Relationship of Upper-Limb and Thoracic Muscle Strength to 6-min Walk Distance in COPD Patients*

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Study objectives: This study was developed to investigate the influence of thoracic and upper-limb muscle function on 6-min walk distance (6MWD) in patients with COPD.

Design: A prospective, cross-sectional study.

Setting: The pulmonary rehabilitation center of a university hospital.

Patients: Thirty-eight patients with mild to very severe COPD were evaluated.

Measurements and results: Pulmonary function and baseline dyspnea index (BDI) were assessed, handgrip strength, maximal inspiratory pressure (PImax), and 6MWD were measured, and the one-repetition maximum (1RM) was determined for each of four exercises (bench press, lat pull down, leg extension, and leg press) performed on gymnasium equipment. Quality of life was assessed using the St. George Respiratory Questionnaire (SGRQ). We found statistically significant positive correlations between 6MWD and body weight ($r$ = 0.32; $p$ < 0.05), BDI ($r$ = 0.50; $p$ < 0.01), FEV$_1$ ($r$ = 0.33; $p$ < 0.05), PImax ($r$ = 0.53; $p$ < 0.01), and all values of 1RM. A statistically significant negative correlation was observed between 6MWD and dyspnea at the end of the 6-min walk test ($r$ = −0.29; $p$ < 0.05), as well as between 6MWD and the SGRQ activity domain ($r$ = −0.45; $p$ < 0.01) and impact domain ($r$ = −0.34; $p$ < 0.05) and total score ($r$ = −0.40; $p$ < 0.01). Multiple regression analysis selected body weight, BDI, PImax, and lat pull down 1RM as predictive factors for 6MWD ($R^2$ = 0.589).

Conclusions: The results of this study showed the importance of the skeletal musculature of the thorax and upper limbs in submaximal exercise tolerance and could open new perspectives for training programs designed to improve functional activity in COPD patients.

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Key words: 6-min walk distance; COPD; one-repetition maximum; thoracic muscles; upper-limb muscles

Abbreviations: 1RM = one-repetition maximum; 6MWD = 6-min walk distance; 6MWT = 6-min walk test; BDI = baseline dyspnea index; BMI = body mass index; LBMI = lean body mass index; PImax = maximal inspiratory pressure; QoL = quality of life; SGRQ = St. George Respiratory Questionnaire; $SpO_2$ = peripheral oxygen saturation.

Testing the capacity of a patient to walk as far as possible for 6 min is a simple, reliable, objective and inexpensive tool used to assess submaximal exercise capacity and functional activity. The 6-min walk test (6MWT) may indicate the ability to carry out the activities of daily life and can be performed by elderly individuals and those with severe conditions like COPD or heart failure.$^{1,2}$ The test is performed in a corridor without sophisticated equip-
ment and does not require highly qualified staff. Contraindications for the 6MWT include unstable angina and recent acute myocardial infarction. However, the intensity of the 6MWT is self-determined, and the test has been undertaken by thousands of people, including patients with cardiovascular disease, without adverse effects.

In COPD patients, the 6-min walk distance (6MWD), alone or as part of a multidimensional scale known as the BODE index, predicts mortality better than do other traditional markers of disease severity, such as FEV₁. In patients with severe diseases, reductions in 6MWD occurred independently of changes in FEV₁. Whereas FEV₁ is the most likely marker of respiratory system involvement in COPD, the 6MWD probably reflects the systemic effects of the disease. Therefore, the 6MWD should be included in COPD patient evaluation, and its determining factors should be thoroughly elucidated.

Several factors may influence the 6MWD in healthy individuals and in COPD patients. Body weight, age, mental health, and comorbidities can affect the test results in elderly individuals. The sensation of breathlessness (dyspnea) and poor nutritional state are manifestations of COPD that can also reduce 6MWD. Muscle strength in the lower limbs has previously been shown to be an important factor in determining the 6MWD. However, data regarding the influence of upper-limb and thoracic muscle strength on 6MWD is scarce and limited to those obtained from studies evaluating handgrip strength and maximal inspiratory pressure (Pmax). Handgrip strength is limited to skeletal muscle strength of the hand, and Pmax is influenced by passive elastic recoil pressure of the respiratory system, including the lungs and chest wall. In addition, when the primary respiratory muscles are dysfunctional or cannot meet the ventilatory demand, muscles whose principal function is to maintain posture may assume an accessory muscle function. The trapezius, latissimus dorsi, pectoralis major, and serratus anterior can all function as inspiratory muscles. We found only one study that evaluated the influence of the large chest muscles and upper-limb muscles on maximum exercise capacity in a heterogeneous population of patients with pulmonary diseases, and we were unable to find any studies evaluating the influence of these muscles on 6MWD. Therefore, the hypothesis of this study was that thoracic and upper-limb muscle strength may affect 6MWD in COPD patients.

To test our hypothesis, we investigated the influence of thoracic and upper-limb muscle strength on 6MWD in COPD patients. We also evaluated the influence of other factors known to interfere with the 6MWD, such as age, pulmonary function, nutritional state, sensation of dyspnea, and lower-limb muscle strength.

**Materials and Methods**

Thirty-eight COPD patients consecutively admitted to a pulmonary rehabilitation center were evaluated. Patients were included if they fulfilled the criteria for COPD according to the Global Initiative for Chronic Obstructive Lung Disease guidelines. FEV₁/FVC ratio < 70% and increase in FEV₁ after inhalation of a β₂-agonist < 15% or 200 mL. Patients were included in the study only when in a clinically stable condition with no history of infections or exacerbation of respiratory symptoms, no changes in medication within the 2 months preceding the study outset, and no clinical signs of edema. Patients presenting with evidence of cardiovascular or osteoarticular impairment were excluded. All patients were made aware of the proposed study procedures and freely gave written informed consent. All procedures were approved by the Research Ethics Committee of the Universidade Estadual Paulista (Paulista State University) School of Medicine at Botucatu, in the state of São Paulo, Brazil.

**Pulmonary Function and Arterial Blood Gas Analysis**

Pulmonary function and reversibility tests were performed with a spirometer (Med-Graph 1070; Medical Graphics Corporation; St. Paul, MN), according to the criteria set by the American Thoracic Society. Values of FEV₁ are expressed in liters, in percentages of FVC, and as percentages of reference values. Blood was drawn from the brachial artery when the patient was at rest and breathing room air. Arterial oxygen tension and carbon dioxide tension (PaO₂ and PaCO₂) were analyzed on a blood analyzer (Stat Profile 5 Plus; Nova Biomedical; Waltham, MA).

**Nutritional Evaluation**

Body weight and height were measured, and body mass index (BMI) [weight/height squared] was calculated. Body composition was evaluated using bioelectrical impedance (BIA 101A; RJL Systems; Detroit, MI). Resistance was measured on the right side of the body in the supine position in accordance with the method described by Lukaski. Lean body mass (LBM) was calculated in kilograms using a group-specific regression equation developed by Kyle et al. The LBM index (LBMI) [LBM/height squared] was also calculated.

**Quality of Life and Baseline Dyspnea**

A version of the St. George Respiratory Questionnaire (SGRQ) validated for application in Brazil was used to evaluate patient quality of life (QoL). A similarly modified version of the baseline dyspnea index (BDI) developed by Mahler et al was used to evaluate baseline dyspnea.

**Respiratory Pressures, Handgrip, and Peripheral Muscle Strength**

We measured Pmax and maximal expiratory pressure in accordance with Black and Hyatt. Skeletal muscle strength of the hand was estimated based on handgrip strength of the dominant hand measured with a dynamometer (TEC-60; Technical Products; Clifton, NJ).
Peripheral muscle strength was assessed through the determination of the one-repetition maximum (1RM).25 The agreed convention for 1RM is the heaviest weight that can be lifted throughout the complete range of determined movement. The 1RM was assessed for each of four exercises performed on gymnastic equipment. Patients were required to perform the following exercises: bench press (pectoralis and triceps), lat pull down (latissimus dorsi, trapezius, rhomboidei, pectorals major and biceps), leg extension (quadiceps), and leg press (quadiceps, gluteus, hamstrings, and calf muscles). A warmup of 10 repetitions with a light weight was performed prior to the test in order to minimize the effects of learning. The 1RM test was initiated at a weight near the suspected maximum to minimize repetition fatigue. All participants attained the 1RM within four attempts. Two to 3 min of rest were allowed between repetitions. The Valsalva maneuver was avoided, and the proper exercise performance technique for each muscle group was emphasized.

6MWT

We conducted the 6MWT according to American Thoracic Society guidelines.26 Patients were instructed to walk, attempting to cover as much ground as possible within 6 min. A research assistant timed the walk, and standardized verbal encouragement was given to each patient. Peripheral oxygen saturation (SpO2) was monitored throughout the test using a pulse oximeter (Ohmeda Biox 3700; Ohmeda; Borkler, CO). Patients who were hypoxic at baseline and patients whose SpO2 decreased to < 95% during the test were given oxygen by a physical therapist that wheeled an oxygen tank in a handicap along the side of the patient. Before and after the test, data were obtained for SpO2, heart rate, respiratory rate, Borg scale dyspnea score, and BP. The distance covered was measured in meters.

Statistical Analysis

To study the correlation between variables, Pearson or Spearman coefficients of correlation were used with the level of statistical significance set at 5%. Data were submitted to multiple regression analysis to evaluate independent variables that might be determinants of 6MWD. Multicollinearity was avoided by removing from the model those variables with high correlation coefficient and variance inflation factor > 4. For variables with associations > 0.70 or > − 0.70, the researchers selected those with the greatest clinical relevance. As body composition parameters, BMI, and the LBMI values were selected, whereas FEV1 and SpO2 were chosen as parameters of pulmonary function. The 6MWD was defined as a dependent variable.

Results

Baseline Characteristics of the Study Population

Baseline characteristics of the 38 COPD patients tested are shown in Table 1. Of the 38 patients, 27 patients (71%) were men, and all were > 40 years of age. Among this group of patients, airflow obstruction was, on average, moderate to severe, and two patients had chronic hypoxia (PaO2 < 55 mm Hg; SpO2 < 88%).16 The COPD was mild in 7 patients, moderate in 17 patients, severe in 11 patients, and very severe in 3 patients. There were 3 patients who were receiving no medication, whereas 16 patients were receiving a short-acting β2-agonist, 13 patients were receiving a long-acting β2-agonist, 11 patients were receiving inhaled corticosteroid; 13 patients were receiving an inhaled corticosteroid, 10 patients were receiving a long-acting β2-agonist plus an inhaled corticosteroid, 1 patient was receiving an oral corticosteroid, and 1 patient was receiving aminophylline.

Mean BMI was 26 ± 5 kg/m2. There were 7 patients (18.4%) presenting with a BMI < 20 kg/m2 and 16 patients (42.1%) with a BMI > 25 kg/m2. Mean LBMI was 18 ± 2 kg/m2. There were 7 patients with LBMI values < 15 kg/m2 for women and < 16 kg/m2 for men. A total of 11 patients (28.9%) were in a depleted nutritional state based on LBMI and BMI values.

In all patients, the sensation of dyspnea on exertion was found to be light to moderate. The SGRQ scores for QoL were > 50% in two domains (symptoms and activities), indicating significant impairment of general health status.

Peripheral and Respiratory Muscle Strength and 6MWD

Mean Pmax was − 71 ± 25 cm H2O (± SD), and mean knee extension force was 32 ± 11 kg, the latter being lower than that reported in literature26 for healthy elderly subjects (40.8 ± 13 kg). Mean 1RM for the lat pull down exercise was greater than that obtained by Taaffe et al26 in healthy elderly subjects (38 ± 9 kg vs 35 ± 9 kg) [Table 1], and handgrip strengths were within predicted values obtained for healthy individuals in the various age groups.27 Mean 6MWD during the study was 560 ± 96 m. Mean male patient distances were 109% of predicted values, compared with 105% of predicted for female patients (Table 1).1

Table 1—Baseline Characteristics of the Study Population

<table>
<thead>
<tr>
<th>Variables</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, yr</td>
<td>62.96</td>
<td>8.82</td>
</tr>
<tr>
<td>Weight, kg</td>
<td>69.61</td>
<td>14.67</td>
</tr>
<tr>
<td>FEV1, % of predicted</td>
<td>57.00</td>
<td>22.14</td>
</tr>
<tr>
<td>PaO2, mm Hg</td>
<td>73.01</td>
<td>9.49</td>
</tr>
<tr>
<td>SpO2, %</td>
<td>94.07</td>
<td>2.58</td>
</tr>
<tr>
<td>BMI, kg/m2</td>
<td>26.00</td>
<td>5.00</td>
</tr>
<tr>
<td>LBMI, kg</td>
<td>48.22</td>
<td>7.48</td>
</tr>
<tr>
<td>LBMI, kg/m2</td>
<td>18.00</td>
<td>2.00</td>
</tr>
<tr>
<td>BDI</td>
<td>1.80</td>
<td>1.14</td>
</tr>
<tr>
<td>Total SGRQ score, %</td>
<td>49.36</td>
<td>17.55</td>
</tr>
<tr>
<td>Pmax, cm H2O</td>
<td>71.00</td>
<td>25.00</td>
</tr>
<tr>
<td>Bench press, 1RM in kg</td>
<td>32.71</td>
<td>8.77</td>
</tr>
<tr>
<td>Lat pull down, 1RM in kg</td>
<td>38.00</td>
<td>9.00</td>
</tr>
<tr>
<td>Leg extension, 1RM in kg</td>
<td>32.00</td>
<td>11.00</td>
</tr>
<tr>
<td>Leg press, 1RM in kg</td>
<td>82.15</td>
<td>26.42</td>
</tr>
<tr>
<td>6MWD, m</td>
<td>560.00</td>
<td>96.00</td>
</tr>
</tbody>
</table>

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**Correlation and Multiple Regression Analysis**

The 6MWD presented statistically significant positive correlations with body weight, BDI score, FEV₁, Pmax, and 1RM for all exercises performed. Conversely, 6MWD was found to correlate negatively, to a statistically significant degree, with a sensation of dyspnea at the end of the 6MWT and with the scores for the SGRQ activity and impact domains as well as with the total SGRQ score (Table 2). Multiple regression analysis revealed Pmax, BMI, body weight, and 1RM in the lat pull down exercise to be predictive of 6MWD (Table 3). These variables explained 59.8% of the total variance in 6MWD. Correlations between 6MWD and peripheral muscle strength variables are presented in Figure 1.

**Discussion**

Results of this study suggested for the first time that thoracic muscle strength is a predictor of 6MWD in COPD patients. Our results also confirm the influence of respiratory muscle strength (Pmax), dyspnea, and body weight on the 6MWD of these patients. Multiple regression analysis revealed that Pmax, BDI, body weight, and 1RM in the lat pull down exercise were responsible for 59.8% of the total 6MWD variance.

Data in literature regarding the influence of thoracic and upper-limb muscle strength on 6MWD are related to Pmax and handgrip strength. The results of this study support previous findings demonstrating the influence of Pmax on 6MWD. Wijkstra et al. evaluated the influence that pulmonary function, Pmax, QoL, and sensation of dyspnea had on the exercise capacity of 40 patients with severe to very severe COPD and determined that Pmax and diffusing capacity explained 54% of the total variance in 6MWD. In 1996, Gosselink et al. also reported that Pmax influenced submaximal exercise capacity in COPD patients. Although Pmax reflects the pressure created by the inspiratory muscles, its measurement is affected by other factors such as passive elastic recoil pressure of the respiratory system, including the lungs and chest wall. Therefore, evaluation of accessory respiratory muscle strength using a procedure unaffected by lung volume and elastic recoil could provide additional information about the influence of these muscles on 6MWD.

The influence of thoracic muscle strength on 6MWD found in the present study has not been previously described in the literature. Hamilton et al. estimated the influence of thoracic and upper-limb muscle strength on the maximal exercise capacity of patients with respiratory disease; however, the authors did not evaluate 6MWD. Nevertheless, the influence of lower-limb peripheral muscle function on exercise capacity in COPD patients has been described by a number of authors. There are considerable data indicating that lower-limb muscle strength is reduced and upper-limb strength is relatively preserved in COPD patients, and it has been established that these muscles have a clear relationship to walking. This may explain the great number of studies evaluating the influence of lower-limb muscle strength, rather than that of thoracic and upper-limb muscle strength, on exercise capacity in such patients.

The influence of thoracic muscle strength on 6MWD might be explained by the large number of accessory respiratory muscles involved in performing the lat pull down exercise. Muscles necessary to carry out the exercise include the latissimus dorsi, trapezius, rhomboids, pectorals major, and biceps. Some of these muscles may assume an accessory respiratory function when the primary respiratory muscles are dysfunctional or cannot meet the ventilatory demand. It has been suggested that improved

### Table 2—Significant Correlations Between 6MWD and the Variables Studied*

<table>
<thead>
<tr>
<th>Variables</th>
<th>r</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>0.32</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>BDI</td>
<td>0.50</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>FEV₁, % of predicted</td>
<td>0.33</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Pmax</td>
<td>0.53</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>0.52</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Bench press</td>
<td>0.47</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Leg press</td>
<td>0.39</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Leg extension</td>
<td>0.48</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Handgrip strength</td>
<td>0.45</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>BorgF-6MWT</td>
<td>−0.29</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>SGRQ activity score</td>
<td>−0.45</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>SGRQ impact score</td>
<td>−0.34</td>
<td>&lt; 0.05</td>
</tr>
<tr>
<td>Total SGRQ score</td>
<td>−0.40</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

*BorgF-6MWT = Borg scale dyspnea score at the end of the 6MWT.

### Table 3—Results of Multiple Regression Analysis of the 6MWD and the Independent Determinants*

<table>
<thead>
<tr>
<th>Determinants</th>
<th>Coefficient</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight</td>
<td>−2.095</td>
<td>0.041</td>
</tr>
<tr>
<td>BDI</td>
<td>41.802</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Pmax</td>
<td>1.806</td>
<td>0.002</td>
</tr>
<tr>
<td>Lat pull down</td>
<td>3.458</td>
<td>0.022</td>
</tr>
</tbody>
</table>

*Adjusted R² = 0.589.
Accessory respiratory muscle function is the mechanism responsible for the increased ventilatory capacity observed in COPD patients performing the 6MWT with the aid of a rollator. In our study, a statistically significant positive correlation was found between 6MWD and handgrip strength. This is in agreement with previous studies showing a significant positive correlation between handgrip strength and 6MWD in COPD patients, and designating this specific muscular strength as a predictor for 6MWD in healthy elderly individuals. Since handgrip strength is a direct measure of skeletal muscle strength of the hand and distal upper-limb muscles, our data support the assertion that upper-limb muscle strength influences walking distance.

Another indicator that systemic manifestations of COPD affected exercise capacity in our study was the identification of body weight as a predictor of 6MWD. Our results showed a statistically significant positive correlation between body weight and 6MWD in COPD patients, in keeping with data in the literature. However, multiple regression analysis of our data revealed a negative coefficient for body weight that can be explained by the nonlinear relationship between 6MWD and weight described by Enright et al. Enright et al showed that underweight, overweight, and obese patients walked shorter distances than did eutrophic individuals. Low body weight is often related to loss of LBM and reduced muscle strength. In addition, obesity increases the energy expended at a given exercise intensity. Therefore, either situation may result in a reduced capacity to walk longer distances.

In our patients, the baseline sensation of dyspnea, as evaluated by the BDI, was also determined to be a predictor of 6MWD, as has been previously demonstrated. Wegner et al observed that the most important determinants of 6MWD included the scores from three different instruments devised to measure dyspnea, as well as the dyspnea domain of the Chronic Respiratory Disease Questionnaire. In a similar manner, Oga et al showed that the sensation of dyspnea was a determinant of maximum oxygen uptake, 6MWD, and endurance time in COPD patients. In fact, it has been shown that the sensation of dyspnea is one of the most important factors in determining the general health status of COPD patients, and that it impacts QoL as evaluated through the use of general and respiratory disease-specific instruments.

We found a statistically significant negative corre-
lation between 6MWD and QoL, as determined by the SGRQ activity domain, impact domain, and total score. However, in the multiple regression analysis, none of the SGRQ scores were identified as determinants of 6MWD. In a study evaluating 6MWD, pulmonary function, peripheral muscle strength, respiratory muscle strength, and body composition, 6MWD was identified as a determinant of the SGRQ activity and impact domains. Other authors have also observed a statistically significant correlation between exercise capacity and QoL indicators in COPD patients. These findings suggest that exercise capacity is an important determinant of QoL in COPD patients, and that the inverse is not true.

There is considerable evidence that lower-limb muscle strength influences maximal and submaximal exercise capacity in healthy individuals and in COPD patients, and various treatments for this condition have been proposed. Although a statistically significant positive correlation between 6MWD and lower-limb muscle strength was found in the present study, when measurements of thoracic and upper-limb muscle strength were included in the regression analysis, lower-limb muscle strength was not identified as a determinant of 6MWD.

**Clinical Application**

The relationship of upper-limb and thoracic muscle strength to exercise capacity seen in our study does not necessarily imply a causal relationship. Further studies will be required in order to evaluate the influence of interventions involving specific muscle reconditioning on submaximal exercise capacity in COPD patients. The most effective component of pulmonary rehabilitation is related to physical conditioning. Therefore, strength training with free weights or on gymnasium equipment is a rational option for muscle reconditioning in COPD patients. Indeed, a number of studies have evaluated the effects of strength training in COPD patients and have demonstrated improvements in QoL and 6MWD. In conclusion, the results of this study underscore the importance of the skeletal musculature in exercise capacity in COPD patients. Body weight, peripheral muscle strength, respiratory muscle strength, and the sensation of dyspnea all have an influence on the capacity of COPD patients to perform exercises. Therefore, there is a real need to develop treatment strategies that, while taking into account individual goals and requirements, are aimed at interrupting the dyspnea-sedentary lifestyle-dyspnea cycle in these patients.

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