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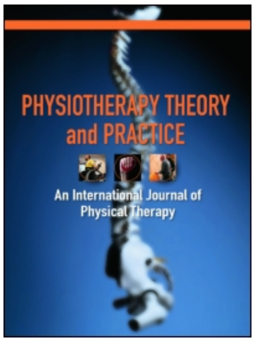

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Cardiorespiratory repercussions according to the abdominal circumference measurement of men with obstructive respiratory disorder submitted to respiratory physiotherapy

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ABSTRACT

Purpose: To examine the effect of respiratory physiotherapy among men with obstructive respiratory disorder, in relation to abdominal circumference (AC). **Methods**: Quasi-experimental study including 26 men split into two groups according to AC(cm): 1) < 102 ($AC_{risk\text{-}free}$); and 2) ≥ 102 (AC_{risk}). Heart rate variability (HRV), diastolic blood pressure (DBP), oxygen saturation (SpO_2), FEV_1/FVC, slow vital capacity (SVC), inspiratory capacity (IC), maximal inspiratory pressure (PI_{max}), thoracoabdominal amplitude (AI) were measured: before (M_1); 5 min after the physiotherapy (i.e. breathing exercises for airway clearance and active kinesiotherapy) (M_2); and at follow-up, 30 min after physiotherapy (M_3). **Results**: The groups differed in age, body mass index and body fat %. At M_2 IC was different between groups ($AC_{risk\text{-}free} < AC_{risk}$). There was an increase in HRV indexes, PI_{max}, SpO_2, axillary AI, FEV_1/FVC, and reduction in HR for $AC_{risk\text{-}free}$. There was a decrease in AI and an increase in DBP for AC_{risk}. **Conclusion**: In men with obstructive respiratory disorder, increased AC measurement limited the thoracoabdominal expansibility and induced a rise of the DBP. Respiratory physiotherapy promotes an increase of cardiac modulation and inspiratory capacity for men with obstructive respiratory disorder.

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Introduction

Both obstructive respiratory disorder (Sidney et al., 2005) and abdominal obesity (Huxley et al., 2010) are factors that contribute for the increase of mortality and hospitalization of individuals, mainly because of respiratory and cardiovascular complications. Thus, the coexistence of these two clinical situations requires attention, since their occurrence is very common. It is known that individuals with airway obstruction disorders, especially those with COPD, can present alterations in cardiac autonomic modulation with a lower heart rate variability (HRV), characterizing damage in baroreflex sensibility and vagal reduction of the sinus node (Pantoni et al., 2007; Rossi et al., 2014). Furthermore, the increase in abdominal circumference (AC) is associated with reductions of HRV (Poliakova et al., 2012; Rossi et al., 2015) and in FEV_1, indicating airways obstruction that may be caused by the dynamic compression of airways (Chen et al., 2001). HRV can be used to evaluate interventions and interpretations of physiological conditions (Ferreira et al., 2013; Pumprla et al., 2002), since it reflects: cardiac autonomic nervous activity; gravity of cardiac and non-cardiac diseases; and predict survival rates and prognosis (European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Kleiger, Stein, and Bigger, 2005).

Physiotherapy treatment for individuals with obstructive respiratory disorder and obesity can have improved outcomes (Sharp, 1985). Respiratory physiotherapy is essential in these cases, since it facilitates the mucociliary clearance, decreasing the retention of secretion in the airway and improving the respiratory compliance (Schans, 2007). Manual respiratory techniques (e.g. thoracic vibration) can increase expired tidal volume (TV), without changing hemodynamic variables. On the other hand, respiratory control by pursed-lip and diaphragmatic breathing decreases breathing frequency (f), improves minute volume (MV), partial gas pressures, SpO_2, dyspnea, tolerance to exercise and functional limitations, and also can change the cardiac autonomic control (Cooke et al., 1998). A potential mechanism for improvement is decreased narrowing of airways during expiration, which

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favors global pulmonary ventilation and reduces the respiratory symptoms and hyperventilation (Ali, Talwar, and Jain, 2014; Bruurs, Giessen, and Moed, 2013; Dechman and Wilson, 2004; Lan et al., 2013; Rodrigues, Alves, and Gonçalves, 2012).

Studying the behavior of cardiorespiratory variables after physiotherapy intervention will allow us to understand the effects in relation to cardiac control and the possible risks and benefits to individuals with airway obstruction respiratory and increased abdominal obesity who have a tendency for cardiovascular diseases.

It is believed that respiratory physiotherapy intervention improves cardiorespiratory function in men with obstructive respiratory disorder and increased AC measurement. This study aimed at evaluating the differences among men with obstructive respiratory disorder according to the measure of AC, and analyzing the cardiorespiratory and metabolic acute responses resulting from a session of respiratory physiotherapy.

Methods

This study was a prospective clinical trial, quasi-experimental with sampling criteria by convenience, approved by the Research Ethics Committee of Universidade do Sagrado Coração (757.430), Clinical Trials Identifier: NCT02217423.

Twenty-six participants, admitted into State Hospitals in the city of Bauru/SP, participated in this study. The flow of participation can be seen in Figure 1. The inclusion criteria were: men over 18 years of age; 10-day maximum hospital admittance; $VEF_1/FVC < 70\%$; $SpO_2 \geq 88\%$ in ambient air; hemodynamic stability; and the ability to understand the commands for the evaluative tests. The exclusion criteria were: dermal chest injury; Borg scale (dyspnea) > 5; sudden weight change; ascites; nephrotic syndrome; congestive heart failure; and cirrhosis.

The participants that meet the inclusion criteria ($n = 26$) were divided into two groups according to the AC (cm) measurement value that represents increased risks for cardiovascular diseases: 1) AC_{risk} ($AC \geq 102$); and 2) $AC_{risk\text{-}free}$ ($AC < 102$) (National Cholesterol Education Program, 2002). The evaluations, always performed by the same physiotherapist, were conducted at three time periods: 1) before (M_1); 2) five minutes after a respiratory physiotherapy session (M_2); and 3) 30 min after the physiotherapy (M_3).

The AC was measured in standing, with the measuring tape encircling the abdomen at the midpoint between the lower costal margin and the iliac crest

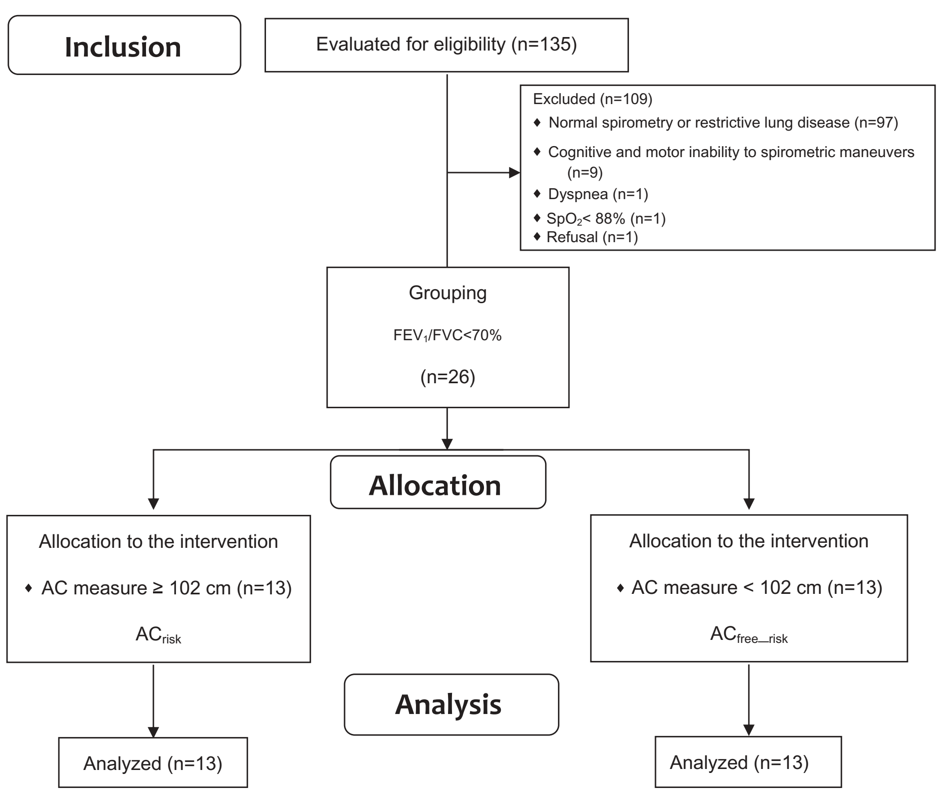

Figure 1. Algorithm representative of the screening process, evaluation and treatment of the men.

Caption: AC: Abdominal Circumference; AC_{risk} (AC ≥102 cm – cardiovascular risk) and $AC_{risk\text{-}free}$ (AC <102 cm); FEV_1: Forced expiratory volume in the first second of Forced Vital Capacity (l); FVC: Forced Vital Capacity (l).

during normal exhalation (Chan, Watts, Barrett, and Burke, 2003). Body weight (kg) and stature (cm) were evaluated by a calibrated scale that contained a stadiometer (Toledo®, Brasil), and Body Mass Index (BMI) was calculated (Keys et al., 1972). Biceps, triceps, subscapular and suprailiac skinfolds thickness of the right side of the body were assessed using a Lange adipometer (Beta Technology®, Cambridge, MD) and body fat percentage was determined (Durnin and Womersley, 1974). Degree of dyspnea was evaluated using the Medical Research Council (MRC) (Kovelis et al., 2008) and the Borg scale (Borg, 1982).

The HRV was studied by linear analysis using the heart rate recorder RS800CX (Polar Electro Oy, Finlândia). Heart rate (HR) and R-R intervals were examined during a five-minute period in sitting position and it was transferred to a computer by the Polar ProTrainer 5TM® software. After visual and software analysis of the records, the ectopic beats or artifact signs were deleted. Only the segments with more than 90% of pure sinusal beats were included in this analysis. During each time period (M_1, M_2 and M3) a segment of the HR response was selected containing 256 points and the best sign of stability. After that, data were exported to Kubios HRV (MATLAB, 2.1, Kuopio, Finlândia). The linear analysis of HRV was carried according to the time domain (vagal modulation index of sinus node (rMSSD), standard deviation of all normal RR intervals (SDNN), average of all normal RR intervals (mean RR), percentage of consecutive RR intervals that presented a difference of more than 50 ms (pNN50) and heart rate average (mean HR)). Frequency domain (Hz) was identified as: low frequency (LF: 0.04–0.15)—sympathetic activity prevalence; and high frequency (HF: 0.15–0.4)—vagal activity; LF/HF—sympathovagal balance. The Poincaré HRV plot analysis yielded the following indexes: SD1—which represents the vagal activity; and SD2—reflecting the general variability (European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996; Pumprla et al., 2002).

The SpO_2 (%) and systemic arterial blood pressures were measured by heart monitor (Dixtal DX2022, Biomédica, Brasil) with the participant seated after having rested for five minutes. Capillary blood analysis was measured by Glucose Meter Optium Xceed (Abbott®, Brasil); range of 20 to 600 mg/dl.

Vital capacity was examined using three reproducible and acceptable measures (Spirobank II MIR®, Itália, Roma), and predictive values were ascertained according to ERS/Knudson. The participant remained seated after having rested for five minutes (Miller et al., 2005). The maximal inspiratory pressure (PI_{max}) was measured by manovacuometer (Commercial Médica®, Brasil) with the scale of ± 120 cmH_2O, which was measured from residual volume (RV) up to the Total Lung Capacity (TLC) (Black and Hyatt, 1969; Neder, Andreoni, Lerario, and Nery, 1999).

The thoracoabdominal expansibility was measured by means of dynamic cirtometry, using an inextensible measuring tape as instrument. The participants were examined in standing position. The difference between the measurements provided the degree of expansibility and retraction of the thoracoabdominal movements, resulting in determination of the amplitude index (AI) (Jamami, Pires, Oishi, and Costa, 1999).

Respiratory physiotherapy intervention protocol

Every technique included three series of one minute with a rest interval of one minute between them and was always performed by the same physiotherapist. The participant was placed in a sitting position and instructed to perform diaphragmatic breathing, and expiration with pursed-lips (DPLB) in order to improve lung ventilation. The DPLB was maintained for all other exercises. After correct execution, thoracic vibrocompression technique was added (rhythmic and rapid movements of isometric contraction of the forearm, applied manually, bilaterally, and simultaneously to the anterior chest area, during expiration, associated with chest compressions). Following this maneuver, passive manual expiration technique was performed (slow or quick chest compressions) and once completed the participant was instructed to cough until coughing became dry. After a minute of rest, the participant performed the DPLB associated with movements of the upper limbs—flexion and shoulder extension. Finally, stationary gait was performed for a minute at the participants preferred pace (Dolmage et al., 2013; Rikli and Jones, 1999; Rossi et al., 2014).

Statistical analysis

To calculate sample size Gpower 3.1 program was used, using spirometric measurements as the primary outcome variable. Alpha value was set for 0.05 and power of 1 - ß of 0.08 and 26 participants were required. The *Statistical Package for the Social Sciences* (SPSS) for Windows version 17.0 (IBM Statistics®, Chicago, Illinois, USA) was used for data analysis. The normal distribution of continuous variables was verified by the application of the Shapiro-Wilk test and the homogeneity of variances by the Levene test. In an attempt to standardize the data collected, the transformation of data by $Log_{10} + 1$ was applied. Data was expressed descriptively by central average statistical tendency and by data dispersion measurements, mean ± standard deviation and mean difference (95% confidence interval). The difference between the values after the intervention and the initial values was identified as Delta (Δ). The categorical variables were presented with absolute and relative frequencies (percentages). For baseline comparison of groups independent t was used. A mixed ANOVA repeated measures (2x3) was applied to test the differences of variables between groups (AC) and the time periods as the independent variables. The adjustment of the comparisons was made by the Bonferroni correction. All tests of significance were 2-tailed and *p*-value of < 0.05 was considered statistically significant.

Results

Twenty-six participants with obstructive respiratory disorder took part in this research, with initial and overlapping clinical diagnosis for each group: $AC_{risk\text{-}free:}$ 13 (60%) respiratory (e.g. pneumonia); 3 (14%) gastrointestinal (e.g. dyspepsia); and 3 (14%) immunologic (e.g. HIV); and AC_{risk}: 16 (49%) respiratory; 9 (27%) cardiovascular disease (e.g. hypertension); and 2 (6%) dermatological (e.g. erysipelas) were part of this study. Regarding prescription drugs, digestive system/metabolism (e.g. gastric protectors) and nervous system (e.g. analgesic drugs) predominated in both groups. Table 1 shows baseline data for age, anthropometry, and respiratory variables of the groups. The AC_{risk} group included the oldest men and had the greatest values for anthropometric measurements ($p < 0.05$).

Table 1. Basal characteristics of the men belonging to defined groups by the abdominal circumference measurement.

Variables	AC_{risk_free}	AC_{risk}	*p*
Age (years)	50.23 ± 10.93	61.31 ± 9.22*	.010
MRC dyspnea (0–4)	1.46 ± 1.12	1.31 ± 0.75	.844
Borg dyspnea (0–10)	0.3 ± 0.6	0.7 ± 1.0	.900
Smoking history (years-pack)	66.88 ± 47.66	50.35 ± 33.81	.318
BMI (kg/m^2)	19.78 ± 2.92	30.62 ± 4.34*	.001
AC (cm)	81.46 ± 9.95	113.54 ± 8.71*	.001
Abdominal body fat (%)	15.70 ± 3.50	30.76 ± 4.13*	.001

Caption: Data presented as mean ± standard deviation; AC: abdominal circumference; AC_{risk} (AC ≥102 cm – cardiovascular risk) and $AC_{risk\text{-}free}$ (AC <102 cm); MRC: Medical Research Council – dyspnea scale; years-pack: quantity of cigarette packs smoked multiplied by the years; BMI: body mass index; * comparison among the groups with significance level of $p < .05$.

HRV was measured during the assessment and intervention process. The largest changes occurred in M_2 and M_3 and in the $AC_{risk\text{-}free}$ group (Figure 2). There was also an increase of the SD2 during M_2 in both groups. The SD1 measurement increased after the intervention (M_2 and M_3) in both groups. Diastolic blood pressure (DBP) increased in the AC_{risk} group, in $M_{3,}$ approximately 6 mmHg when compared to $M_{1.}$ Both groups, in $M_{1,}$ had elevated glucose levels > 100 mg/dl, and there was not a statistically significant difference between groups (Table 2).

The AC_{risk} group did not display significant respiratory changes in the intra-group analysis, on the other hand, there was an increase in PImax, FEV_1/FVC, Slow Vital Capacity%—SVC% and SpO_2% in the $AC_{risk\text{-}free}$ group (Figure 3). In addition, the $AC_{risk\text{-}free}$ group had higher values for the thoracoabdominal mobility measurements at all time periods. Also the $AC_{risk\text{-}free}$ group axillary AI showed elevated values after intervention, at both M_2 and M_3 (Table 3).

In the inter-groups comparison, the percentage of Inspiratory Capacity (IC%) was statistically higher in the AC_{risk} group, immediately after the physiotherapeutic intervention (M_2) (Figure 4). There were no complications during the evaluation and treatment.

Discussion

The main outcome of this study was that men with obstructive respiratory disorders and abdominal obesity,

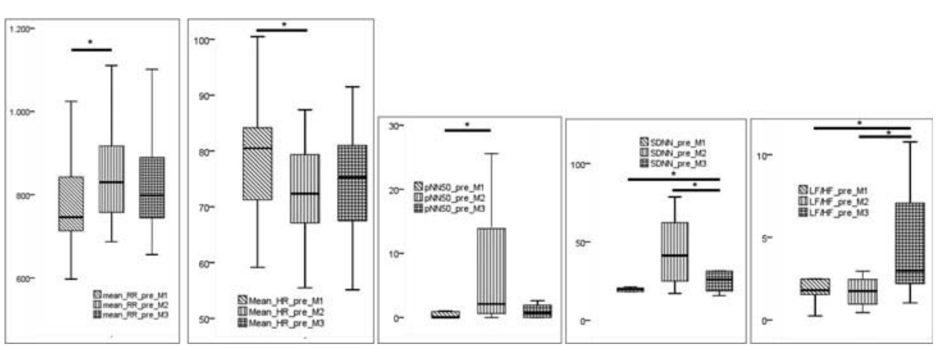

Figure 2. Variables related to cardiac autonomic control, cardiovascular and metabolic in men ($n = 13$) with obstructive respiratory disorder and abdominal circumference < 102 cm in the initial moment (M_1), immediately post-intervention (M_2) and 30 min later (M_3).

Caption: AC: abdominal circumference, M: moments; M_1 (diagonal lines): initial moment, M_2 (vertical lines): immediate moment post-protocol, M_3 (checkered): 30 min moment post-protocol, RR: Oscillations of the intervals between consecutive heartbeats; Mean RR (ms): RR intervals of time mean, SDNN (ms): standard deviation of all normal RR intervals (ms), Mean HR (1/min): mean heart rate, pNN50 (%): percentage of adjacent RR intervals with a difference duration greater than 50 ms, LF: low frequency, HF: high frequency LF/HF (ms^2): the ratio between low and high frequency; M_1 (diagonal lines): initial moment; M_2 (vertical lines): immediate moment post-protocol; M_3 (checkered): 30 min moment post-protocol; *: comparison among moments (intragroup - $p < .05$).

Table 2. Identification of the variables related to cardiac autonomic control, cardiovascular and metabolic in men (n = 26) with obstructive respiratory disorder and groups according to the abdominal circumference configuration in the initial moment (M_1), immediately post-intervention (M_2) and 30 min later (M_3).

	AC_{risk_free} (n = 13)						AC_{risk} (n = 13)					
Variables	M_1	M_2	Δ M_2-M_1 (95%CI)	M_3	Δ M_3-M_1 (95%CI)	Δ M_3-M_2 (95%CI)	M_1	M_2	Δ M_2-M_1 (95%CI)	M_3	Δ M_3-M_1 (95%CI)	Δ M_3-M_2 (95%CI)
rMSSD (ms)	14.7 ± 10.4	**29.9 ± 19.9***	15.2 (6.1 to 24.2)	**18.5 ± 11.7‡**	3.8 (−2.0 to 9.7)	−11.3 (−21.5 to −1.1)	20.6 ± 15.4	**26.9 ± 17.1***	6.2 (−2.7 to 15.3)	24.3 ± 15.2	3.7 (−2.2 to 9.6)	−2.5 (−12.7 to 7.6)
SD1	10.4 ± 7.3	**21.2 ± 14.1***	10.7 (4.3 to 17.1)	**13.1 ± 8.3† ‡**	2.6 (−1.5 to 6.8)	−8.0 (−15.2 to −0.8)	14.6 ± 10.9	**19.0 ± 12.1***	4.4 (−1.9 to 10.8)	**17.2 ± 10.8†**	2. 6 (−1.5 to 6.8)	−1.8 (−9.0 to 5.4)
SD2	34.6 ± 31.0	**81.4 ± 75.8***	46.7 (8.1 to 85.4)	**46.8 ± 35.3‡**	12.1 (1.5 to 22.7)	−34.6 (−70.1 to 0.8)	34.2 ± 17.3	**66.8 ± 45.8***	32.5 (−6.0 to 71.2)	**47.7 ± 21.6†**	13.4 (2.8 to 24.0)	−19.1 (−54.6 to 16.4)
DBP (mm Hg)	73.6 ± 12.6	75.3 ± 13.1	1.6 (−2.3 to 5.7)	76.4 ± 14.2	2.7 (−2.2 to 7.7)	1.0 (−2.6 to 4.7)	76.0 ± 9.5	79.0 ± 8.3	3.0 (−1.0 to 7.0)	**82.2 ± 12.3†**	6.2 (1.2 to 11.2)	3.2 (−0.4 to 6.9)
Glycemia (mg/dl)	107.2 ± 27.1	106.5 ± 27.6	−0.6 (−11.1 to 9.7)	107.4 ± 30.1	0.2 (−11.0 to 11.5)	0.9 (−5.5 to 7.4)	126.5 ± 36.6	118.3 ± 30.0	−8.1 (−18.6 to 2.3)	116.7 ± 29.3	−9.73 (−21.0 to 1,5)	−1.6 (−8.0 to 4.8)

Caption: Data presented as mean ± standard deviation and mean difference (95% confidence interval for difference, lower bound to upper bound); Δ: difference between moments; rMSSD: square root of the square mean of the differences among adjacent normal RR intervals (ms); SD1: dispersion of perpendicular point to the identity line; SD2: represents the dispersion of the points along the line of identity; DBP: diastolic blood pressure; M: moments; AC: abdominal circumference; AC_{risk} (AC ≥102 cm – cardiovascular risk) and $AC_{risk\text{-}free}$ (AC <102 cm); *: comparison among M_1 and M_2 (intragroup - $p < .05$); †: comparison among M_1 and M_3 (intragroup - $p < .05$); ‡: comparison among M_2 and M_3 (intragroup - $p < .05$).

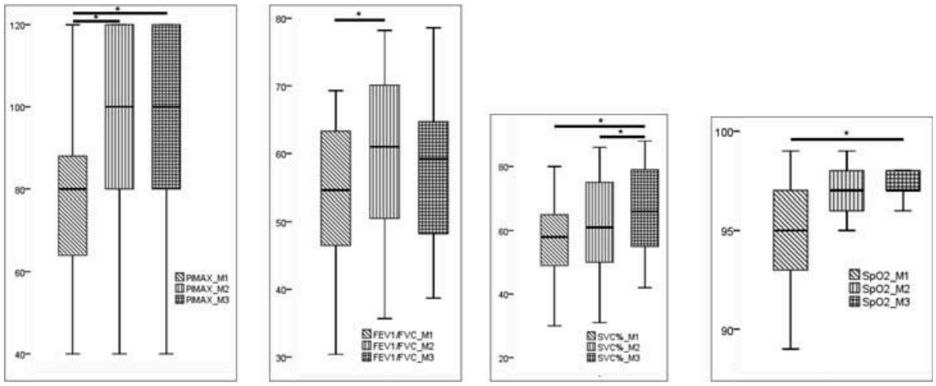

Figure 3. Respiratory variables of the men with obstructive respiratory disorder and the abdominal circumference < 102 cm in the initial moment (M_1), immediately post-intervention (M_2) and 30 min later (M_3).

Caption: AC: abdominal circumference; M: moments, M_1 (diagonal lines): initial moment, M_2 (vertical lines): immediate moment post-protocol, M_3 (checkered): 30 min moment post-protocol; PI_{max} (cmH_2O): maximal inspiratory pressure, FEV_1/FVC: Forced expiratory volume in the first second of forced vital capacity (l), FVC: Forced Vital Capacity (l), SVC (%): Slow Vital Capacity, SpO_2 (%): peripheral oxygen saturation; *: comparison among moments (intragroup - $p < .05$).

when compared to men without obesity, showed lower thoracoabdominal amplitude in all evaluations, and higher IC immediately after respiratory physiotherapy.

Ac_{risk_free} versus ca_{risk}

The CA_{risk} group was older, almost a 10-year difference, and had higher anthropometric measurements. The sample was one of convenience and age was not controlled.

The process of aging deteriorates physiological systems promoting accumulation of body fat, increasing cardiovascular risk (Aronis et al., 2015) and reducing HRV (American College of Sports Medicine, 2009; European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). However, the CA_{risk} group did not show a noticeable difference between the baseline measurements of HRV (Poliakova et al., 2012). In addition, the respiratory system also undergoes changes with advanced age, affecting the rib cage and lung parenchyma (Sharma and Goodwin, 2006).

The higher values of BMI and AC corresponded to lower values of FVC and FEV_1. This may be due to increased elastic recoil of the chest wall by the imbalance of structures, mainly to higher levels of tissue in the chest wall. Moreover, diaphragmatic expansion is also mechanically affected (Steier et al., 2009). The compliance of the respiratory system is reduced due to the fact that respiration is performed at abnormally low lung volumes. Normal breathing starts at low-end expiratory volumes where the lungs are less compliant and the airways are prone to collapse during expiration (Behazin, Jones, Cohen, and Loring, 2010). However, pulmonary compression with reduced expiratory reserve volume leads to a compensatory increase in the inspiratory reserve volume (IRV) in an attempt to maintain constant vital capacity (VC) (Costa et al., 2008). The accumulation of adipose tissue along with probable chest tightness/rigidity caused by advanced age are limiting factors that compromise chest expansion (Sharma and Goodwin, 2006; Steier et al., 2009). It can be inferred that these aforementioned mechanisms were probably those which contributed to the reduction of the thoracoabdominal AI at all time periods in the CA_{risk} group.

The CA_{risk} group had higher measurements of IC, a 19% difference, after respiratory intervention (M_2). IC is higher in obese individuals due to a compensatory increase in the activation of inspiratory muscles against the deposition of fat (Rasslan et al., 2004). Indeed, the IC is likely to change in the presence of obesity and what stands out is that only this spirometric variable was affected, and the explanation for this would be how the spirometric maneuver was performed (i.e. slowly). Therefore, this study suggests that respiratory physiotherapy improves inspiratory capacity of men with increased abdominal circumference and that abdominal obesity limits thoracic expansibility.

CA_{risk_free}

Because they were thinner and younger, the general condition of the cardiovascular system in the CA_{risk_free} group proved to be preserved. The breathing control exercises included in the breathing techniques were useful as an adjunct therapy for cardiorespiratory adjustment (Cooke et al., 1998; Rossi et al., 2014). The HRV increased from M_1 to M_2, especially global and vagal modulation. In addition, the variable HF/LF showed an increase in M_3. Increased HRV is a sign of

Table 3. Thoracic abdominal amplitude index of the men with obstructive respiratory disorder and the abdominal circumference size in the initial moment (M_1), immediately post-intervention (M_2) and 30 min later (M_3).

	AC_{risk_free} (n = 13)						AC_{risk} (n = 13)					
Variables	M_1	M_2	Δ M_2-M_1 (95%CI)	M_3	Δ M_3-M_1 (95%CI)	Δ M_3-M_2 (95%CI)	M_1	M_2	Δ M_2-M_1 (95%CI)	M_3	Δ M_3-M_1 (95%CI)	Δ M_3-M_2 (95%CI)
AI axillary	1.9 ± 1.0	**2.7 ± 1.1***	0.8 (0.1 to 1.4)	**2.8 ± 0.9**†	0.9 (0.2 to 1.6)	0.1 (−0.2 to 0.5)	**1.0 ± 0.8**§	**1.1 ± 0.6**§	0.1 (−0.5 to 0.8)	**1.3 ± 0.7**§	0.3 (−0.3 to 1.0)	0.1 (−0.2 to 0.5)
AI thoracic	2.7 ± 1.8	2.5 ± 1.5	−0,2 (−0.9 to 0.5)	3.0 ± 1.5	0.2 (−0.6 to 1.1)	0.4 (−0.2 to 1.1)	**1.0 ± 1.0**§	**0.8 ± 0.6**§	−0.2 (−0.9 to 0.4)	**0.8 ± 0.9**§	−0.2 (−1.1 to 0.5)	−0.0 (−0.7 to 0.6)
AI abdominal	1.5 ± 1.1	2.1 ± 1.5	0.5 (0.0 to 1.1)	2.1 ± 1.6	0.5 (0.0 to 1.1)	0.0 (−0.6 to 0.6)	**0.6 ± 0.8**§	**0.6 ± 0.8**§	−0.0 (−0.5 to 0.5)	**0.9 ± 0.8**§	0.2 (−0.3 to 0.7)	0.2 (−0.4 to 0.8)

Caption: Data presented as mean ± standard deviation and mean difference (95% confidence interval for difference, lower bound to upper bound); Δ: difference between moments; AC: abdominal circumference; AC_{risk} (AC ≥102 cm – cardiovascular risk) and $AC_{risk\text{-}free}$ (AC <102 cm); M: moments; AI: thoracic abdominal amplitude index; * = comparison among between M_1 and M_2 (intragroup – $p < .05$); † = comparison among M_1 and M_3 (intragroup – $p < .05$); ‡ = comparison among M_2 and M_3 (intragroup – $p < .05$); § = comparison among groups AC_{risk_free} and AC_{risk} ($p < .05$).

good adaptation, indicating that the autonomic mechanisms are efficient. The increase in vagal activity after 30 min of physical exercise occurs causing the return to resting values of the variables (Javorka, Zila, Balhárek, and Javorka, 2002). During this time period, the increase in global HRV persisted in these participants, which allows us to infer that there was a satisfactory response after respiratory therapy.

Also, there was a reduction of six bpm HR ($p < 0.05$), but only in M_2, returning to baseline in M_3. The fact that performing the respiratory maneuver FVC during spirometric evaluation, specifically for obstructive disease, results in increases of 16 to reductions of 5 bpm, without changing the values of BP and HRV indexes (Mendes et al., 2011). The average HR reduction is consistent with the current study. In addition, after physical exercise, heart rate reduction is related to early recovery of the measures of HRV (Javorka, Zila, Balhárek, and Javorka, 2002).

Respiratory changes were more evident in this group and during the M_3 period. The protocol was able to improve lung ventilation (FEV_1/FVC, SVC% and SpO_2), inspiratory muscle strength (PI_{max}) and axillary AI, in a short period of time. The improvement was identified by an increase in SVC (Δ: 8.6%), SpO2 (Δ 2.2%) and axillary AI (Δ: 0.8 cm).

There was also an increase in FEV_1/FVC, suggesting airway clearance, either by bronchial hygiene or by the application of respiratory re-education, an important effect for the basal respiratory condition. Reduced adipose tissue was probably the factor that contributed to this good response. These results are consistent with other studies that have applied other techniques different from those applied in the current protocol. These studies have found that individuals undergoing obstructive respiratory intervention tended to increase PI_{max}, SpO_2, AI and FEV_1/FVC (Ali, Talwar, and Jain, 2014; Lan et al., 2013; Rodrigues, Alves, and Gonçalves, 2012).

The increase in PI_{max} remained for up to 30 min after M_2, in conjunction with axillary IA. The increased inspiratory muscle function could have been one of the factors that contributed to the increase in thoracic amplitude. Pulmonary clearance could also have contributed to this phenomenon, but the increase was only identified during M_2 by the FEV_1/FVC variable. One can infer that the absence of abdominal obesity and the intervention contributed to a better efficiency of the inspiratory muscles, promoting a certain gain in respiratory muscle performance. This gain may also have contributed to the cardiac autonomic control and respiratory performance, since the PI_{max} in COPD correlates with cardiac autonomic control (Reis et al., 2010).

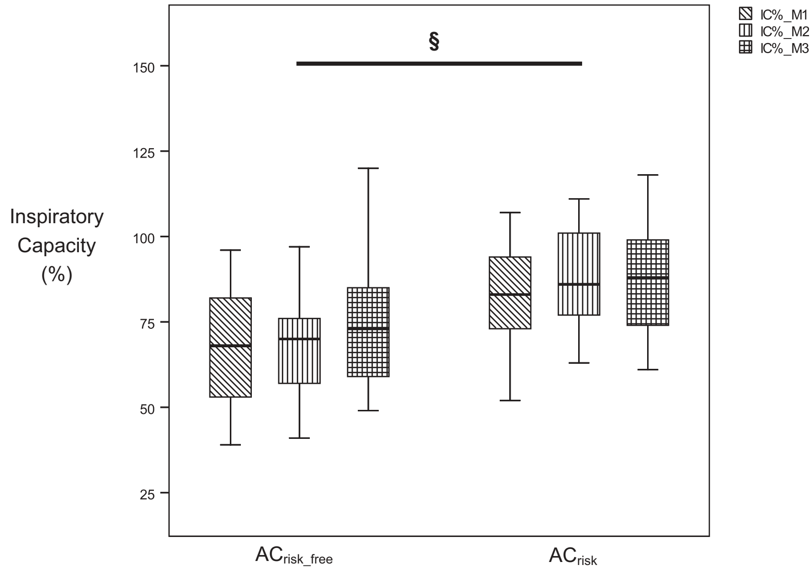

Figure 4. Presentation of the inspiratory capacity percentage (IC%) in the different moments.

Caption: AC: abdominal circumference; AC: abdominal circumference; AC_{risk} (AC ≥102 cm – cardiovascular risk) and $AC_{risk\text{-}free}$ (AC <102 cm); M_1 (diagonal lines): initial moment; M_2 (vertical lines): immediate moment post-protocol; M_3 (checkered): 30 min moment post-protocol; IC %: Inspiratory Capacity percentage; § = comparison among the groups AC_{risk_free} and AC_{risk} (p < .05).

The increase in SpO_2 (Δ: 2.2%) may have contributed to both cardiac and respiratory functions, since individuals with COPD are prone to hypoxia, which causes abnormal operation of the Autonomic Nervous System, reduced HRV and abnormal autonomic responses (Scalvini et al., 1998).

CA_{risk}

In the intra-group analysis, no respiratory changes were noticed, however, long-term studies in obese individuals found changes in these variables and they will be discussed below. Obese individuals undergoing pulmonary rehabilitation showed an increase in PI_{max} (Δ: −28 cm H_2O), chest (Δ: 1.4), xiphoid and abdominal amplitudes (Δ: 3 cm) (Costa et al., 2003). Aerobic and resistance exercise increased axillary cirtometry (cm) (Δ: 1.58) and expiratory xiphoid (Δ: 1.68) and PI_{max} (Δ: −8.5 cmH_2O) (Sonehara et al., 2011). Another study showed an increase in VRI (Δ: 0.32 l), VRE (Δ: 0.21 l) and axillary mobility (Δ: 1.4 cm) (Costa, Forti, Barbalho-Moulim, and Rasera-Junior, 2009).

In the current study which focused on the acute responses following a single intervention session there was an increase in PI_{max} (Δ: 7.4 cmH_2O) and up to 0.3 cm in thoracoabdominal amplitudes, but without statistical significance. Perhaps, for this population, repeated acute responses demanding more effort, causing higher stimulation, either by the imposition of load or the number of sets and repetitions, might reduce obstruction and overcome the restrictive factors caused by excessive adipose tissue.

It became evident that for obese men with COPD, acute changes occur only in the cardiac variables. HRV increased in the CA_{risk} group after respiratory therapy with a predominance of vagal modulation even after 30 min post-exercise identifying a useful response.

A protocol of respiratory and lower limb exercises, performed in hospitalized overweight individuals, caused reduction in rMSSD and AF, increased LF/HF ratio, systolic blood pressure (Δ: 6 mmHg) and Heart Frequency (Δ: 9 bpm) (Hiss et al., 2012). Despite the similarities between this population (Hiss et al., 2012) and the current study, with regard to risk and cardiovascular compromise (increase in AC and cardiac event), the intervention applied in the present study generated an increase in the HRV index which contributed to a better cardiac autonomic modulation.

Another finding in this group was the rise in diastolic blood pressure (DBP) at M_3. It is important to note that the pressure change after exercise is dependent on neural mechanisms and peripheral vascular resistance (PVR). Thus, the inhibition of sympathetic activity and the reduction in circulating hormones, post-exercise, led to a reduction of PVR and HR, and an increase in baroreflex sensitivity (American College of Sports Medicine, 2009; Gonçalves et al., 2015; Halliwill, Taylor, and Eckberg, 1996; Whelton, Chin, Xin, and He, 2002; Wolthuis, Froelicher, Fischer, and Triebwasser, 1977).

Despite the increase in post-intervention DBP, the rise observed was only 6.2 mmHg, which is lower than an elevation of 10 to 15 mmHg regarded as important in other studies (Akhras, Upward, and Jackson, 1985; Pescatello et al., 2004). One reason that may explain this is the change in the regulation of vascular reactivity present in cardiovascular and metabolic diseases (Brett, Ritter, and Chowienczyk, 2000). The CA_{risk} group showed characteristics of Metabolic Syndrome (i.e. 29% of the men had diagnosis related to cardiovascular diseases). In addition, the basal blood glucose was 126.5 ± 3.6 mg/dl, indicating a metabolic change in the glycemic profile (American Diabetes Association, 2016). Furthermore, advanced age tends to increase PVR, which would also explain the poor response of the post-exercise DBP (American College of Sports Medicine, 2009).

This study is original for investigating the effects of respiratory physiotherapy on the condition of obstructive respiratory disorders and increased abdominal circumference and has contributed to the current body of knowledge in this area by identifying that a single respiratory session promotes benefits to these individuals. It is clear that respiratory therapy in the hospital improves cardiac autonomic modulation by decreasing sympathetic influence. This increased parasympathetic modulation can improve the prognosis of individuals with COPD that are obese or not.

Study limitations

Studying AC separately can generate possible confounders. When studying the anthropometric measurements, such as BMI and CA, it is difficult to understand and differentiate these elements, their interferences, since they are interrelated anthropometric factors. It is worth noting that BMI above normal is not indicative of a high AC. In contrast, the AC is the measure of fatness that takes into account the accumulation of fat in the abdominal cavity. However, the main focus of this study was to AC.

Some medications may alter cardiorespiratory responses but all participants were medicated according to their care situation or hospitalization. The use of medications was imperative for these participants and there was not possibility to reduce or withhold these medications.

Restricting the study to male participants increased the internal validity of the study and eliminated the possibility of gender bias. The deposition of body fat differs between genders, being more central in men and more peripheral in women. The findings allow inference only in males, and cannot be extrapolated to women.

Conclusions

The increased AC measurement which represents increased risks for cardiovascular diseases, in men with obstructive respiratory disorders, limits the thoracoabdominal expansibility and induces rise of the diastolic blood pressure, however respiratory physiotherapy promotes increase in cardiac modulation and inspiratory capacity.

Declaration of Interest

The authors report no declarations of interest.

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