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Peripheral and respiratory muscle strength in chronic obstructive pulmonary disease

Força muscular periférica e respiratória na doença pulmonar obstrutiva crônica

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Abstract - COPD is a pulmonary pathology associated with numerous systemic manifestations, among them musculoskeletal dysfunction. The aim of the study was to evaluate and compare respiratory and peripheral muscle strength in patients with COPD and healthy individuals. This is a cross-sectional, analytical and observational study, in which 18 individuals were evaluated, nine of them with COPD and nine healthy. Femoral quadriceps neuromuscular performance (assessed by means of isokinetic dynamometry), handgrip strength (manual dynamometer) and maximum respiratory pressure (manovacuometry) were evaluated. Data were expressed by mean and standard deviation, analyzed in the SPSS 20.0 statistical package. Significance level of 5% and confidence interval of 95% for all measures were considered. Individuals with COPD had lower quadriceps femoral neuromuscular performance and lower respiratory pressures than healthy subjects; however, there was a statistically significant difference only for muscle power and MIP ($p < 0.05$). Handgrip strength was higher in individuals with COPD ($p < 0.05$). individuals with COPD have neuromuscular changes in peripheral and respiratory muscles that may possibly cause reduced functional performance.

Key words: Muscle strength; Physical therapy specialty; Chronic obstructive pulmonary disease; Respiratory muscles.

Resumo - *A DPOC é uma patologia pulmonar, mas que está associada à inúmeras manifestações sistêmicas, dentre elas a disfunção músculoesquelética. Objetivou-se avaliar e comparar a força muscular respiratória e periférica em pacientes com DPOC e indivíduos saudáveis. Trata-se de um estudo transversal, analítico e observacional, no qual foram avaliados 18 indivíduos, sendo nove com DPOC e nove saudáveis. Foram avaliados quanto ao desempenho neuromuscular do quadríceps femoral (avaliado por meio da dinamometria isocinética), força de preensão manual (dinamômetro manual) e pressões respiratórias máximas (manovacuometria). Os dados foram expressos por meio de média e desvio padrão, analisados no pacote estatístico SPSS 20.0. Foi considerado um nível de significância de 5% e intervalo de confiança de 95% para todas as medidas. Os indivíduos com DPOC apresentam desempenho neuromuscular de quadríceps femoral e pressões respiratórias máximas inferiores aos sujeitos saudáveis, no entanto houve diferença estatisticamente significante apenas para potência muscular e PImáx (p<0,05). Já a força de preensão manual foi maior em indivíduos com DPOC (p<0,05). Os sujeitos com DPOC possuem alterações neuromusculares em músculos periféricos e respiratórios que possivelmente podem causar redução do desempenho funcional.*

Palavras-chave: *Doença pulmonar obstrutiva crônica; Fisioterapia; Força muscular; Músculos respiratórios.*

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is a preventable and treatable condition characterized by persistent, progressive and partially reversible obstruction of the airways, associated with abnormal inflammatory response of the lungs to noxious particles or gases[1]. Although COPD is a primarily pulmonary disease, the natural history of COPD is associated with numerous systemic manifestations and comorbidities, such as significant weight loss, respiratory muscle weakness, decreased strength and/or endurance of upper and lower limb musculature, osteoporosis, mood disturbance, anemia, and hormonal imbalance. Of these, skeletal muscle dysfunction, defined as loss of muscle strength and endurance, can reach respiratory and peripheral muscles at different degrees[2,3].

Despite these impressive temporal adaptations, the presence of severe pulmonary hyperinflation and reduced inspiratory capacity means that the ventilatory reserve in COPD is decreased and the ability to increase ventilation when demand suddenly increases, as in exercise or exacerbation, is very limited[2-5].

The peripheral muscles, especially the lower limbs, become underutilized due to the lifestyle adopted by these patients, leading to muscular deconditioning and/or atrophy by disuse, reducing muscle mass and oxidative capacity, making them also more susceptible to fatigue[6-8]. This difficulty is partially due to changes in respiratory mechanics associated with the disease, so that muscles required for upper limb activities are also necessary for breathing[9].

Factors such as individual genetic susceptibility and / or inadequate amplification of the inflammatory response to smoking stimulus, decontamination due to disuse, reduction of anabolic hormones (testosterone), malnutrition and prolonged use of corticosteroids are likely mechanisms for the development of such a systemic manifestation[2,10,11].

COPD promotes structural, physiological and psychological changes in the lives of patients, bringing important morbidity and mortality in those who are affected by the disease. In addition to the impact on the lives of patients, it promotes changes in the lives of their families, not only by spending on health resources, but also by the repercussions on the daily lives of patients, including their quality of life.

In view of the above, it is extremely important to develop a study to evaluate respiratory and peripheral muscle strength and its relationships in patients with COPD.

METHODOLOGICAL PROCEDURES

It is a cross-sectional, analytical and observational study; developed in the Laboratory of the Physiotherapy of the Federal University of Rio Grande do Norte (UFRN). The research followed criteria of resolution 466/12 of the National Health Council, with favorable opinion from the Ethics Research Committee (CEP) under No. 1,323,824.

The G*Power 3.1.9.2 software (Franz Faul, Universitat Kiel, Germany) was used for the sample calculation after pilot study with handgrip strength, following recommendations of Beck[12]. A priori, statistical power of 0.8 was adopted considering significance level of 5%; correction coefficient of 0.5; non-sphericity correction of 1; and effect size of 0.25 and for that, total "n" of 14 subjects (2 groups with 7 subjects) was calculated. This analysis was performed to reduce the probability of type II error and to determine the minimum number of subjects required for this investigation. Thus, the sample size was sufficient to provide 82% statistical power.

Therefore, 25 subjects of both sexes aged 48-76 years were included. Volunteers from the COPD (GD) group were recruited from the pulmonology department of a high-complexity university hospital, with medical diagnosis of COPD, who should be under prescribed and clinically stable medical treatment.

In all, 16 patients diagnosed with COPD (48-76 years) were evaluated. For the healthy group (GS), 9 healthy individuals (aged 48-70 years) physically inactive in the last year were evaluated.

After signing the Informed Consent Form (ICF), data collection was started. A Koko Digidoser model spirometer was used to evaluate lung function. The analysis of Quadriceps performance was performed by means of a computerized isokinetic dynamometer. The hydraulic JAMAR® dynamometer was used to measure handgrip strength. A digital Manovacuometer was used to evaluate maximum respiratory pressures (MIP and MEP). The effort perception was evaluated through the BORG scale, Portuguese version. In addition to monitoring blood pressure, heart rate and peripheral oxygen saturation were also evaluated.

Evaluations were performed in the following order: spirometry test to evaluate current lung function, followed by manual dynamometry to evaluate handgrip strength, and, finally, muscular performance test in the isokinetic dynamometer (ID) for the quadriceps femoris muscle.

All participants underwent spirometry to classify the severity of the obstruction. The test consists of an inspiratory maneuver up to total lung capacity (TLC), followed by forced maximal expiration to residual volume (RV)[13]. At least three tests were performed, with variation of less than 5% and the highest value obtained in one of the tests was compared with the predicted values of pulmonary function parameters for the Brazilian population[14].

In order to measure the handgrip strength (HGS), patients performed the test with the dominant limb in a sitting position with the elbow flexed at a 90º angle, forearm and wrist in a neutral position[15]. Subjects were instructed to perform three maximal isometric contractions, with a one-minute interval between measurements; the highest value was considered.

In the MIP evaluation, individuals performed forced inspirations starting from the residual volume (RV); and for MEP, expiratory efforts were performed based on total lung capacity (TLC). Maximum sustained pressures were considered for at least one second. Measurements were performed for a maximum of ten times, until three values with variation of less than 5% were obtained, and the highest value was considered for the analysis[16].

Before starting the ID test, the volunteer performed a 5-minute warm-up on an exercise bicycle. Then, the subject was positioned in the ID chair, with hip flexed at approximately 90º and neutral pelvis. Soon after, stabilization was performed with belts in the pelvic and thoracic region, as well as in the thigh of the dominant lower limb evaluated. The rotation axis of the ID test was aligned at the level of the lateral epicondyle of the femur and the lever arm fixed approximately 3 cm above the medial malleolus of the ankle[17]. During the test, standardized verbal encouragement was provided and rigorously instructions were applied for all volunteers.

Subjects performed 20 concentric repetitions at angular velocity of 120°/sec[17], in a joint motion range of 85° in total. Likewise, a pre-test (an average of 3 repetitions at submaximal intensity) was performed prior to the beginning of the collection to familiarize the subject with the ID test in order to reduce the learning effect.

Data are presented through measures of central tendency and dispersion for quantitative variables, and absolute and relative frequencies for qualitative variables. The normal distribution of data was verified by the Shapiro-Wilk test. The T-student test was used, in cases of normal data distribution to compare variables in both groups; in cases of non-normal distribution, Mann Whitney the test was used to analyze the correlations between the analyzed variables, and the Pearson's correlation coefficient was used in case of normal data distribution, or Spearman's correlation coefficient in case of non-normal data distribution. For statistical significance, p-value less than or equal to 0.05 was considered.

Data were analyzed using Statistical Package for Social Sciences (SPSS) software version 20.0. In all statistical analyses, 95% confidence interval (CI) and 5% significance level were considered.

RESULTS

The study sample consisted of 25 subjects. Of these, 16 patients diagnosed with COPD (48-76 years) were evaluated. Six were excluded during the study: two for lack of understanding to perform the spirometry test and four for not completing the entire evaluation. Therefore, 9 patients with COPD (7 men and 2 women) and 9 healthy individuals (7 men and 2 women) participated in the study.

Table 1 presents the sample characterization with mean values (± standard deviation) of anthropometric data, as well as the severity of the disease. It was observed that there were no statistically significant anthropometric differences between groups. Spirometric data show normal values for GS individuals, characterizing them as individuals without ventilatory disorder. On the other hand, the GD values show values characterized by the presence of COPD.

Regarding heart rate (HR) at rest, GD presented mean value of 81.00 ± 10.40; and GS 80.40 ± 9.70, with p = 0.90. The peripheral oxygen saturation ($SpO2$) assessment presented mean value of 96.80 ± 1.40 for GD and 97.40

± 1.42 for GS, with p = 0.42; therefore there was no significant difference between groups in these variables. Regarding respiratory frequency (RF) at rest, significant difference (p <0.002) was found, with GD presenting average value of 22.50 ± 4.00 and GS 15.60 ± 3.70.

Table 2 shows the values regarding the evaluation of muscle performance in the ID test, as well as handgrip strength and maximal respiratory pressures (MIP and MEP), showing that there was a statistically signifi-

Table 1. Sample characteristics

	COPD group n = 9	Control Group n= 9	p-value
Anthropometry			
Age (years)	63.40 ± 8.50	59.40 ± 6.90	0.29
Women (%)	02 (22.20%)	02 (22.20%)	
Men	07 (77.80%)	07 (77.80%)	
Weight	69.40 ± 13.10	78.30 ± 16.60	0.22
Height	1.64 ± 0.03	1.70 ± 0.07	0.06
BMI (Kg/m)	25.40 ± 4.50	26.70 ± 3.60	0.52
Severity of the disease			
Years/pack*	69.40 ± 27.80	-	-
FEV 1 (% predicted)	31.10 ± 21.20	93.00 ± 10.50	<0.01
FEV 1 (L)	1.10± 0.50	3.20 ± 0.60	<0.01
FVC (%predicted)	62.20 ± 20.80	92.70 ± 8.90	<0.01
FVC (L)	2.20 ± 0.60	3.90 ± 0.70	<0.01
FEF1/ FVC	0.40 ± 0.10	0.80 ± 0.05	<0.01
FEF1/ FVC (%predicted)	61.00 ± 13.70	101.10 ± 5.30	<0.01
GOLD I (FEV1 > 80% predicted value), n (%)	01 (11.10)	-	
GOLD II (FEV1, 50–80% predicted value)	04 (44.40)	-	-
GOLD III (FEV1, 30–50% predicted value)	03 (33.30)	-	-
GOLD IV (FEV1 ≤ 30% predicted value)	01 (11.10)	-	-

COPD - Chronic Obstructive Pulmonary Disease; BMI - body mass index; Years / pack * = number of years of smoking × average number of cigarettes smoked per day / 20; FEV 1, forced expiratory volume in 1 second; FVC, forced vital capacity; GOLD, Global Initiative for Chronic Obstructive Pulmonary Disease.

Table 2. Variables of isokinetic dynamometry of knee extensors, manual dynamometry and maximum respiratory pressures

	COPD n=09	Control n=09	p-value
Isokinetic dynamometry			
PT (Nm)	85.70 ± 24.40	104.40 ± 31.00	0.17
PT (% of predicted value)	62.90 ± 9.60	66.30 ± 8.80	0.45
TW (J)	1305.50 ± 329.90	1671.50 ± 444.50	0.06
P (W)	99.90 ± 21.00	145.10 ± 51.50	0.02
Manual dynamometry			
HGS (Kgf)	63.50 ± 19.00	38.70 ± 9.70	<0.01
HGS (%of predicted value)	167.40 ± 49.30	93.90 ± 15.80	<0.01
Maximum Respiratory Pressure			
MIP (cmH2O)	73.00 ± 27.70	131.40 ± 53.20	<0.01
MIP (%of predicted value)	73.60 ± 22.50	126.70± 41.00	<0.01
MEP (cmH2O)	120.80 ± 51.90	147.80 ± 50.00	0.27
MEP (%of predicted value)	112.30 ± 35.00	133.80 ± 31.90	0.19

PT - peak torque (in newtons • meter); TW - total work (in watt); HGS - handgrip strength (in kilogram force); MIP - maximal inspiratory pressure (in centimeters of water); MEP - maximum expiratory pressure (in centimeters of water).

cant difference for muscle P of knee extensors, HGS and MIP. The other dependent variables evaluated did not present significant difference.

DISCUSSION

The aim of the present study was to evaluate and compare the peripheral and respiratory muscle strength between patients with COPD and healthy individuals. Data collected from the evaluation of the knee extensor muscles in the ID test indicated that volunteers with COPD had power or movement speed 31% lower when compared with healthy individuals of the same age group. This result suggests that individuals with COPD have reduced capacity, however sufficient, to perform the task satisfactorily.

According to Abizanda Soler et al.[18], physical inactivity may be one of the mechanisms of this peripheral muscular dysfunction. Izquierdo et al.[19] evaluated muscle strength and power in middle-aged men and concluded that skeletal muscle power decreases earlier than peak torque with advancing age. This conclusion corroborates our findings, in which no statistically significant difference for PT and TW between groups was observed.

This characteristic may be elucidated by a probable loss of muscle mass, fibrotic infiltration or the existence of intramuscular fat deposits in this population[6]. In addition, it is believed that there is an intimate relationship with ventilatory limitation, dynamic hyperinflation or increased respiratory muscle work, as opposed to an inability to produce the power required by the task[20].

Although PT and TW values were not statistically significant, the results may indicate clinical relevance, since their mean value for GD was lower, 18 and 22%, respectively, than for GS. These data may be associated with an abnormality in muscle metabolism, which presents less oxidative activity, contributing to the appearance of functional limitations[20].

Functional deterioration of the muscles of upper and lower limbs may not be homogeneous[2,19], being the lower limb muscles largely responsible for limitations in activities such as walking and climbing stairs and, in addition, reduction in the quadriceps strength is a potent predictor of mortality in severe COPD[21]. Yende et al.[22] suggest that muscular strength of the upper limbs is preserved in patients with COPD, as in our findings, which showed higher and statistically significant HGS when compared with healthy individuals.

Among the possible explanations, the following can be mentioned: 1) patients with COPD are inactive in their daily life activities, with less expenditure of daily time with activities that involve weight support, such as walking and staying in the orthostatic position and, conversely, spend more time sitting and lying down; 2) predominance of activities of daily living performed with the upper body; and 3) a large part of the scapular girdle muscles, responsible for elevation of the upper limbs, participates concomitantly with accessory breathing[2,23].

In addition, the literature shows important changes in the proportion of muscle fiber type in patients with COPD, when compared to healthy subjects. Results of muscle biopsies in patients with COPD show atrophy of both type I and type II muscle fibers[24]. No disproportion between the two types of muscle fibers was observed in the upper limbs, probably due to the great need of the upper body in activities of the daily living[25].

Thus, the reduction of inspiratory muscle strength seems to occur more intensely than the expiratory in subjects with COPD. In our study, patients with COPD had 44% lower MIP values than normal subjects of the same age group, while the percentage difference between MEP values was 18%; corroborating with literature.

Gosselink et al.[26] found that inspiratory muscle strength is more severely reduced than the expiratory in stable COPD. One possible explanation may be due to the alterations in the typing of muscle fibers in the diaphragm of this population.

The diaphragm of patients with COPD has increased proportions of type I fibers compared to the control group[4]. This was first documented by Levine et al.[6], who reported that the proportion of type I fibers averaged 64% of the total fibers in the diaphragms of the COPD group, while the proportion of these fibers averaged only 45% of the total number of fibers in the control group.

The reasons remain obscure; however, many researchers propose that recruitment and daily muscle activation largely determine the degree to which it is affected in these patients[7], like ventilatory muscles that are in a state of chronic overload due to increased breathing work caused by airflow obstruction and hyperinflation[15].

The reduction of diaphragm resistance in patients with COPD has traditionally been attributed to the length shortening induced by hyperinflation, which negatively influences the length-tension relationship[3], which is confirmed by the observation that lung volume reduction surgery results in increased diaphragm length and restoration of MIP in patients with COPD[27].

Some methodology limitations may affect the assumptions arising from this study. The limited sample size should be considered when the results are applied to the broader COPD population, while data from healthy individuals of the same age group cannot be extrapolated to populations in a broader context.

Another study limitation is found in the protocol proposed to evaluate muscle performance in the DI test, since the adopted angular velocity (120°/s) may not be ideal for assessing the quadriceps femoral strength, being necessary to use smaller angular velocity, around 60 to 90 °/s.

CONCLUSIONS

In the present study, evidence that the strength of the quadriceps femoris muscles and respiratory muscles are reduced in patients with COPD was obtained; while the upper limb muscles can remain preserved. Further studies are needed to identify the loss of strength mechanisms in this population.

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