

Is there an association between quadriceps muscle endurance and performance on activities of daily living in individuals with COPD?

Existe associação entre a resistência muscular do quadríceps e o desempenho nas atividades da vida diária em indivíduos com DPOC?

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Abstract

Introduction: Chronic obstructive pulmonary disease (COPD) is characterized by limited airflow associated with inflammatory response and systemic manifestations, such as dyspnea, as well as physical inactivity and intolerance to exercise. The sum of these changes can lead to peripheral muscle fatigue and exert an impact on the performance of activities of daily living (ADL). **Objective:** To investigate the possible association between peripheral muscle fatigue and performance on ADL in individuals with COPD, and to compare the results to those of healthy age-matched individuals. **Methods:** Individuals with a diagnosis of COPD and healthy volunteers aged 60 years or older were submitted to evaluations of peripheral muscle fatigue (using surface electromyography) and performance on the Glittre-ADL test. **Results:** Nine individuals with COPD and ten controls were evaluated. Median isometric quadriceps contraction time was 72 [38] and 56 [51] seconds, respectively. Execution time on the ADL test was 6.1 [4] and 3.6 [1.3] minutes for COPD and control group respectively, with a significant difference between groups ($p < 0.05$). However, no significant correlation was found between the evaluations. **Conclusion:** No association was found between quadriceps muscle fatigue and performance on ADL in the sample studied. In the intergroup comparison, the individuals with COPD exhibited worse ADL time execution, but no significant difference was found regarding quadriceps muscle fatigue.

Keywords: Activities of daily living. Chronic obstructive pulmonary disease. Muscle fatigue.

Resumo

Introdução: *A doença pulmonar obstrutiva crônica (DPOC) é caracterizada por fluxo aéreo limitado associado à resposta inflamatória e manifestações sistêmicas, como dispneia, além de inatividade física e intolerância ao exercício. A soma dessas alterações pode levar à fadiga muscular periférica e exercer impacto no desempenho das atividades de vida diária (AVD).* ***Objetivo:*** *Investigar a possível associação entre fadiga muscular periférica e desempenho em AVD em indivíduos com DPOC e comparar os resultados com indivíduos saudáveis da mesma faixa etária.* ***Métodos:*** *Indivíduos com diagnóstico de DPOC e voluntários saudáveis com idade igual ou superior a 60 anos foram submetidos a avaliações de fadiga muscular periférica (por meio de eletromiografia de superfície) e desempenho no teste Glittre-ADL.* ***Resultados:*** *Foram avaliados nove indivíduos com DPOC e dez controles. O tempo médio de contração isométrica do quadríceps foi de 72 [38] e 56 [51] segundos, respectivamente. O tempo de execução do teste de AVD foi de 6,18 [4,09] e 3,67 [1,3] minutos para DPOC e grupo controle, respectivamente, com diferença significativa entre os grupos (p < 0,05). No entanto não encontrou-se correlação significativa entre as avaliações.* ***Conclusão:*** *Não encontrou-se associação entre a fadiga muscular do quadríceps e o desempenho nas AVD na amostra estudada. Na comparação intergrupos, os indivíduos com DPOC apresentaram pior tempo de execução das AVD, mas não encontrou-se diferença significativa em relação à fadiga muscular do quadríceps.*

Palavras-chave: *Atividades da vida diária. Doença de obstrução pulmonar crônica. Fadiga muscular.*

Introduction

Chronic obstructive pulmonary disease (COPD) is defined as limited airflow resulting from exposure to toxic gases and harmful particles associated with an inflammatory response.[1] It is characterized as a common, preventable and treatable disease, but is not completely reversible, leading to lung and extrapulmonary impairment.

As COPD is a systemic inflammatory disease, extrapulmonary manifestations may contribute to the severity of the disease.[2] Skeletal muscle dysfunction is an apparent manifestation in the initial stages[3] and involves muscle weakness of the upper and lower limbs, muscle atrophy, reduction in muscle oxidative capacity, the prevalence of type II fibers, reduction in capillary density and reduction in aerobic enzymes.[4-6] Besides weakness, some studies have reported that individuals with COPD have lower limb muscle fatigue, especially in the quadriceps, which is directly associated with the severity of the disease.[7-9]

All these factors together lead to a progressive reduction in the level of daily physical activity, reduction in the capacity for physical exercise, limited tolerance to exercise and poorer quality of life. This vicious circle can lead to debility and generalized immobility.[5,10] The reduction in functional capacity explained by muscle weakness and fatigue, especially in the lower limbs, is well documented in the literature on COPD[7-9,11-14] and the sum of these systemic alterations can exert a negative impact on quality of life.

However, a possible association between peripheral muscle fatigue, especially in the quadriceps, and an effective performance on ADL in this population is not yet well established. Therefore, the aims of the present study were to investigate the possible association between quadriceps muscle endurance and performance on ADL in individuals with COPD, and to compare the results to those of healthy age-matched individuals.

Methods

A cross-sectional study was conducted at the Laboratório de Avaliação Funcional Pulmonar (LARESP; Lung Function Assessment Lab) of Universidade Nove de Julho involving patients with a clinical diagnosis of COPD and healthy individuals, of both sexes, and older than 60 years of age. This study received approval from the institutional review board of the university (certificate number: 4.308.091) and all volunteers agreed to participate by signing a statement of informed consent.

The inclusion criteria were age 60 years or older, a clinical diagnosis of COPD confirmed by post-bronchodilator spirometry, clinical stability and not having undergone any lung rehabilitation program in the previous three months. The healthy individuals were recruited from the same city through personal invitation and were also 60 years of age or older. Exclusion criteria were incapacity to perform any of the tests, dropping out of the protocol and not agreeing to participate in the study (Figure 1).

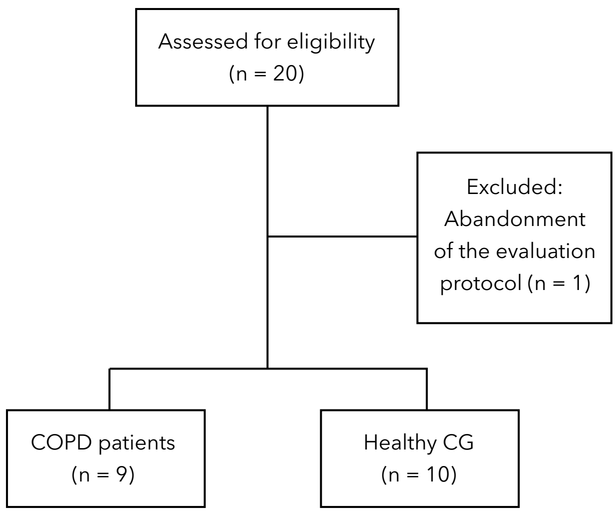

Figure 1 - Flowchart of sample selection.

Note: COPD = Chronic obstructive pulmonary disease; CG = control group.

The tests were performed by the same evaluators, on two non-consecutive days, with an interval of 24 hours between them, so that the results of the estimates did not interfere with each other. On the first day, anamnesis, anthropometry, spirometry and quadriceps fatigue were performed; on the second day, the two ADL tests were performed.

Experimental procedure

Complete patient histories were taken, followed by the collection of anthropometric data. Height was measured using a metric tape (Wiso®) and body mass was determined in the standing position using a digital scale (FILIZOLA®). The body mass index (BMI) was then calculated using the equation: body weight (kg)/height (m^2). Spirometry was then performed with a portable spirometer (Easy One®, Ndd, Zurich, Switzerland) in a temperature-controlled environment (22 to 24 °C). The volunteers were instructed to remain seated with the back supported on the chair. The nose was occluded with a clip and the volunteers received verbal instructions to perform slow vital capacity and forced vital capacity (FVC), which enabled the following determinations: expiratory volume in the first second (FEV_1), FEV_1/FVC, and maximum voluntary ventilation, following the norms and criteria of acceptability and reproducibility established by the American Thoracic Society/European Respiratory Society.[15] All values were compared to predicted values for the Brazilian population.[16] The aim of this test is to classify the level of COPD in patients with a previous clinical diagnosis.

Peripheral muscle fatigue was assessed with the aid of surface electromyography (EMG). The EMG signals were captured using an eight-channel biological signal acquisition system (EMG System do Brasil Ltda®) composed of active bipolar electrodes with a 20-fold gain, an analog 20 to 500 Hz bandpass filter and a common mode rejection of 120 dB. One of the channels was activated for the use of a force transducer (EMG System do Brasil Ltda®). The signals were sampled at a frequency of 2000 Hz and digitized through an analog-digital converter with 16 bits of resolution.

The signals were captured with circular self-adhesive silver chloride (Ag/AgCl) electrodes. Hair was removed from the placement sites and the skin was cleaned with alcohol. The electrodes were positioned over the motor points of the respective muscles following the guidelines and standardization of Surface Electromyography for Noninvasive Assessment of Muscles (SENIAM).[17] The electrodes were positioned as follows: rectus femoris - midpoint on the line between the anterosuperior iliac spine and edge of the base of the patella; vastus lateralis - 2/3 from the iliac spine along a line between the anterosuperior iliac spine and lateral edge of the patella; and vastus medialis - lower fifth of the distance between the anterosuperior iliac spine and medial joint space of the knee.[17] A reference electrode was placed on the head of the fibula ipsilateral to the limb being analyzed.

For the readings, the volunteers remained seated with the knee flexed and ankle supported on one arm of the equipment. The volunteers were then instructed to perform knee extension to 60° against the extensor chair (NakaGym) in maximum voluntary isometric contraction (MVIC).[7] The force in kilograms generated during this static contraction was measured using a load cell attached to the arm of the extensor chair. The procedure was performed three times with five-second readings and one-minute rest between readings. During the tests, the volunteers were verbally encouraged to perform maximum contraction. The largest value was considered 100% MVIC.[18]

After five minutes of rest, the volunteers were familiarized with the fatigue assessment protocol, during which they were instructed to perform a sustained contraction until exhaustion (tolerance limit) with visual feedback provided by a line of the previously established training at 60% MVIC.[19] After five minutes of rest, a new reading was performed, which was considered the fatigue protocol.

The EMG signals collected at 60% MVIC were evaluated based on the isometric endurance time considering two moments: until initiating a greater than 10% change in the contraction force, and until the tolerance limit of endurance. In each previously selected signal, a baseline was determined with an increase of 25% until reaching 100% of the total time of the signal.[20] For each moment (baseline – 100%), the median frequency (MDF) of the signal was calculated using the Fourier fast transform (FFT) with a Hamming window with 50% overlap (windows with 1024 points). The amplitude was verified using the root mean squared (RMS). The EMG signals were processed using specific routines developed in Matlab, version 7.1 (The MathWorks Inc., Natick, Massachusetts, USA).

Performance on activities of daily living was assessed using the Glittre-ADL test. The volunteer began by sitting in a chair wearing a backpack containing a weight (2.5 kg for women and 5.0 kg for men). The volunteer was instructed to stand up from the chair and walk along a 10-meter track with a stair positioned in the middle. At the end of the track, a bookstand was positioned with shelves at shoulder height and waist height. The volunteer moved three 1-kg weights from the top shelf to the lower shelf and then to the floor. The volunteer then moved the weights from the floor to the lower shelf and then to the top shelf, returned along the 10-meter track, over the step, until reaching the chair. The volunteer sat down and began the course again. The test was finished after five complete runs. The volunteers were instructed to perform the test as quickly as possible. No verbal encouragement was given during the test.[21]

Execution time of the Glittre-ADL test was determined with a stopwatch from the onset until the volunteer sat down after completing the fifth run of the course. Throughout the test, heart rate was monitored using a heart rate meter (Polar®) and peripheral oxygen saturation (SpO_2) was monitored using a pulse oximeter (NONIN®). At the end of each run, the volunteers were asked about shortness-of-breath, upper limb fatigue and lower limb fatigue using the modified Borg scale. Two tests were performed, with a 30-minute rest between tests to ensure the learning effect. As represent better performance, the tests with the shortest execution time were considered for interpretation.

If SpO_2 dropped below 85%, oxygen was offered through a nasal cannula to maintain the SpO_2 above 90%. The test would be interrupted if the volunteer reported a score higher than 6 on the Borg scale, exhibited signs of low cardiac output, reported chest pain or dizziness, or if the SpO_2 remained low even with oxygen supplementation.

Statistical analysis

The sample size was calculated based on a previous cross-sectional study[8] using the correlation coefficient for muscle fatigue of the vastus medialis measured using EMG correlated to the distance travelled on the six-minute walk test, with an effect size of r = 0.77, two-tailed of α = 0.05 and 80% power. The minimum sample was determined to be ten individuals.

The Shapiro-Wilk test was used to determine the normality of the data. The data were expressed as median and inter-quartile range. The paired t-test and t-test for independent samples were used for the intra-group and inter-group comparisons. Repeated-measures analysis of variance (ANOVA) was used to determine interactions between the EMG data, with the Bonferroni correction and Bonferroni post hoc test. Pearson's correlation test was used for the correlation analyses. The level of significance was set at 5% ($p \leq 0.05$). All analyses were performed with the aid of SPSS 20.0 (IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp).

Results

Twenty volunteers were recruited (10 in the control group and 10 in the COPD group). One volunteer in the COPD group was excluded for not finishing the evaluation protocol. Thus, the final sample was composed of 19 volunteers.

Table 1 displays the general characteristics of the sample, anthropometric data and spirometric findings. The COPD group presentes significantly lower values in the spirometric data, characterized as mild to moderate airway obstruction, while healthy individuals had normal values, as expected. With regard to BMI, even though the control group had higher BMI values compared to the COPD group, characterizing overweight and normal weight, respectively, we do not believe they are characterized as possible biases, as these values were very close.

Table 1 - General characteristics of the sample

Characteristics	Control group (n = 10)	COPD group (n = 9)	p-value
Age (years)	62 [10]	63 [11]	0.200
Sex (male/female)	5/5	7/2	-
Height (m)	1.67 [0.1]	1.64 [0.1]	0.830
Weight (kg)	73.0 [22.9]	63.0 [16.5]	0.100
BMI (kg/m²)	25.5 [5.4]	22.6 [5.1]	0.048*
FEV_1 (L)	2.4 [0.8]	1.4 [0.8]	0.007*
FEV_1 (%predicted)	88.0 [26.0]	53.0 [47.0]	0.004*
FVC (L)	3.1 [0.9]	2.6 [1.0]	0.550
FVC (%predicted)	88.0 [20.0]	81.0 [31.0]	0.180
FEV_1/FVC (%)	78.0 [4.9]	55.0 [33.0]	0.007*
FEV_1/FVC (%predicted)	99.0 [7.0]	69.0 [39.0]	0.006*
MVV (L)	98.4 [22.0]	54.2 [36.3]	0.000*
MVV (% predicted)	95.0 [14.0]	52.0 [43.0]	0.001*

Note: COPD = chronic obstructive pulmonary disease; BMI = body mass index; FEV_1= forced expiratory volume in the first second; FVC= forced vital capacity; MVV= maximum voluntary ventilation. *Inter-group comparison (p ≤ 0.05). Data are expressed in median [interquartile range].

Table 2 displays the data on quadriceps muscle performance represented by mean MVIC, 60% MVIC (used for the fatigue protocol) and tolerance limit. No significant differences were found between groups.

Figure 2 displays the MDF data of the quadriceps muscle determined by EMG, with the means of the rectus femoris, vastus medialis and vastus lateralis. The participants exhibited muscle fatigue at the end of the test (100%), as demonstrated by the significant reduction in MDF. No significant differences between groups were found in any of the steps or phases of the contractions.

Table 2 - Quadriceps muscle performance

Variables	Control group	COPD group	p-value
MVIC (kg)	19.6 [17.2]	14.0 [7.5]	0.06
60% MVIC (kg)	11.8 [10.3]	8.4 [4.5]	0.06
Tlim (seconds)	56.0 [51.0]	72.0 [38.0]	0.78

Note: COPD = Chronic obstructive pulmonary disease; MVIC = maximum voluntary isometric contraction; Tlim = tolerance limit. Data are expressed in median [interquartile range].

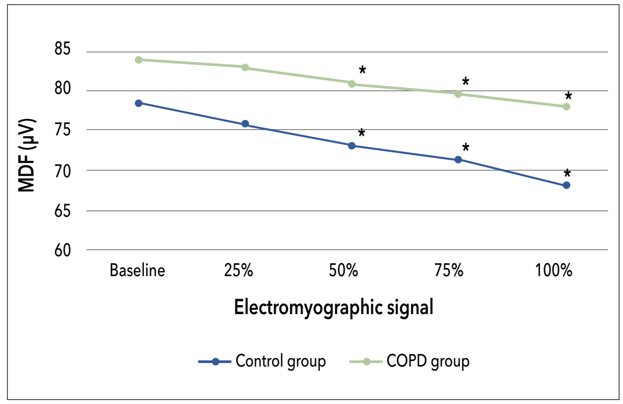

Figure 2 - Median frequency behavior (MDF) during the electromyographic signal.

Note: COPD = Chronic obstructive pulmonary disease. *p ≤ 0.05 in relation to baseline.

Table 3 displays the execution times on the first and second Glittre-ADL test. Significant differences were found between the first and second test. Moreover, the COPD group had significantly longer execution times compared to the healthy individuals. The analysis of the quadriceps muscle fatigue data and performance on the Glittre-ADL test revealed no significant correlations.

Table 3 - Comparison of execution times on first and second Glittre-ADL tests

Glittre-ADL test	Control group	COPD group	p-value
First (minutes)	4.1 [0.7]	6.5 [3.3]	0.005*
Second (minutes)	3.6 [1.3]#	6.1 [4.0]#	0.010*

Note: COPD = Chronic obstructive pulmonary disease. *Inter-group comparison (p ≤ 0.05); #Intra-group comparison (p ≤ 0.05). Data are expressed in median [interquartile range].

Discussion

The present results showed a significant reduction in MDF, suggesting peripheral muscle fatigue. This reduction during contraction suggests a reduction in action potential and consequent reduction in the firing of motor units, indicating an incapacity to maintain voluntary contraction.[22]

The findings also demonstrated no significant difference between groups regarding the tolerance limit of isometric contraction, although the COPD group had a tendency to sustain the contraction for a longer period of time. A previous study reported that individuals with COPD have an increased proportion of type II fibers in the lower limb muscles, which may be associated with the loss of body weight, and secondarily present less peripheral muscle endurance compared to healthy individuals.[23]

Regarding the execution time on the Glittre-ADL test, the present results are in agreement with findings from the validation study of the test,[21] in which a reduction in execution time was found on the second test compared to the first among individuals with COPD, suggesting influence of the learning effect on the second test, resulting in a shorter execution time of the tasks. In the inter-group comparison, individuals with COPD required a longer time to complete the test than healthy adults, suggesting worse functional capacity, which is in agreement with data reported in a previous study.[24]

Although peripheral muscle fatigue is directly related to one's performance on activities of daily living and cardiorespiratory fitness, we detected no correlation between quadriceps muscle fatigue and performance on the Glittre-ADL test in either group. Boccia et al.[8] found a strong correlation between conduction velocity of electrical stimuli in the vastus lateralis and vastus medialis muscles and functional capacity measured using the six-minute walk test in individuals with COPD. This divergence may be explained by the fact that the cited study involved individuals with different degrees of obstruction, including severe and very severe obstruction, and the fact that different tests were employed.[8]

One study found that quadriceps endurance is more related to the distance travelled on the six-minute walk test than peripheral muscle strength.[25] Another study found that quadriceps endurance has greater predictive capacity than muscle strength for cardiopulmonary exercise testing.[26] Data from a third study indicate a greater relation between quadriceps endurance (represented by total work in Joules) and both the distance travelled on the six-minute walk test and peak oxygen uptake (VO_2) on an exercise cycle.[27]

Two studies found relations between both dynamic and isometric quadriceps measures and functional capacity tests, such as the short physical performance battery, six-minute walk test, one-minute sit-to-stand test and Glittre-ADL test.[28,29] As all these tests are dynamic and therefore require variations in movements and the recruitment of different muscle groups, the findings seem reasonable and differ from the present study, both in the methodological aspect - as they are dynamic tests - and in the results - because they found associations between the assessments, a fact that did not occur in the present study.

The main limitation of the present study is the sample size which, although within the expected range by the sample calculation, presents disparity between genders and does not represent all COPD phenotypes. Thus, further studies with larger samples are needed to investigate the correlations sought in this study.

Conclusion

Based on the results of the present study, despite the small sample size, performance on the ADL test is not associated with peripheral muscle endurance measured by surface electromyography during isometric contraction of the quadriceps muscle in the individuals with a diagnosis of COPD, but it strengthens the previous findings regarding the decrease in activities of daily living in patients with COPD.

Authors´ contributions

CBC, RPL and DI were responsible for the data collection, while CBC, ELFDG, FP and DC for the data analysis. CBC, RPL and DI conducted the literature review, CBC wrote the manuscript, and all authors reviewed and approved the final version.

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