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The effect of inspiratory and expiratory loads on abdominal muscle activity during breathing in subjects "at risk" for the development of chronic obstructive pulmonary disease and healthy

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ABSTRACT

The abdominal muscle activity has been shown to be variable in subjects with chronic obstructive pulmonary disease (COPD) when respiratory demand increases and their recruitment pattern may change the mechanics, as well as the work and cost of breathing. The scientific evidence in subjects "at risk" for the development of COPD may be important to understand the natural history of this disease. This study aims to evaluate the effect of inspiratory and expiratory loads on the abdominal muscle activity during breathing in subjects "at risk" for the development of COPD and healthy. Thirty-one volunteers, divided in "At Risk" for COPD (n = 17; 47.71 ± 5.11 years) and Healthy (n = 14; 48.21 ± 6.87 years) groups, breathed at the same rhythm without load and with 10% of the maximal inspiratory or expiratory pressures, in standing. Surface electromyography was performed to assess the activation intensity of *rectus abdominis* (RA), external oblique and *transversus abdominis*/internal oblique (TrA/IO) muscles, during inspiration and expiration. During inspiration, in "At Risk" for COPD group, RA muscle activation was higher with loaded expiration ($p = 0.016$); however, in Healthy group it was observed a higher activation of external oblique and TrA/IO muscles ($p < 0.050$). During expiration, while in "At Risk" for COPD group, RA muscle activation was higher with loaded inspiration ($p = 0.009$), in Healthy group TrA/IO muscle showed a higher activation ($p = 0.025$). Subjects "at risk" for the development of COPD seemed to have a specific recruitment of the superficial layer of ventrolateral abdominal wall for the mechanics of breathing.

1. Introduction

Chronic obstructive pulmonary disease (COPD) is described as the presence of persistent airflow limitation that is usually progressive and associated with an enhanced chronic inflammatory response in the airways (Global Initiative for Chronic Obstructive Lung Disease, 2016; Vestbo et al., 2013). The chronic inflammation causes structural changes and narrowing of the small airways, as well as the loss of alveolar attachments to the small airways and decreases lung elastic recoil. These changes diminish the ability of airways to remain open during expiration (Baraldo et al., 2012). Although the primary physiological defect, inherent to the subjects with COPD, is the expiratory flow limitation, an important mechanical consequence of this phenomenon is the incomplete lung emptying during resting tidal breathing – lung hyperinflation (O'Donnell, 2001). From a mechanical point of view, the lung hyperinflation shortens and flattens the diaphragm muscle and negatively modifies its length-tension relationship. As a result, the diaphragm muscle reduces the flow and pressure-generating capacity (Gea et al., 2015). Therefore, neural drive (increased firing rate and recruitment) to the diaphragm muscle (De Troyer et al., 1997; Gorini et al., 1990) and activity of parasternal intercostal and scalene muscles (Gandevia et al., 1996) are increased in COPD, during breathing at rest or when ventilation increases. Furthermore, the expiratory contraction of abdominal muscles in subjects with COPD may be an "automatic" response to the increased work

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of breathing and ventilatory stimulation, even during resting breathing (Martinez et al., 1990; Ninane et al., 1992). It has been proposed that an increased abdominal muscle activity is an appropriated response to assist inspiratory muscles, reducing the end-expiratory lung volume (Aliverti et al., 1997). This action of abdominal muscles changes diaphragmatic configuration, optimizing its length-tension characteristics (De Troyer and Estenne, 1988), or it allows the release of stored elastic energy at the onset of inspiration (Aliverti et al., 1997). Nevertheless, the abdominal muscle activity has been shown to be variable in subjects with COPD when respiratory demand increases (Laveneziana et al., 2014), and their recruitment pattern may change the mechanics, as well as the work and cost of breathing (Aliverti and Macklem, 2008).

The impact of different respiratory loads on abdominal muscle activity, during both breathing phases, for mechanics of breathing is not yet clear in subjects "at risk" for the development of COPD (presence of chronic respiratory symptoms, in addiction to some evidence of impaired lung function) (Rodriguez-Roisin et al., 2016). Although many subjects in COPD "Stage 0" do not necessarily progress to chronic airflow limitation, unobstructed smokers with other chronic respiratory symptoms (such as dyspnea, wheeze and limited physical activity) experience significant morbidity and need health care resources, which represents a potential clinical entity (de Marco et al., 2007; de Oca et al., 2012; Mannino et al., 2006; Stavem et al., 2006). The scientific evidence in these subjects may be important to understand the natural history of COPD. The aim of the present study was to evaluate the effect of inspiratory and expiratory loads on the abdominal muscle activity during breathing in subjects "at risk" for the development of COPD and healthy. Specifically, it was analysed the activation intensity of *rectus abdominis* (RA), external oblique (EO) and *transversus abdominis*/internal oblique (TrA/IO) muscles, during inspiration and expiration, without respiratory load and with inspiratory or expiratory loads. To our knowledge, the possible changes on the mechanics of breathing associated with early lung disease in smokers have not been investigated. Therefore, we hypothesized that the recruitment pattern of abdominal muscles would be different in subjects "at risk" for the development of COPD, when respiratory demand increases.

2. Methods

2.1. Sample

The study followed a cross-sectional design with a sample composed by thirty-one volunteers of an higher education institution: seventeen subjects "at risk" for the development of COPD – "At Risk" for COPD group; and fourteen healthy subjects – Healthy group. Sociodemographic, anthropometric and body composition data were similar between groups (Table 1). Participants had not participated in aerobic physical activities with a moderate intensity (a minimum of 30 min on five days a week) and/or aerobic physical activities with a vigorous intensity (a minimum of 20 min on 3 days a week), for a period exceeding one year (Thompson, 2014). As inclusion criteria for the "At Risk" for COPD group, participants had dyspnea, chronic cough and sputum production at least for three months in two consecutive years, as well as history of exposure to risk factors (namely smoking habits at least for fifteen years) (Rodriguez-Roisin et al., 2016). Moreover, these participants had to have Grade 1 or more in the Modified British Medical Research Council (mMRC) questionnaire and one point or more, out of five points, in the first four items of the COPD Assessment Test (CAT) (presence of cough, mucus, chest tightness and breathlessness) (Global Initiative for Chronic Obstructive Lung Disease, 2016). Exclusion criteria for both groups included chronic nonspecific lumbopelvic pain (recurrent episodes of lumbopelvic pain for a period longer than three months); scoliosis, length discrepancy of the lower limbs or other postural asymmetries; history of spinal, gynaecological or abdominal surgery in the previous year; neurological or inflammatory disorders; metabolic or chronic cardio-respiratory diseases; pregnancy or post-delivery in the previous six months; long-term corticosteroid therapy; and any conditions that may interfere with the data collection (American Thoracic Society/European Respiratory, 2002; Beith et al., 2001; Chanthapetch et al., 2009; Hermens et al., 2000; Mew, 2009; Miller et al., 2005; Reeve and Dilley, 2009). Each participant provided written informed consent, according to the Declaration of Helsinki. The anonymity of participants and the confidentiality of data were guaranteed. The Institutional Research Ethics Committee approved this study.

Table 1
"At Risk" for COPD and Healthy groups' characterization: sociodemographic, anthropometric and body composition data, with mean and standard deviation. *p* values for significant differences between groups are also presented.

	"At Risk" for COPD group (n = 17)	Healthy group (n = 14)	Between groups comparison (*p* value)
Sociodemographic and anthropometric data			
Gender (n male)	5	6	0.477
Age (years)	47.71 ± 5.11	48.21 ± 6.87	0.815
Body mass (kg)	70.85 ± 14.37	79.65 ± 15.28	0.110
Height (m)	1.67 ± 0.11	1.67 ± 0.10	0.917
Body composition data			
Body fat (%)	28.85 ± 9.29	32.66 ± 8.91	0.256
Total body water (%)	49.19 ± 5.73	48.13 ± 4.93	0.588
Muscle mass (kg)	48.51 ± 11.21	52.27 ± 13.02	0.395
Bone mineral mass (kg)	2.57 ± 0.56	2.76 ± 0.63	0.374
Visceral fat	7.12 ± 3.14	9.21 ± 2.83	0.063

2.2. Instruments

2.2.1. Surface electromyography (sEMG)

sEMG was performed to assess the muscle activity of RA, EO and TrA/IO of the dominant hand side. The muscle activity was collected using the BioPlux research device (Plux wireless biosignals S.A., Arruda dos Vinhos, Portugal) with analogue channels of 12 bits and a sampling frequency of 1000 Hz, using double differential electrode leads. Disposable, self-adhesive Ag/AgCl dual snap electrodes (Noraxon Corporate, Scottsdale AZ, United States of America) were used for the sEMG. The electrode characteristics were 4×2.2 cm of adhesive area, 1 cm diameter of each circular conductive area and 2 cm of inter-electrode distance. These electrodes were connected to bipolar active sensors emgPLUX (Plux wireless biosignals S.A., Arruda dos Vinhos, Portugal) with a gain of 1000, an analogue filter at 25–500 Hz and a common-mode rejection ratio of 110 dB. The reference electrode used was a disposable self-adhesive Ag/AgCl snap electrode (Noraxon Corporate, Scottsdale AZ, United States of America) for the sEMG, with 3.8 cm diameter of circular adhesive area and 1 cm diameter of circular conductive area. The sensors were Bluetooth connected through the sEMG device to a laptop. MonitorPlux software, version 2.0 (Plux wireless biosignals S.A., Arruda dos Vinhos, Portugal), was used to display and acquire the sEMG signal. An electrode impedance checker was used to assess the impedance level of skin (Noraxon Corporate, Scottsdale AZ, United States of America).

2.2.2. Respiratory flow

A respiratory flow transducer TSD117 – Medium Flow Trans 300 L.min-1 (Biopac Systems Inc., Goleta CA, United States of America) connected to an amplifier DA100C – General Purpose Transducer Amplifier Module (Biopac Systems Inc., Goleta CA, Uni-