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Postural balance, muscle strength and functional capacity on the severity level of chronic obstructive pulmonary disease

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ABSTRACT

Background: Chronic obstructive pulmonary disease (COPD) is characterized by persistent and progressive airflow obstruction. It is a lung disease with systemic manifestations, which contributes to an increase in morbidity and mortality in the elderly. The greater the severity of the disease, more muscle loss occurs, especially the quadriceps muscle, leading to decreased resistance to exercise, increased fatigue, and dyspnea to small efforts. The presence of COPD is associated with an increased risk of falls, and patients with COPD have a greater imbalance when compared with subjects of the same age without the disease. To investigate whether the different degrees of severity of COPD interfere in the balance, muscle strength, and functional capacity of the patients. **Methods:** 25 individuals diagnosed with COPD (COPD-G) and 32 individuals without pulmonary disease (CG - Control Group) were assessed. Both groups were submitted to anamnesis, spirometry, dynamometry, manovacuometry, Incremental Shuttle Walking Test (ISWT), load testing for one repetition maximum (1RM), balance platform assessment, Stair-Climbing Test (SCT) and 6 Minutes Walk Test (6MWT). The variables obtained were compared using the t-test. For comparison between groups, a one-way ANOVA was used. **Results:** The comparison between the two groups showed a difference in the result of the ISWT, 6MWT and SCT. When compared between groups in different degrees of severity, there was a difference only in SCT between CG and severe COPD-G. There was no significant difference in strength and postural balance. **Conclusion:** Cardiorespiratory functional capacity is impaired in individuals with COPD and is more evident in the severe stage of the disease. The balance, the strength of the respiratory muscles, upper and lower limbs are similar in the mild, moderate, and severe stages.

Keywords: Chronic obstructive pulmonary disease; Postural balance; Muscle strength; Exercise tolerance.

BACKGROUND

Chronic obstructive pulmonary disease (COPD) is characterized by persistent and progressive airflow obstruction, associated with a chronic inflammatory response to harmful particles or gases. It is a lung disease with systemic manifestations, which contributes to an increase in morbidity and mortality in the elderly[(1)]. Among the various systemic manifestations of the disease, cardiovascular comorbidities and peripheral muscle dysfunction are the more important[2].

The greater the severity of the disease, more muscle loss occurs, especially the quadriceps muscle, leading to decreased resistance to exercise, increased fatigue, and dyspnea to small efforts. These symptoms reduce the ability to perform activities of daily living and limit tolerance to exercise, leading to generalized immobility and usually to deconditioning[(2,3)].

The presence of COPD is associated with an increased risk of falls[(4,5)], and patients with COPD have a greater imbalance when compared with subjects of the same age without the disease[(6)]. Factors that increase imbalance are muscle weakness, the need for supplemental oxygen, mobility limitations, age, and physical inactivity[(5,7)]. The six-minute walk test (6MWT), in addition to assessing cardiorespiratory fitness, can be a predictor of fall, with a cutoff distance of 300 meters[(7)].

The balance impairment, and sometimes falls, can affect the performance in activities of daily living resulting in worse quality and expectancy of life[(8,9)]. The assessment of balance and fall risk allows the indication of specific therapies, such as pulmonary rehabilitation with components aimed to balance recovery, since its benefits have already been proven[(10)].

This study aimed to investigate the balance, muscle strength, and functional capacity in patients with COPD at different levels of severity. The results will allow a better understanding of the mechanisms that lead to balance changes in this population and allow the adoption of specific strategies in the elaboration of pulmonary rehabilitation programs.

METHOD

Sample

The COPD group (COPD-G) was composed of individuals over 50 years old of both sexes, with a clinical and functional diagnosis of COPD according to the criteria of the Global Initiative for Chronic Obstructive Lung Disease[(11)]. Those who had a forced expiratory volume in the first second (FEV1) lower than 30% of the predicted value were excluded. The Control group (CG) was composed of individuals with no previous history of lung disease. We also excluded those who had a medical history of unstable angina, myocardial infarction within less than three months, or any musculoskeletal, neurological or vascular changes that hindered the execution of the tests.

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Outcomes measures

Subjects were assessed on two non-consecutive days, one week apart, and always performed by the same evaluator. On the first day, anamnesis, spirometry, manovacuometry, dynamometry, the Incremental Shuttle Walking Test (ISWT) and the load evaluation for one-repetition maximum (1MR) were assessed. On the second day, the balance test on a force platform, the Stair-Climbing Test (SCT) and the 6MWT was also assessed[12-14].

In the anamnesis, was collected information about the presence of comorbidities and smoking habits. Smokers were asked about the time of consumption in years and the number of packs per day, to calculate the pack-years of smoking. Those who denied the smoking habit were asked about the previous habit and the time of abstinence. They were also asked about the occurrence of falls in the last 12 months[12-14].

The body-weight evaluation (in kilograms) on a digital scale, and height measure (in meters) on a graduated stadiometer were assessed. The Body Mass Index (BMI) was obtained by dividing the body-weight by the squared height.

Strength assessment

Respiratory muscle strength was assessed by measuring the maximal inspiratory pressure (MIP) and maximum expiratory pressure (MEP) using an aneroid manovacuometer. The subjects, in sitting position and using a noseclip, were instructed to perform maximal inspiratory effort from the residual volume for MIP, and maximal expiratory effort from total lung capacity, for MEP. To assess handgrip strength, a hand-grip dynamometer was used with the individual in sitting position, with its upper limb supported and flexed elbow[15]. The assessment of the muscular strength of the lower limbs was performed on a 45-degree leg press machine. The test was performed to find the 1MR of knee and hip extensions. Considering the fragility of the assessed volunteers, they were instructed to push the maximum load until reaching 10 repetitions or fatigue. After reaching 10 repetitions, the resistance was increased by 2 to 10 kilograms until the subject could no longer complete the subsequent attempt. In this case, 50% of the load added in the last attempt was subtracted. When the subject did not perform 10 repetitions, the weight and number of repetitions were recorded for further analysis using the formula proposed by Brzycki[16] for the prediction of 1MR.

Balance

Static balance was assessed on a force platform, configured with a frequency of 100 Hz and normalization performed using the value corresponding to body weight. The individual was instructed to look at a fixed point on the wall in front of him. Three balance measurements of 30 seconds each were performed, with intervals of 30 seconds between them.

The data were visualized and exported by AMTI's NetForce Software, and later analyzed by specific routines in a MatLab environment. The variables in the time domain were analyzed, the area, the anteroposterior and mid-lateral perimeter and the total displacement of the pressure center. The evaluation was performed in the orthostatic position in two sensory conditions, defined according to the visual stimulus: Condition I: firm/stable surface, eyes opened. Condition II: firm/stable surface, eyes closed.

Stair-climbing test

The SCT was assessed on a shaded staircase, consisting of 4 flights (47 steps), each step measuring 0.18m, with a total height of 8.46 meters and with a 30-degree inclination. The subjects were instructed to climb as fast as they could, and the time of ascent was timed (SCTt). The evaluator gave verbal stimuli in each flight of the stairs. If the subject reported fatigue, severe dyspnea, chest pain or exhaustion, the test was interrupted [17-19].

Six-minute walk test

The 6MWT was performed according to the American Thoracic Society[20] standards, in an open corridor with a distance of 30 meters. The subject was instructed to walk the longest distance possible in 6 minutes, being able to stop or slow down. The test was interrupted if the patient reported chest pain, severe dyspnea, fatigue and exhaustion, or if it was requested by the subject.

Statistical analysis

The normality of data distribution will be evaluated with the Shapiro-Wilk normality test.
The variables obtained in the tests were compared between groups using a t-test or a Mann-Whitney test. For comparison between CG and COPD-G subgroups in different degrees of obstruction severity, using the two-way analysis of variance (ANOVA) followed by the Kruskal-Wallis and Dunn's post-hoc tests to identify significant differences. All tests considered 5% for inferring statistical significance.

RESULTS

Eighty-seven volunteers were selected for the study, eleven did not complete the assessments and nineteen were excluded. Thus, fifty-seven volunteers were divided into CG (n = 32), and COPD-G (n = 25), with twelve (37.5%) men in the CG, and eight (32.0%) men in the COPD-G. When the COPD-G was divided according to the severity of the disease, nine had mild obstruction (COPD-G-m), eleven moderate obstruction (COPD-G-M) and five severe obstruction (COPD-G-S).

The main comorbidities reported in the CG and COPD-G, respectively, were arterial hypertension (46.9%, 60.0%), type 2 diabetes (28.1%, 20.0%), dyslipidemia (15.6%, 32.0%), heart problems (9.4%, 4.0%) and thyroid disorders (9.37% / 8%). Twenty-two subjects in the CG group (68.75%) and seven in the COPD-G (28.0%) did not report smoking habits. The data related to smoking (current and previous habits), pack-years and withdrawal time are shown in Table 1. Regarding self-reported falls, four individuals (12.5%) in the CG and three (12.0%) in the COPD-G have reported falling in the past 12 months.

Table 1. Characteristics related to smoking history, pack-years and abstinence time in the groups

Parameter	CG (n=32)	COPD-G (n=25)
Never Smoking$^{\alpha}$	22 (68,7)	7 (28,0)
Current Smoking$^{\alpha}$	0 (0)	5 (20,0)
Former Smoking$^{\alpha}$	10(31,3)	13 (52,0)
Pack-years*	15,5±19,1	47,7±28,1
Abstinence (years)*	28,2±12,9	15,4±14,9

***Note:** Abbreviations: CG=Control group; COPD-G= for Chronic Obstructive Pulmonary Disease group; *mean±SD; $^{\alpha}$n (%)

The variables of age and BMI of both groups were similar. In terms of lung function, the CG had significantly higher values in FEV1 (real and %) and in the FEV1/FVC ratio (Table 2).

Table 2. Characteristics of patientes in the control group and in the groups

	CG (n=32)	COPD-G (n= 25)
Age (years)$^{\alpha}$	62,9±7,2	66,8±7,8
BMI (Kg/m²)$^{\alpha}$	29,2±4,6	27,6±4,2
FCV (L)$^{\beta}$	2,8 [2,3 – 3,4]	2,8 [2,2 – 3,5]
FCV (%)$^{\alpha}$	102,6±19,1	99,1±29,2
FEV_1 (L)$^{\alpha}$	2,3±0,6	1,6±0,6#
FEV_1 (%)$^{\alpha}$	98,1±17,7	67,9±20,9#
FEV_1/FCV (%)$^{\alpha}$	79,8±7,9	56,8±11,6#

***Note:** Abbreviations: α = mean±SD; β = median [minimum – maximum]. FVC = Forced vital capacity; CG=Control group; COPD-G= for Chronic Obstructive Pulmonary Disease group; BMI = Body Mass index; FEV_1 = Forced expiratory volume in the first second. # = p<0,001.

The assessments of respiratory muscle strength, upper and lower limbs showed no significant difference between groups. In the stress tests, the ISWT and the 6MWT were lower in the COPD-G, and in the SCT the time was shorter in the CG (Table 3).

Table 3. Exercise test, Respiratory and peripheral muscle strength in the groups

	CG (n=32)	COPD-G (n= 25)
ISWT (m)$^{\alpha}$	400,4±170,0	305,6 ± 158,4*
tSCT (s)$^{\beta}$	22,5 [18,0 – 28,0]	27,0 [21,5 – 31,0]*
6MWT (m)$^{\beta}$	558,5 [526,5 – 620,0]	516,0 [414,0 -562,3]*
MIP (cmH_2O)$^{\beta}$	-94,0 [-114,0 – -72,0]	-88,0 [-109,0 – -63,0]
MEP (cmH_2O)$^{\beta}$	110,0 [84,0 – 120,0]	100,0 [91,0 – 120,0]
Dynamometer (kgf)$^{\beta}$	10,0 [7,5 – 12,0]	8,0 [5,8 – 12,3]
1 MR (Kg)$^{\beta}$	101,5 [81,5 – 131,0]	93,5 [73,0 – 104,5]

*Note: Abbreviation: α = mean±SD; β = median [minimum – maximum]; 1MR=one-repetition maximum; CG=Control group; COPD-G= for Chronic Obstructive Pulmonary Disease group; ISWT = Incremental Shuttle Walking Test; MEP = Maximum expiratory pressure; MIP = Maximum inspiratory pressure; 6MWT = six minute walking test; tSCT = time in Stair Climbing Test; *<0,05.

There were no statistically significant differences in relation to the analyzed static balance variables (Table 4).

Table 4. Static balance in the groups in the situation opened eyes and closed eyes.

Eyes opened	CG (n=32)	COPD-G (n= 25)
Area (mm^2)	0,13 [0,07 – 0,03]	0,11 [0,08 – 0,15]
AP perimeter (cm)	1,5 [1,1 – 2,3]	1,8 [1,5 – 2,3]
ML perimeter (cm)	0,8 [0,6 – 1,1]	0,8 [0,7 – 1,0]
Displacement (cm)	29,7 [20,4 – 51,2]	31,8 [21,5 – 37,8]
Eyes closed		
Area (mm^2)	0,18 [0,11 – 0,38]	0,16 [0,12 – 0,26]
AP perimeter (cm)	2,5 [1,8 – 3,8]	2,6 [2,2 – 3,0]
ML perimeter (cm)	1,0 [0,7 – 1,2]	1,0 [0,8 – 1,2]
Displacement (cm)	41,0 [24,6 – 63,6]	36,7 [31,7 – 44,0]

***Note:** Abbreviation: median [minimum – maximum]; AP = anteroposterior; ML = mid-lateral; CG=Control group; COPD-G= for Chronic Obstructive Pulmonary Disease group; p>0,05.

The variables of body composition, muscle strength, functional capacity and balance when compared between the CG and COPD-G groups in the different degrees of severity of the obstruction showed a statistical difference only for SCT and 6MWT in CG and severe COPD-G (Table 5).

Table 5. Comparison of the mean and standard deviation of the variables between the groups.

	CG (n=32)	COPD-G (n= 25)		
		Mild	Moderate	Severe
BMI (Kg/m^2)	29,2±4,6	27,3±3,0	28,9±5,0	25,1 ±3,6
ISWT (m)	400,4±167,0	352,7±144,7	294,9±182,5	244,2±124,0
tSCT (s)	24,7±11,2	24,1±3,9	31,3±±13,5	33,8±9,2*
6MWT (m)	570,2±80,2	517,6±102,4	474,0±126,9	375,6±208,5*
MIP (cmH_2O)	-85,5±44,8	-102,0±20,9	-84,9±25,8	-65,6±10,4
MEP (cmH_2O)	101,4±22,3	99,1±18,3	10,3±18,3	88,0±12,3
Dynamometer (kgf)	10,0±4,1	8,7±5,1	9,6±5,3	9,6±2,9
1 MR (Kg)	152,8±267,1	111,2±33,0	92,7±47,5	60,3±30,6
Eyes opened				
Area (mm^2)	0,319±0,504	0,192±0,307	0,166±0,092	0,104±0,032
AP perimeter (cm)	1,8±1,1	2,0±1,0	2,0±0,5	1,9±0,5
ML perimeter (cm)	1,28±1,53	0,84±0,32	0,93±0,26	0,74±0,14
Displacement (cm)	37,7±23,6	38,1±31,0	36,3±16,5	37,3±8,9
Eyes closed				
Area (mm^2)	0,644±1,88	0,193±0,116	0,33±0,31	0,13±0,034
AP perimeter (cm)	2,9±1,5	2,6±0,6	2,8±0,7	2,6±1,0
ML perimeter (cm)	1,45±2,71	0,96±0,29	1,0±0,3	0,94±0,19
Displacement (cm)	52,6±47,4	42,7±13,8	27,5±8,3	40,8±6,5

***Note:** Abbreviation: AP = anteroposterior; BMI = Body Mass index; ISWT = Incremental Shuttle Walking Test; MEP = Maximum expiratory pressure; MIP = Maximum inspiratory pressure; 6MWT = six minute walking test; tSCT = time in Stair Climbing Test; CG=Control group; COPD-G= for Chronic Obstructive Pulmonary Disease group; 1MR=one-repetition maximum; * compared with CG p<0,05

DISCUSSION

The results of this study shows that COPD patients with different degrees of obstruction did not show any difference in the of respiratory muscles strength, upper and lower limbs, as well as in static balance, when compared to healthy individuals. The cardiorespiratory functional capacity assessed through stress tests (ISWT, SCT and 6MWT), as expected, was significantly reduced.

Considering that COPD is a systemic disease, it was expected to find a decrease in muscle strength, but our results in COPD-G the difference was not significant. One possible explanations is the fact that the COPD-G consisted mostly of patients with mild or moderate obstruction, and the severity of the disease is directly related to muscle dysfunction[(21–23)]. The results presented here are similar to the results of a study that correlated muscle performance and FEV1, and observed a low correlation between them, suggesting that the degree of airway obstruction may not be a good predictor to quantify muscular dysfunctions of patients with COPD[(24)].

In this study, it was observed that the cardiorespiratory functional capacity is reduced in comparison to healthy individuals, as already demonstrated in several previous studies[(25–30)]. In this study, three field stress tests were performed, with different characteristics. Even though it was not the objective of the study, it was observed that the cardiorespiratory changes in the two groups studied did not differ from each. Therefore, the choice of any of the tests for assessing COPD patients would lead to similar cardiorespiratory stress, despite their requirement of different metabolic pathways.

This study evaluated the static balance through the force platform, a methodology used to analyze oscillations on the pressure center (PC), which is the point of application of the resultant of the vertical forces acting on the support surface[(31)]. The method used in this study did not detect significant differences in relation to the analyzed balance variables in the proposed conditions. The sensory conditions in which the volunteers were assessed may not have sufficiently challenged the postural control of the subjects to the point of generating significant differences or changes. In a study that also used the force platform and evaluated patients with moderate to very severe COPD, they found results like those shown here[(32)].

In another study that also used the force platform, but that sought to assess whether balance recovery was different in COPD patients, it was demonstrated that these patients take more time to perform postural adjustments after performing a dynamic activity[(33)]. Another study also states that balance disorders occur more frequently in patients with COPD while performing dynamic activities, which require greater integration of systems involved in balance[6]. Both studies help to prove the hypothesis that the patients evaluated in this study did not show balance changes due to the situation in which they were placed.

From the intergroup analysis, according to the severity of the disease, there was a difference in the SCT and the 6MWT, between the control group and COPD patients with severe obstruction, since the SCT is a test of high metabolic and ventilatory demands, and the 6MWT is a test relatively long with good correlation with the degree of obstruction[(34)]. A study that compared the distance in the 6MWT of COPD patients in different degrees of obstruction concluded that the greater the limitation to airflow, the lower the tolerance to physical effort. These findings differ from our findings since there was only a difference between severe obstruction and the control group.

Other studies should be carried out using the force platform in this population, placing patients in situations of greater sensory challenge, which may enable the detection of postural changes, that were not detected under the conditions imposed in this study. In addition, increasing the number of subjects, especially with a higher degree of obstruction, will allow more relevant conclusions.

CONCLUSION

Our results show that cardiorespiratory functional capacity is impaired in individuals with COPD, and it is more evident in the severe stage of the disease. Static balance, respiratory muscle strength, upper and lower limbs are similar in the mild, moderate, and severe stages of the disease, according to the methodology used in this study.

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