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ORIGINAL RESEARCH

Relationship between the work developed in maximal and submaximal exercise capacity tests and the degree of airflow obstruction in individuals with Chronic Obstructive Pulmonary Disease

Relação do trabalho desenvolvido em testes máximo e submáximo de capacidade de exercício com o grau de obstrução ao fluxo aéreo em indivíduos com Doença Pulmonar Obstrutiva Crônica

Relación de labor desarrollada en tests máximo y submáximo de capacidad de ejercicio con el grado de obstrucción del flujo aéreo en individuos con Enfermedad Pulmonar Obstrutiva Crónica

Lucas Araújo de Oliveira¹, Rafael Mesquita^{1,2}, Igor Lopes de Brito¹, Viviane de Moraes Laburú¹, Fabio Pitta^{1,3}, Vanessa Suziane Probst^{2,3,4}

ABSTRACT | The aim of this study was to investigate the relationship between the work in two exercise capacity tests, a maximum and a submaximal exercise, and the level of airflow obstruction in patients with Chronic Obstructive Pulmonary Disease (COPD). Fifty-three subjects with COPD (29 men, 70±9 years old, 65±14 kg, forced expiratory volume in the first second [FEV₁] 38[31-54]% predicted) had their lung function assessed by spirometry, and maximal and submaximal exercise capacity were evaluated by the Incremental Shuttle Walking test (ISWT) and the 6-Minute Walk Test (6MWT), respectively. The work in the tests was calculated by multiplying the covered distance and the individual's body weight (W). To evaluate the contribution of weight on the developed work, subjects were separated into two groups: higher weight (n=32), and lower weight (n=21). FEV₁ correlated with the distance on the ISWT and with the ISWT*W (r=0.43 and r=0.49, respectively; p<0.05 for both). Moreover, the distance on the ISWT correlated with the ISWT*W (r=0.88, p<0.0001). Regarding the 6MWT, it was observed that FEV₁ had a weak correlation with the covered distance (r=0.29, p=0.003) and a moderate one with the 6MWT*W (r=0.51, p<0.0001). Moreover, the distance

covered in the 6MWT was moderately correlated with the 6MWT*W (r=0.47, p=0.0004). The higher weight group showed worse performance only in the 6MWT compared to the lower weight group (407±85 versus 469±64 meters, respectively; p=0.004). The work on the used exercise tests was similarly related to the level of airflow obstruction. The submaximal test, however, appears to have its performance more influenced by the individuals' body weight.

Keywords | Pulmonary Disease, Chronic Obstructive; Exercise Tolerance; Airway Obstruction.

RESUMO | Objetivou-se investigar a relação do trabalho desenvolvido em dois testes de capacidade de exercício, um máximo e outro submáximo, com o grau de obstrução ao fluxo aéreo em indivíduos com Doença Pulmonar Obstrutiva Crônica (DPOC). 53 indivíduos com DPOC (29 homens, 70±9 anos, 65±14 kg, volume expiratório forçado no primeiro segundo [VEF₁] 38[31-54]% previsto) tiveram avaliadas sua função pulmonar, por meio de espirometria, e capacidade de exercício máxima, pelo *Incremental Shuttle Walking Test (ISWT)*, e submáxima, pelo teste de caminhada

Study conducted at the Universidade Estadual de Londrina (UEL) and at Universidade Norte do Paraná (UNOPAR) - Londrina (PR), Brazil.

¹Research Laboratory of Pulmonary Physical Therapy (LFIP) at UEL - Londrina (PR), Brazil.

²Research Center of Health Sciences (CPCS) at UNOPAR - Londrina (PR), Brazil.

³Physical Therapy Department at UEL - Londrina (PR), Brazil.

⁴Physical Therapy course at UNOPAR - Londrina (PR), Brazil.

Correspondence address: Vanessa S. Probst - Centro de Pesquisa em Ciências da Saúde da Universidade Norte do Paraná - Rua Marselha, 591 - CEP: 86041-140 - Londrina (PR), Brasil - E-mail: vanessaprobst@uol.com.br
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de seis minutos (TC6min). O trabalho desenvolvido nos testes foi calculado pelo produto da distância percorrida com o peso corporal do indivíduo (P). Para avaliar a contribuição do peso no desempenho dos testes, os indivíduos foram separados em dois grupos: maior peso (n=32), e menor peso (n=21). Observou-se correlação do VEF₁ com a distância percorrida no *ISWT* e com o *ISWT**P (r=0,43 e r=0,49, respectivamente; p<0,05 para ambas). Além disso, a distância percorrida no *ISWT* correlacionou-se com o *ISWT**P (r=0,88; p<0,0001). Em relação ao TC6min, observou-se que o VEF₁ apresentou correlação fraca com a distância percorrida (r=0,29; p=0,03) e moderada com o TC6min*P (r=0,51; p<0,0001). Além disso, a distância percorrida no TC6min correlacionou-se moderadamente com o TC6min*P (r=0,47; p=0,0004). O grupo maior peso apresentou pior desempenho somente no TC6min comparado ao menor peso (407±85 versus 469±64 metros, respectivamente; p=0,004). O trabalho desenvolvido nos testes utilizados relacionou-se com o grau de obstrução ao fluxo aéreo de forma semelhante nos dois testes. O teste submáximo, contudo, teve seu desempenho mais influenciado pelo peso corporal dos indivíduos.

Descritores | Doença Pulmonar Obstrutiva Crônica; Tolerância ao Exercício; Obstrução das Vias Respiratórias.

RESUMEN | Este estudio tuvo como objetivo investigar la relación de labor desarrollada en dos tests de capacidad de ejercicio, un máximo y otro submáximo, con el grado de obstrucción del flujo aéreo en individuos con Enfermedad Pulmonar Obstrutiva Crónica

(EPOC). Los 53 individuos con EPOC (29 hombres, 70±9Años, 65±14kg, volumen espiratorio forzado en el primer segundo [VEF1] 38 [31-54]% previsto) tuvieron evaluadas su función pulmonar, a través de espirometría, y capacidad máxima de ejercicio en por el Incremental Shuttle Walking Test (ISWT), y submáxima, por el test de caminata de seis minutos (TC6min). El trabajo desarrollado en los tests fue calculado por el producto de la distancia recorrida con el peso corporal del individuo (P). Para evaluar la contribución del peso en el rendimiento de los tests, los individuos fueron separados en dos grupos : de alto peso (n=32) y bajo peso (n=21). Se observó una correlación del VEF1 con la distancia recorrida en el ISWT y con el ISWT*P (r=0,43 y r=0,49, respectivamente; P<0,05 para ambos). Además, la distancia recorrida en ISWT se correlacionó con el ISWT*P (r=0,88;P<0,0001). En cuanto al TC6min, se observó que el VEF1 presentó una correlación débil con la distancia recorrida (r=0,29; P=0,03) y moderada a TC6min*P (r=0,51; P<0,0001). Aparte, la distancia recorrida en la TC6min se correlacionó moderadamente con el TC6min*P (r=0,47; P=0,0004). El grupo de alto peso mostró peor desempeño solamente en el TC6min en comparación con el de bajo peso (407±85 vs. 469±64 metros, respectivamente; P=0,004). El trabajo en los tests utilizados se relacionó con el grado de obstrucción del flujo de aire de manera similar en ambos los tests. El test submáximo, sin embargo, tuvo su rendimiento más influenciado por el peso corporal de los individuos.

Palabras clave | Enfermedad Pulmonar Obstrutiva Crónica; Tolerancia al Ejercicio; Obstrucción Respiratoria.

INTRODUCTION

Chronic Obstructive Pulmonary Disease (COPD) is characterized by limited airflow, usually progressive and associated with an abnormal inflammatory response of the lungs to the inhaling of toxic particles and/or gases, especially the smoke from cigarettes¹. Data from the World Health Organization (WHO) indicate that, in 2030, COPD can be the third major cause of death in the world².

Even though COPD affects primarily the lungs, it also has significant systemic effects¹. Individuals with COPD present relevant decrease in exercise capacity³, which happens especially due to ventilatory limitation, abnormalities in gas exchanges, cardiovascular limitation, and respiratory and peripheral muscle dysfunction⁴. The assessment of exercise capacity in individuals with COPD is clinically important, since it allows to measure the severity of the disease⁵, the response to pharmacological and non-pharmacological interventions^{6,7}, and even preoperative risk⁸.

Several authors have found weak or no correlation between measures of pulmonary function and covered distance in exercise capacity tests among patients with COPD⁹⁻¹¹. Some authors, however, defend that the covered distance in these tests may not be the best outcome to be investigated, and that its product times body weight may have more clinical significance^{11,12}. This new outcome has been described as the performance in tests, and it has been used to prescribe the intensity of training in pulmonary rehabilitation programs and to estimate the maximal load in incremental tests¹³.

A few authors investigated the relationship between level of airflow obstruction with the work in exercise capacity tests, and none of them seems to have assessed and compared this relationship between maximal and submaximal tests. While Carter *et al.*¹⁴ and Chuang *et al.*¹² found correlation between FEV₁ and the work in the 6MWT, Teixeira *et al.*¹¹ did not find any correlation. With regard to the Incremental Shuttle Walking Test (field test with incremental aspect), there are no studies that correlated the work in this test with the level of airflow obstruction.

Therefore, the objective of this study was to investigate the relationship between the work in two exercise capacity tests, a maximal and a submaximal one, with the level of airflow obstruction in individuals with COPD.

METHODOLOGY

Study design and subjects

Individuals were recruited in the initial assessment to participate in pulmonary rehabilitation programs. The study was approved by the Ethics Committee, and individuals responded to the informed consent form.

Inclusion criteria were: diagnosis of COPD — according to the criteria from the Global Initiative for Chronic Obstructive Lung Disease (GOLD)¹ — absence of exacerbations/respiratory infections for at least three months before the beginning of the study; absence of severe and/or impairing comorbidities, which might interfere in the performance of evaluations and; not having followed any exercise program in the past year. Individuals were excluded in case they did not demonstrate physical and/or cognitive conditions to perform the tests, or in case they gave up participating in the study for any reason.

Procedures

- *Pulmonary function:* Simple spirometry was conducted (SpiroBank G, MIR, Italy). The technique was in accordance with international standardization¹⁵. Measures were obtained after the use of bronchodilator medications (400 mcg of salbutamol), and individuals were classified according to GOLD¹. Reference values for the Brazilian population were used¹⁶.
- *Maximal exercise capacity:* The Incremental Shuttle Walking Test (ISWT)¹⁷ was used, in its modified version¹⁸, to assess the maximal exercise capacity. Reference values were the ones described by Probst *et al.*¹⁹.
- *Submaximal exercise capacity:* It was assessed by the 6 Minute Walking Test (6MWT), conducted according to the guidelines of the American Thoracic Society (ATS)¹⁹. The reference values of Troosters *et al.*²⁰ were used.

The exercise capacity tests were used on different days, and each of them was repeated twice, with minimum interval of thirty minutes between them. The largest covered distance was considered for analysis. The work in each test was calculated by the product of the distance times the individual's body weight (distance in kilometers x weight in kilograms)¹². This formula comes from the calculation of work in a horizontal surface on a treadmill: $K \cdot m \cdot V \cdot T \cdot \cos\theta$ ¹², in which "K" is the performance coefficient, "m" is body weight, "V" is velocity, and "T" is walking time. Inclination is null and "K" and "T" are constant. Therefore, the formula changes into velocity (V) — which may be considered as a performance measure and replaced by distance — multiplied by weight (m)¹².

In order to assess the contribution of body weight on the performance during tests, individuals were separated in 2 groups: higher weight and lower weight (above or below, respectively, the mean body weight of the total sample).

Statistical analysis

Sampling calculation was based on the study by Carter *et al.*¹⁴, who found a correlation coefficient between FEV₁ and performance in 6MWT of 0.52. By using the software BioEstat® 3.0 (Belém, Brazil), with 85% power and 0.01 alpha, added by 20% of loss, 53 subjects would be necessary to detect statistically significant correlation.

The Shapiro-Wilk test was used to verify data distribution. For the comparison between groups, the non-paired Student *t*-test — or the One-Way ANOVA (*post hoc* Tukey) —, and the Mann-Whitney test were used — or Kruskal Wallis (*post hoc* Dunn). For correlations, the Pearson or Spearman correlation coefficient was used. The adopted significance level was $p < 0,05$, and the used software was GraphPad Prism 5 (GraphPad Software Inc., La Jolla, California, USA).

RESULTS

The characteristics of the 53 patients are in Table 1. In the comparison between groups, there was difference only in variables of pulmonary function, as expected. The absolute value of covered distance, in the percentage of the predicted value, and the performance in the

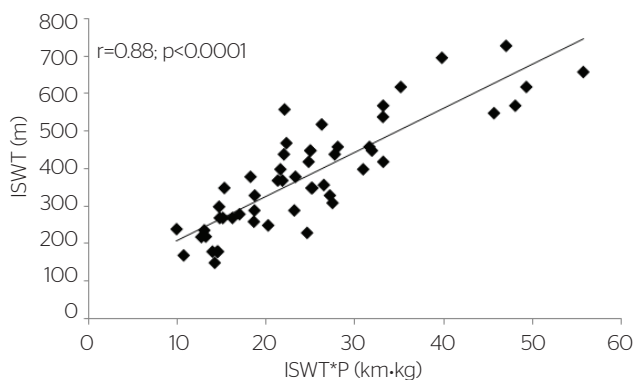
ISWT in the total sample were of 382 ± 145 m, $60 \pm 21\%$ of the predicted value and $23.2 [15.8-29.5]$ km·kg, respectively. The values for the same outcomes in the 6MWT were 445 ± 79 m, $75 \pm 13\%$ of the predicted value and $28.1 [24.3-33.5]$ km·kg, respectively.

There was correlation between FEV₁ and covered distance ($r=0.43$; $p=0.001$) and performance ($r=0.49$; $p=0.0002$) in the ISWT (Figure 1). In the

Table 1. General characteristics of individuals included in this study

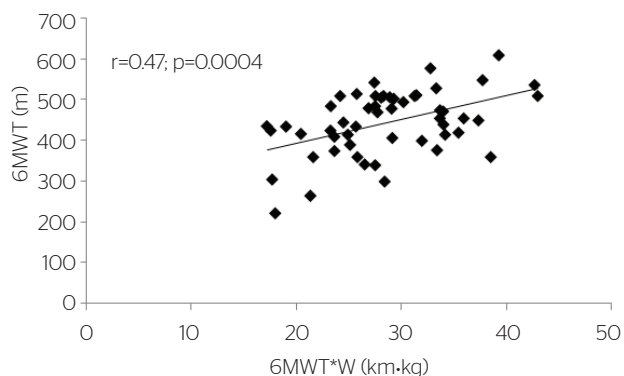
Characteristic	Total sample	GOLD II	GOLD III	GOLD IV
n (M/W)	53 (29/24)	18 (8/10)	26 (15/11)	9 (6/3)
Age (years)	70±9	64±9	69±9	66±7
Weight (kg)	66±14	67 [57-80]	61 [57-73]	55 [46-76]
Height (m)	1,61±0,08	1,59±0,09	1,62±0,08	1,61±0,08
BMI (kg/m ²)	26±6	27 [22-31]	24 [21-29]	20 [18-30]
FEV ₁ (% prev)	38 [31-54]	60 [53-66]	37 [34-42]*	26 [22-27]*†
FVC (% prev)	66±14	76 [69-83]	60 [55-70]*	62 [41-74]*
FEV ₁ /FVC (%)	64±16	78±9	61±12*	45±12*†

Data expressed in absolute frequency, mean ± standard deviation or median [interquartile interval]; M: men; W: women; BMI: Body Mass Index; FEV₁: Forced Expiratory Volume in the first second; FVC: Forced Vital Capacity; GOLD: Global Initiative for Chronic Obstructive Lung Disease; * $p<0.05$ versus GOLD II; † $p<0.05$ versus GOLD III



ISWT: Incremental Shuttle Walking Test

Figure 1. Correlation between covered distance and maximal work developed in the Incremental Shuttle Walking Test



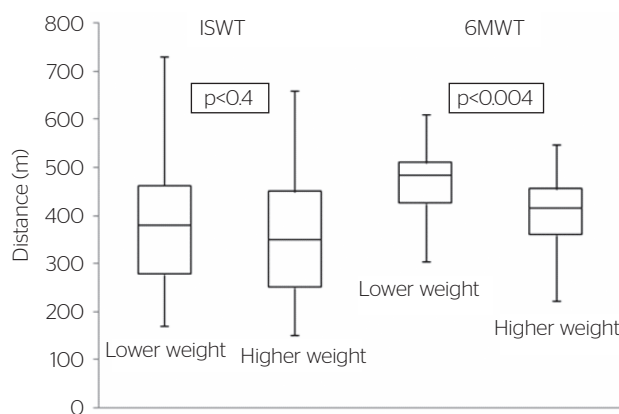
6MWT: six minutes walking test

Figure 2. Correlation between covered distance and maximal work performed in the 6 Minute Walking Test

analysis of ISWT*P between groups classified by GOLD, it was observed that the group GOLD II ($28.7 [23.0-41.3]$ km·kg) presented more work than groups GOLD III and GOLD IV ($21.5 [14.7-27.3]$ km·kg and $15.3 [13.8-21.7]$ km·kg, respectively; $p<0,05$). The same happened when compared to the covered distance in ISWT ($p<0.05$).

In the same analyses for the 6MWT, FEV₁ was positively and weakly correlated with the covered distance in the test ($r=0.29$; $p=0.03$), and positively and moderately correlated with the 6MWT*P ($r=0.51$; $p<0.0001$). A moderate correlation was also found between the covered distance in the 6MWT and the 6MWT*P (Figure 2). There was no difference in the comparison between the covered distance in groups (GOLD II: 475 ± 63 m versus GOLD III: 437 ± 87 m versus GOLD IV: 404 ± 63 m, $p>0.05$). However, there were differences in the comparison of the 6MWT*P, since group GOLD II presented higher value than GOLD IV (31.5 ± 6.3 km·kg versus 23.7 ± 4.6 km·kg, respectively; $p<0.05$).

There was no statistical difference in the comparison between covered distance in the ISWT among higher weight ($n=21$) and lower weight ($n=32$) groups (i.e., above or below sampling mean, respectively). However, in the 6MWT, the higher weight group covered a shorter distance (Figure 3). It was also observed that there was no statistical difference in the comparison of FEV₁ between groups (predicted lower weight: $37 [31-52]\%$ versus predicted higher weight: $42 [31-60]\%$; $p=0.27$).



ISWT: Incremental Shuttle Walking Test; 6MWT: six minutes walking test

Figure 3. Comparison between covered distance and higher and lower weight groups in the Incremental Shuttle Walking Test and the 6 Minute Walking Test

DISCUSSION

In this study, it was observed that the work performed in maximal and submaximal exercise capacity tests was similarly correlated with the level of airflow obstruction in individuals with COPD. When the relationship between this last variable and the distance covered in tests was analyzed, however, a lower value was observed in the submaximal test. Besides, a weaker correlation was noticed between distance and the work performed in this test. Finally, it was possible to observe that heavier individuals presented with worse submaximal exercise capacity, but not maximal, in relation to those with lower weight.

Several authors investigated the relationship between pulmonary function and distance covered in the 6MWT and in the ISWT^{9,10}, however, only a few investigated the relationship with the work performed in these tests. Pitta *et al.*¹⁰ did not find any significant correlation between distance covered in the 6MWT and FEV₁. Fink *et al.*⁹ also demonstrated that airflow obstruction is not correlated with exercise capacity in patients with COPD. Other authors even found statistically significant correlations, however, weak ones²¹⁻²³. In this study, FEV₁ was correlated with the distance covered in both tests, however, a stronger correlation, even if modest, was verified with the ISWT.

According to Chuang *et al.*¹², work is defined as the necessary energy to transport the weight of the body, through specific distance and in a certain period of time. In this study, the work performed in the 6MWT was assessed, and a 0.36 correlation coefficient was found with FEV₁ ($P=0.06$). Likewise, Carter *et al.*¹⁴ demonstrated the correlation of pulmonary function variables, like FEV₁, with the work performed in the 6MWT. Results in this study, as well as the ones in the analyses by Chuang *et al.*¹² and Carter *et al.*¹⁴, showed higher correlation between FEV₁ and the work performed in the 6MWT than with the covered distance. Besides, both authors found that walking presented more sensitivity and specificity to predict the exercise capacity in patients with COPD²⁴. Differently, Teixeira *et al.*¹¹ did not find a significant correlation between the level of airflow obstruction and the 6MWT*P, as well as in relation to the covered distance in this test. There are no studies correlating the work performed in the ISWT with pulmonary function variables. In this study, unlike the 6MWT, similar correlation coefficient values were found between FEV₁ and the distance and the work performed in ISWT.

It is worth to mention that heavier individuals with COPD presented worse submaximal exercise capacity than lighter individuals; however, there was no difference in the comparison of maximal exercise capacity. Recently, it has been demonstrated that higher body weight (i.e., overweight and obesity) provides better mechanical advantage concerning hyperinsufflation^{25,26}. However, this finding does not reflect on more exercise capacity. It is believed that due to differences in test protocols, the performance in the 6MWT is more prone to changes in heavier individuals than the performance in ISWT, because during the 6MWT people can decrease and adapt velocity to their conditions when feeling difficulties. This is not true for the ISWT, since the individual has no choice but to go according to a standardized velocity to complete the test.

It is known that the 6MWT can also work as a maximal test. According to Troosters *et al.*²⁷, the oxygen consumption (VO₂) reached and maintained in the 6MWT can be equivalent to the peak VO₂ reached during the incremental test on the bicycle. However, by analyzing the test design, we observed it is a submaximal test. By considering the weight of the patient to find the real work required to conclude the test, we come closer to the person's daily reality. On the other hand, when the objective is to assess the maximal exercise capacity of a patient, tests with standardized protocols, such as ISWT, are necessary.

In spite of all efforts to perform this study, some limitations have occurred. No individual classified as GOLD I was included in the study, which might reduce the external validity of findings; however, it is known that most of these individuals are asymptomatic, and that is why they do not seek medical care, which makes diagnosis more difficult and, consequently, also the participation in studies. In order to assess exercise capacity, the gold standard test (i.e., cardiopulmonary exercise testing²⁸) was not used due to the difficulty to access laboratories with specific devices. However, in ISWT, the test used to measure the maximal exercise capacity has been proven to be valid in relation to the gold standard⁴.

CONCLUSION

By means of this study, it is possible to conclude that the work performed in exercise capacity tests is correlated with the level of airflow obstruction similarly

between maximal and submaximal tests in individuals with COPD. The performance in submaximal tests, however seems to be more influenced by the body weight of individuals than the performance in the maximal test. However, further studies are necessary to prove this finding.

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