão Preto - FORP/USP, Ribeirão Preto, São Paulo Brazil

²Faculty of Medicine of Ribeirão Preto - FMRP/USP, Ribeirão Preto, São Paulo, Brazil

³University Center UNIFAFIBE, Bebedouro, São Paulo, Brazil

⁴Claretiano University Center, Batatais, São Paulo, Brazil

⁵University Center Barão de Mauá, Ribeirão Preto, São Paulo, Brazil

*Corresponding Author: Saulo Fabrin, School of Dentistry of Ribeirão Preto, University of São Paulo, Avenida do Café s/n, Bairro Monte Alegre, Ribeirão Preto, São Paulo, Brazil.

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Abstract

Background: Chronic obstructive pulmonary disease (COPD) produces changes in the thoracic cavity and in the respiratory mechanics by regulating the diaphragm strength during expiration. Thus, the abdominal muscles can help activate the diaphragm, forcing the air out of the lungs. The objective of the present study was to verify the association between the maximal expiratory pressure (MEP) and the activity of the abdominal muscles in individuals with COPD.

Methods: The study sample consisted of twenty patients (10 men, 10 women), with mean age = 65.65 ± 8.11 years and BMI = 24.92 ± 2.97 kg. The diagnosis of COPD was confirmed using spirometry. COPD was classified into stage II and IV. The maximal expiratory pressure was used to measure the maximal efforts of the respiratory muscles. The surface electromyographic (EMG) activity of the rectus abdominis and external oblique muscles were assessed. Spearman's correlation coefficient was applied to quantify the correlation between the quantitative variables, with a significance level of $p < 0.05$.

Results: A positive correlation was found between MEP and the EMG variables of the rectus abdominis and the external oblique muscles in individuals with COPD during forced expiration.

Conclusion: The study showed that higher EMG activity of the rectus abdominis and the external oblique muscles is necessary to increase the expiratory muscle capacity during forced expiration.

Keywords: Exhalation; Electromyography; Muscle Strength; Spirometry; Diaphragm

Introduction

In chronic obstructive pulmonary disease (COPD), airflow resistance impairs respiratory mechanics and may alter the shape of the thoracic cage. The zone of apposition of the diaphragm is decreased, causing alterations due to the rectification of the muscle fibers and the horizontalization of the ribs [1].

The structural alterations of the thoracic muscles caused by COPD make the diaphragmatic incursion more difficult, leading to respiratory muscle overload. This diaphragmatic eventration decreases the length of the respiratory muscle fibers and the strength required for their movement. Also, their elastic properties are modified during passive expiration [2].

Expiration makes the abdominal muscles contract to raise abdominal pressure, pushing the diaphragm upward and forcing air out of the lungs. When the diaphragm mechanics is altered, its incursion is reduced, limiting the action of abdominal contents. The diaphragm is responsible for regulating expiration. Its expiratory activity preserves lung volume and protects against lung collapse [3]. Considering that the ability of the diaphragm to assist at expiration is impaired in subjects with COPD, the abdominal muscles may exert particular strength and help mobilize the diaphragm into the chest cavity. While expiration is generally a passive process, the contraction of the abdominal wall muscles plays an important role in COPD subjects, since the output of air from the lungs is impaired due to changes caused by the disease or perform active expiration in stress situations [4].

Individuals with COPD are prone to fatigue and present chronic airflow limitation. The tools available to establish the correct diagnosis of COPD, which include manovacuometry and surface electromyography (EMG), have been applied in numerous studies. Manovacuometer is a simple, quick and non-invasive test used to measure MIP and MEP. MEP measurements are useful for differentiating between neuromuscular weakness of abdominal muscles or specific diaphragm weakness [5]. Some previous studies have used EMG as a non-invasive assessment, recording and analyzing the respiratory muscle electrical activity to obtain qualitative and quantitative data under different conditions [6].

Aim of the Study

The aim of this study was to verify the correlation between MEP and the EMG activity of the abdominal muscles in patients with COPD.

Materials and Methods

This was a case-control study with the purpose of evaluating the electromyographic activities of the expiratory muscles and the respiratory muscle strength, as measured by spirometry in COPD patients.

The research was approved by the Human Research Ethics Committee of the institution (case N. 1.749.718. All subjects were informed regarding the research procedures and signed a free informed consent, according to resolution 466/12 of the Health National Council.

Twenty patients of both sexes (10 men, 10 women), with a mean age of 65.65 ± 8.11 years, $BMI = 24.92 \pm 2.97$, with a diagnosis of COPD were selected for the study. The spirometric classification staged the disease of participants in II to IV [7] and peripheral oxygen saturation (SpO_2) $> 88\%$.

Those patients who met inclusion criteria were eligible for participation in this study. Demographic and clinical characteristics of patients are presented in table 1. Those subjects diagnosed with COPD stage I, with $SpO_2 < 88\%$, $BMI = < 18$ or > 30 Kg/m^2 , who had trained hard within a 12-hour period, with neuromuscular and/or orthopedics impairment, with cold symptoms seven days prior to the assessment, and with difficulty in understanding the tasks proposed were excluded from the study.

Characteristics	COPD
Age (yrs)	65.65 ± 8.11
Sex (M/F)	$10/10 \pm 0.51$
BMI (kg/m^2)	24.92 ± 2.97
HR (bpm)	80.30 ± 12.68
RR (ipm)	22 ± 3.30
SpO_2 (%)	92.30 ± 2.95
SBP (mmHg)	125.50 ± 10.99
DBP (mmHg)	80.50 ± 8.87

Table 1: General characteristics of patients.

Body mass index (BMI), heart rate (HR), respiratory rate (RR), peripheral oxygen saturation (SpO_2), systolic blood pressure (SBP), diastolic blood pressure (DBP).

Surface electromyography was carried out using twelve channels of the portable MyoSystem-BrI apparatus, including eight channels for EMG (active and passive electrodes) and four auxiliary channels. A high-performance signal acquisition system and software were also used for controlling, storing and processing data [8].

For the assessment of the abdominal muscle recruitment activity, an experimental protocol was performed using EMG recordings of the rectus abdominis and the external oblique muscles, normalized by the signal obtained during sustained maximal expiration maneuver (4 seconds) [9]. However, since the respiratory muscles of the left hemibody produce an undesired EMG signal called “crosstalk”, it contaminates the signal and may lead to an inaccurate interpretation of the signal information [10]. Therefore, to avoid impedance, the electromyographic signals were collected from the muscles of the right hemibody, according to the protocol proposed by Andrade, *et al.* (2008) [11].

For fixation of the electrodes to collect the EMG activity of the abdominal muscles, the subjects performed maximum voluntary isometric contractions (MVIC) during expiration. Electrode placement was based on previous studies to determine the best muscle portion for the EMG analysis, as described in table 2 [12].

Muscle	Electrode placement	Study
Rectus abdominis	Mid portion between the xiphoid process and the umbilicus, 3 cm lateral from the midline of the body	Escamilla, <i>et al.</i> 2010 [13].
External oblique	Upper distance from the anterior superior iliac spine, 15 cm lateral from the umbilical scar	García-Vaquero, <i>et al.</i> 2012 [14].

Table 2: Electrode placement for the respiratory muscles.

The EMG assessment was conducted with the participant sitting, upper limbs along the body and the legs bent at a 90° angle [15]. For the EMG analysis of the abdominal muscles during forced expiration, the subject was requested to hold the maximal expiration for 4 seconds.

The Myosystem Br-1 software version 3.5 (Datahominis Tecnologia Ltda®, Uberlândia, MG - Brazil) was used for the EMG signal processing. The raw EMG signal was used to determine the values of the amplitude range of EMG signal obtained by calculating the mean square root (RMS) used for maximum sustained expiration.

A Comercial Médica® analog manovacuometer, with an operational interval of ± 120 cmH₂O, was utilize to assess the respiratory muscle strength. Subjects were informed about the test procedures. The first measurement was applied for testing and later discarded. The participant sat on chair adopting a Fowler position (Patient’s head is placed at a 45-degree angle) with the upper limbs along the side of the body and the legs bent at a 90° angle, with a mouthpiece properly adjusted to the lips and a nose clip. The participant was verbally instructed by the evaluator to exhale as quickly and forcefully as he/she could, making sure to empty the lungs fully. Therefore, the measurement of the TLC (total lung capacity) provided the MEP. This procedure is normally repeated at least 3 times, within a 1 minute interval between measurements, considering the highest value obtained. The tests were performed by a single evaluator to prevent bias. Three consecutive efforts were made and recorded, with a 1-min pause between each effort. The reproducible measurements were those with a variation less than or equal to 10% of the greatest value. The highest value achieved during the three peak pressure efforts was used for statistical analysis and compared to previous ones, according to [16].

The values obtained were submitted to statistical analysis using SPSS version 22.0 for Windows (SPSS Inc.; Chicago IL, USA). Spearman correlation coefficient was used to measure the correlation between variables. The level of significance was set at $p \leq 0.05$.

Results and Discussion

The results showed that a higher EMG activity of the abdominal muscles in forced expiration was necessary in individuals with COPD, as demonstrated in figure 1 and 2. A positive correlation was observed between the EMG activity of these muscles and the MEP. Accordingly, an increase in the expiratory muscle strength required higher activity of the abdominal muscles during forced expiration, as shown in table 3.

Variables	MEP External oblique	MEP Rectus abdominis
Correlation	0.860*	0.763*
p ≤ 0.05	0.00	0.00

Table 3: Correlation between variables of expiratory muscle strength and EMG activity of the expiratory muscles.

*=Significant (p ≤ 0.05); NS=Non-Significant.

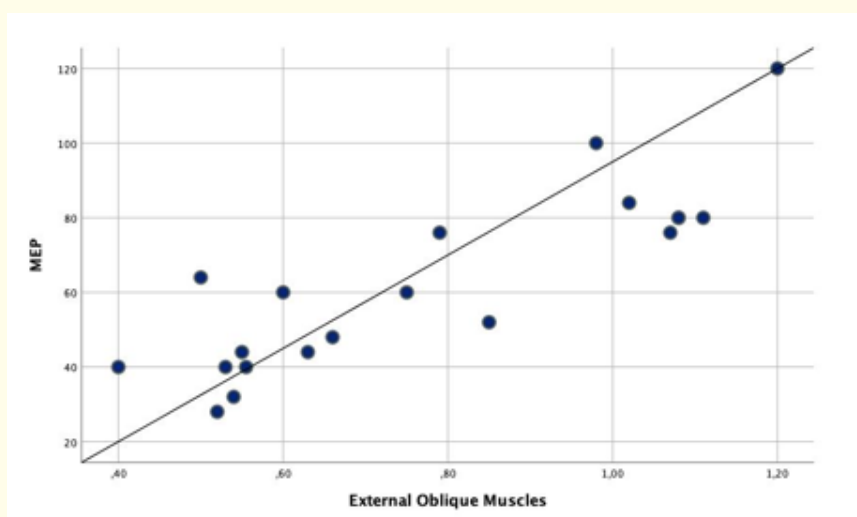


Figure 1: Correlation between MEP and EMG activity of the external oblique muscles in forced expiration in individuals with COPD.

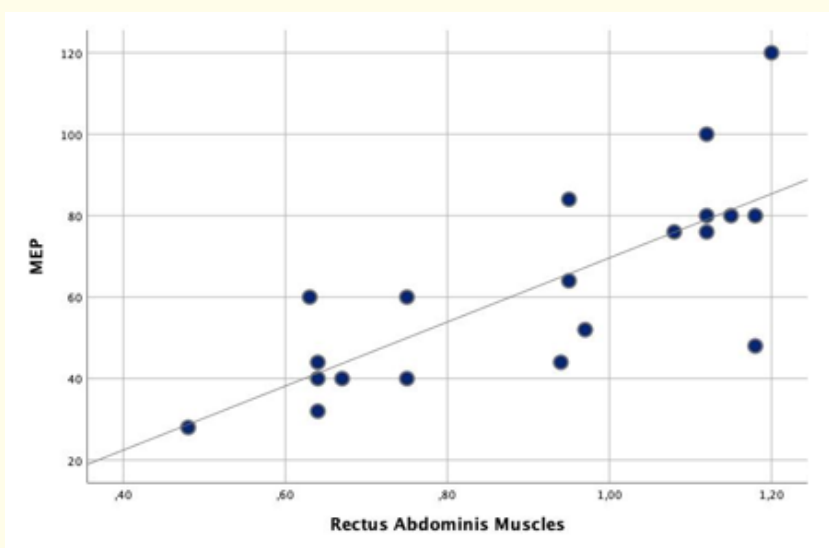


Figure 2: Correlation between MEP and EMG activity of the rectus abdominis muscles in forced expiration in individuals with COPD.

Figure 1 and 2 show that when there is greater activity in the abdominal muscles, it is possible to produce greater muscle strength gradient during forced expiration.

The data obtained in the present study suggest a positive correlation between the EMG activity and the expiratory muscle strength in individuals with COPD, considering that to increase MEP a significantly higher activation intensity of the abdominal muscles is needed during forced expiration. These data corroborate the study by Mesquita Montes, *et al.* (2017), who assessed the effect of expiratory loads on abdominal muscle activity during respiration. Those individuals at risk for the development of COPD showed a specific recruitment pattern in the superficial muscle layer of the rectus abdominis, when respiratory demand increased [17]. In fact, research evidence has indicated that the recruitment of abdominal muscles is related to the degree of blockage and airflow and is frequent in individuals with COPD, i.e. breathing at rest in supine causes higher activation of abdominal muscles [18]. Thus, the individuals with limited expiratory flow are unable to increase the expiratory flow rates and to reduce the end-expiratory lung volume without the support of the abdominal muscles [19].

Contraction of expiratory muscle during exhalation may be a nonspecific response to higher respiratory stimulation. Regardless of lung hyperinflation, abdominal muscle recruitment during expiration preserves fiber length and the capacity of the diaphragm muscle to generate force for the onset of inhalation [20,21]. Thereby, the inspiratory muscle may develop fatigue in case of expiratory muscle dysfunction. The results obtained in the present study are consistent with those of other studies since there was an increase in the expiratory muscle activity during expiration, suggesting that these muscles helped reduce the load imposed on the diaphragm. A possible mechanism underlying this correlation could be the recruitment muscles of the respiratory muscles during the effort to stabilize the thoracic wall, which seemed to increase the abdominal pressure and improve the ventilatory pattern, as described in individuals with COPD [22]. A study has shown correlations between exercise capacity, demonstrated by the distance traveled in the six-minute walk test (6MWT), and expiratory muscle strength. Also, exercise capacity was directly associated with pulmonary function, better prognosis and survival rate [23].

According to Aliverti (2016), when respiratory flow is limited during exercise, the inspiratory muscles have to overcome a higher elastic load offered by the lung and chest wall.

Therefore, it is possible to direct respiratory and abdominal muscle exercises in COPD individuals in order to reduce the diaphragm muscle fatigue whose mechanism has been altered by low pulmonary complacency and elastance [24].

Conclusion

The present study showed a positive correlation between MEP and EMG activity of the abdominal muscles during forced expiration. Therefore, higher EMG activity of the rectus abdominis and the external oblique muscles during forced expiration is necessary to increase the expiratory muscle capacity.

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Conflict of Interest

We declare that there are no conflicts of interest.

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