Original Article

Evaluating physical capacity in patients with chronic obstructive pulmonary disease: comparing the shuttle walk test with the encouraged 6-minute walk test*

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ABSTRACT

Objective: To evaluate the applicability of the incremental (shuttle) walk test in patients with chronic obstructive pulmonary disease and compare the performance of those patients on the shuttle walk test to that of the same patients on the encouraged 6-minute walk test. **Methods:** A cross-sectional study was conducted, in which 24 patients with chronic obstructive pulmonary disease were selected. In random order, patients were, after an initial practice period, submitted to a shuttle walk test and an encouraged 6-minute walk test. **Results:** The patients obtained a higher heart rate (expressed as a percentage of that predicted based on gender and age) on the encouraged 6-minute walk test (84.1 ± 11.4%) than on the shuttle walk test (76.4 ± 9.7%) ($p = 0.003$). The post-test sensation of dyspnea (Borg scale) was also higher on the encouraged 6-minute walk test. On average, the patients walked 307.0 ± 89.3 meters on the shuttle walk test and 515.5 ± 102.3 meters on the encouraged 6-minute walk test ($p < 0.001$). There was a good correlation between the two tests in terms of the distance walked ($r = 0.80$, $p < 0.001$). **Conclusion:** The shuttle walk test is simple and easy to implement in patients with chronic obstructive pulmonary disease. The encouraged 6-minute walk test produced higher post-test heart rate and greater post-test sensation of dyspnea than did the shuttle walk test.

Keywords: Pulmonary disease, chronic obstructive/rehabilitation; Exercise test; Motor activity; Reproducibility of results; Walking; Exercise tolerance

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INTRODUCTION

Chronic obstructive pulmonary disease (COPD) is characterized by the chronic presence of symptoms such as cough and sputum production and, in more advanced cases, dyspnea (upon exertion or at rest), all caused by changes in pulmonary mechanics and gas exchange, as well as by a reduction in skeletal muscle aerobic capacity.[1] To date, except for smoking cessation, there have been no therapeutic means of altering the progressive functional decline in forced expiratory volume in one second, which is a pronounced aspect of this disease.[1] However, there are other factors, such as dyspnea, quality of life, nutritional state and exercise tolerance, that can be improved through intervention.[2] One popular program of pulmonary rehabilitation is based on an ample group of interventions, chief among which is an intervention based on the evaluation and improvement of physical capacity by means of a physical training program.[1]

Despite the increasing numbers of pulmonary rehabilitation centers in Latin America,[3] the foundation of evaluation and physical training of COPD patients submitted to pulmonary rehabilitation is still accompanied by the use of complex, costly equipment that can only be operated by specialized personnel. For example, cardiopulmonary exercise testing is combined with direct determination of peak or maximal oxygen consumption and the determination of the anaerobic threshold, all used for designing a physical exercise program.[4-6]

Therefore, in order to facilitate the evaluation of the physical capacity of patients and reduce the costs of a pulmonary rehabilitation program, inexpensive field tests that can be easily carried out have been developed. Such tests include the six-minute walk test (6MWT),[7] step test[8] and incremental walk test, also known as the shuttle walk test (SWT).[9]

The SWT is considered a maximal incremental test since patients are induced to walk at standardized, increasing speeds, at twelve different levels, each lasting one minute with the help an auditory cue used to control pace on a ten-meter shuttle circuit delineated by two traffic cones. The test should be carried out until the point of exhaustion (Chart 1). The SWT is simple, with good reproducibility, and is based on walking on any flat surface; it requires no specific ergometers;[9-10] it is used as an outcome measure in the evaluation of various interventions used for COPD patients.[9,11-14] Regarding exercise tolerance, this test has shown good correlation between the walking distance and peak oxygen consumption at the end of the test (r = 0.81), which is similar to that obtained in maximal treadmill stress tests (r = 0.88).[15] Peak oxygen consumption at the end of the SWT has a correlation of 0.71 when compared to that obtained using a cycle ergometer.[6] To the best of our knowledge, there have been no studies evaluating the applicability of the SWT in Brazil.

In contrast, the 6MWT is the most commonly used test and is a component of the multidimensional index. In addition, it is a better predictor of mortality in COPD patients than is forced expiratory volume in one second.[2] The 6MWT is considered a submaximal test since patients are instructed to walk at the highest speed tolerated for six minutes, motivated through standardized verbal encouragement. Therefore, during its performance, the 6MWT depends on individually adjusted characteristics, which are determined by the patients, who may even stop walking if they wish to. Variability is higher on the 6MWT than on the SWT, but the two present similar correlations with peak oxygen consumption (r = 0.73).[7] A variation of the 6MWT was developed at the Pulmonary Rehabilitation Center of the Federal University of São Paulo.[16] In this modified 6MWT, a professional (physician or physical therapist) encourages patients

Chart 1 - Levels in the incremental walk test and their respective speed, together with the number of shuttles per level and time per shuttle

Level	Speed		# shuttles per level	Time per shuttle seconds
	m/s	mph		
1	0.50	1.12	3	20”
2	0.67	1.50	4	15”
3	0.84	1.88	5	12”
4	1.01	2.26	6	10”
5	1.18	2.64	7	8”57
6	1.35	3.02	8	7”50
7	1.52	3.40	9	6”66
8	1.69	3.78	10	6”
9	1.86	4.16	11	5”45
10	2.03	4.54	12	5”
11	2.20	4.92	13	4”61
12	2.37	5.30	14	4”28

by walking ahead of them, imposing a certain speed that must be maintained for six minutes. This test has been designated the encouraged six-minute walk test (E6MWT).[16] In the E6MWT, patients can be led to maintain maximum walking speed throughout the test, approximating the performance achieved on a maximal test.

The objective of this study was to evaluate the applicability of the SWT in COPD patients and, based on the characteristics of the SWT and the E6MWT - low cost and ease of implementation - to compare the two tests in terms of COPD patient performance.

METHODS

A cross-sectional descriptive study was conducted. A total of 24 consecutive patients with COPD[1] were selected from among patients treated at the COPD clinic of the Pulmonary Rehabilitation Center of the Federal University of São Paulo.

Inclusion criteria were arterial oxygen tension = 55 mmHg or arterial oxygen saturation by pulse oximetry (SpO_2) = 92% (at rest and on room air), as well as at least 6 weeks of clinical stability and satisfactory ability to walk unaided. Patients with SpO_2 = 80% during exercise were excluded, as were those suffering from other pulmonary diseases, heart diseases, cardiac insufficiency or other comorbidities considered uncontrolled or significant, as well as those presenting formal contraindications for performing exercise tests. All patients were submitted to an incremental cardiopulmonary test on a treadmill in accordance with Harbor's protocol, with no oxygen supplementation, in order to rule out active coronary disease, exercise-induced arrhythmias or abnormal blood pressure responses.[17]

All patients were submitted to spirometry. A KoKo spirometer (Pulmonary Data Service Instrumentation, Inc., Louisville, KY, USA) was used in accordance with the criteria established by the American Thoracic Society.[18] In addition, all patients were submitted to arterial blood gas analysis as well as to respiratory muscle strength determination using a vacuum manometer (IMEBRÁS, Sâo Paulo, Brazil). Body mass index was obtained by calculating the ratio between weight (kg) and height (m^2).

The SWT was carried out in accordance with the standards described in the literature,[9] which require patients to walk in a level corridor on a 10-meter shuttle course. Walking from one end to the other was considered one 'shuttle', and returning was considered another. The distance was delineated by two traffic cones placed half a meter prior to the end of each shuttle in order to avoid forcing patients to make abrupt direction changes (Figure 1). Walking speed was determined by an auditory cue indicating when patients were supposed to be by the cone and change direction and, consequently, the rhythm was also altered. The auditory cues were previously recorded on a cassette tape. Instructions for patients were standardized, and they were able to listen to the cassette tape prior to the beginning of the test. Patients were advised: "walk at a steady pace, aiming to be next to one of the cones and change directions when you hear the audio signal; you should keep walking until you feel that you are no longer able to maintain the required speed". Heart rate (HR), respiratory frequency, arterial blood pressure and SpO_2 were determined at the end of the test with patients at rest. Throughout the test, HR was constantly monitored by means of telemetry (Polar Electro Oy, Kempele, Finland), and SpO_2 by means of a pulse oximeter. The modified Borg scale was used in order to quantify the perception of dyspnea and lower limb fatigue, at rest and after maximum exercise. The following criteria were applied for the discontinuation of the SWT: dyspnea or fatigue preventing the patient from maintaining the required speed (being at a distance equal to or greater than three meters from the cones when the auditory cue for changing directions sounded).

All patients performed one to two E6MWT and SWT practice sessions prior to the tests themselves in order to nullify the learning effect and to become familiar with the differences between the two tests. The E6MWT was carried out in a 28-meter corridor and was monitored by a physiotherapist or a physician who walked ahead of the patient during the test in order to try to impose maximum walking speed for six minutes. There was no oxygen supplementation, and the minimum SpO_2 was 80% for both tests. The two tests were carried out on the same day, in random order. There was an interval of at least 30 minutes between tests. When necessary, this interval was extended to allow cardiovascular and ventilatory variables to return to baseline levels. For each patient, HR was continuously monitored through telemetry and oximetry. Respiratory frequency, dyspnea and lower limb fatigue (Borg scale) and arterial blood pressure

were determined at rest and immediately after the tests. The distance walked was recorded after the tests.

We used the Saint George's Respiratory Questionnaire (SGRQ), previously validated in Brazil,[19] and Mahler baseline dyspnea index[20] to evaluate quality of life.

The ethics research committee approved the protocol, and all patients gave written informed consent.

Results are expressed as means and standard deviations. We used the Wilcoxon test to analyze the differences between the SWT and the E6MWT. The Spearman correlation coefficient was used to determine the associations between continuous variables. Non-parametric tests were justified using the Kolmogorov-Smirnov test. Sample size had an 80% power to detect a 10-meter difference in the SWT (estimating an 11-meter standard deviation),[21-22] assuming an alpha error of 0.05. We used the SPSS program, version 10.0, to make the statistical analysis.

TABLE 1

Demographic and pulmonary function data for the 24 patients with chronic obstructive pulmonary disease

Variable	Mean ± SD
Age (years)	67.8 ± 7.5
BMI (kg/m^2)	24.2 ± 4.2
FVC (%)*	80.9 ± 21.0
FEV_1 (%)*	48.6 ± 21.0
FEV_1/FVC (%)*	45.6 ± 9.8
MVV (L/min)	48.5 ± 23.4
PaO_2 (mmHg)	68.1 ± 8.5
$PaCO_2$ (mmHg)	38.9 ± 4.8
SaO_2 (%)	93.2 ± 2.4
MIP (mmHg)	-63.3 ± 23.5
MEP (mmHg)	111.0 ± 28.6

SD: standard deviation; BMI: body mass index; FVC: forced vital capacity; FEV_1: forced expiratory volume in one second; MVV: maximum voluntary ventilation; PaO_2: arterial oxygen tension; $PaCO_2$: arterial carbon dioxide tension; SaO_2: arterial oxygen saturation; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure *Postbronchodilator

RESULTS

Demographic data, as well as pulmonary function data, for the 24 patients (17 males) with COPD are shown in Table 1. Mean age was 67.8 ± 7.5 years (range, 55-84 years), and mean body mass index was 24.2 ± 4.2 kg/m^2. According to the Global Initiative for Chronic Obstructive Lung Disease criteria,[1] 2 patients (8.3%) had stage 1 (mild) COPD, 7 (29.2%) had stage 2 (moderate) COPD, 12 (50%) had stage 3 (severe) COPD, and 3 (12.5%) had stage 4 or higher (extremely severe) COPD. Two patients (8.3%) presented hypercapnia (arterial carbon dioxide tension > 45 mmHg). According to the percentage data (mean ± standard deviation) obtained from the SGRQ, all patients presented altered quality of life: Symptoms domain, 58.18 ± 19.23; Impact domain, 39.94 ± 23.61; Activity domain, 61.94 ± 21.64; total score, 49.60 ± 20.15. The mean Mahler baseline dyspnea index was 7.5 ± 2.1.

Baseline values on both tests were similar for the following variables: sensation of dyspnea and lower limb fatigue (Borg), systolic arterial pressure, diastolic arterial pressure, HR, SpO_2 and respiratory frequency (data not shown). After the E6MWT, patients presented higher HR and sensation of dyspnea than after the SWT ($p < 0.001$ and $p = 0.003$, respectively, for the two variables). There were no statistically significant post-test differences in any of the other parameters (Table 2).

We compared maximum HR obtained during both tests to the maximum predicted values for age and gender (males: 211 - 0.87*years of age; females: 212 - 0.89*years of age).(23) On average, patients presented 76.1 ± 9.8% of maximum predicted values after the SWT, which was lower than the 83.8 ± 11.6% presented after the E6MWT ($p = 0.003$). When the same parameters were compared to the maximum HR attained on the incremental treadmill test, which was lower than the predicted value according to age, we found, on average, 85.6 ± 9.7% for the SWT and 94.0 ± 9.1% for the E6MWT. In both situations, the difference (higher HR values after the E6MWT) was statistically significant ($p = 0.004$). It is of note that mean HR on the incremental treadmill test was lower than that predicted for the age (137.2 ± 15.9 bpm versus 152.6 + 8.4 bpm, respectively; $p < 0.001$).

No complications (indisposition, syncope, chest pain or any other symptoms, as spontaneously reported by patients) occurred during the tests.

On average, patients walked 307.0 + 89.3 meters on the SWT and 515.5 ± 102.3 meters on the E6MWT ($p < 0.001$). There was a good

TABLE 2

Maximal arterial pressure, respiratory frequency, heart rate, SpO2 and sensation of dyspnea on the shuttle walk test and encouraged six-minute walk test

Variable (maximum values)	SWT	E6MWT	Mean difference	p
Respiratory frequency (rpm)	31.6 ± 5.0	32.4 ± 4.3	-0.8 ± 3.6	0.27
SpO_2 (%)	88.6 ± 4.1	87.6 ± 3.9	1.0 ± 3.7	0.18
Heart rate (bpm)	115.9 ± 14.9	127.7 ± 17.6	11.8 ± 14.1	<0.001
Systolic arterial pressure (mmHg)	156.3 ± 19.3	152.5 ± 14.5	3.8 ± 16.6	0.281
Diastolic arterial pressure (mmHg)	92.5 ± 7.9	93.8 ± 8.8	-1.3 ± 7.4	0.417
Borg dyspnea	2.8 ± 1.4	4.4 ± 2.7	-1.7 ± 2.4	0.003
Borg lower limbs	2.9 ± 2.0	3.9 ± 2.6	-1.0 ± 2.5	0.061

SWT: shuttle walk test; E6MWT: encouraged 6-minute walk test; SpO_2: arterial oxygen saturation by pulse oximetry

correlation between the two tests in terms of the distance walked ($r = 0.81$, $p < 0.001$).

In order to compare the construction validity properties between the tests, we calculated the correlation coefficients between the various functional and nutritional variables, as well as those related to quality of life, symptoms and respiratory muscle strength. The results are shown in Table 3.

DISCUSSION

A recent study showed that the multidimensional evaluation of COPD can provide better information regarding survival, morbidity and mortality when compared to that provided by evaluations of forced expiratory volume in one second.[2] In COPD patients, a great deal of information is obtained from the study of exercise tolerance, which can, in isolation, be considered a predictive factor for mortality.[24] The SWT and the 6MWT are both inexpensive, simple tests. However, they are probably underutilized in the day-to-day clinical evaluation of COPD patients in Brazil. To the best of our knowledge, this was the first study on the use of the SWT to assess patients diagnosed with chronic pulmonary disease in Brazil.

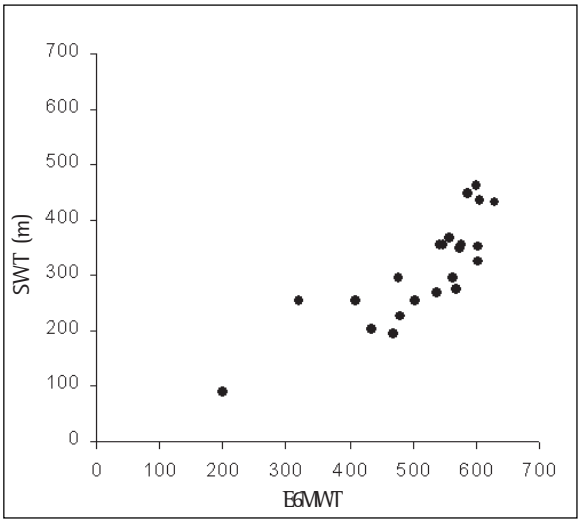

Figure 1 - Correlation between the SWT and the E6MWT in terms of the distance walked (Spearman)

TABLE 3

Correlations between the SWT and the 6MWT in terms of functional and nutritional variables, as well as those regarding quality of life, symptoms and respiratory muscle force

	SWT (m)	E6MWT (m)
FEV_1 %	0.42*	0.54**
BDI	0.15	0.49*
PaO_2 (mmHg)	0.42*	0.42*
SGRQ Symptoms %	0.07	0.05
SGRQ Activity %	-0.06	-0.38
SGRQ Impact %	-0.21	-0.50*
SGRQ total score %	-0.14	-0.42
MIP (cmH_2O)	-0.44*	-0.22
MEP (cmH_2O)	0.12	0.10
BMI (kg/m^2)	0.16	0.20

*$p < 0.05$; **$p < 0.001$

BDI: (Mahler) baseline dyspnea index; SWT: shuttle walk test; E6MWT: encouraged 6-minute walk test; FEV_1: forced expiratory volume in one second; PaO_2: arterial oxygen tension; SGRQ: Saint George's Respiratory Questionnaire; MIP: maximum inspiratory pressure; MEP: maximum expiratory pressure; BMI: body mass index

In the present study, the SWT proved to be easily implemented, requiring only a portable sound system (for playing the auditory cue), a 10-meter level corridor of at least 10 meters in length and one investigator. The standard 6MWT requires a long free space of 30 meters in length, although it can range from 20 to 50 meters[7] (in the present study, the corridor was 28 meters long, which was considered adequate). However, the length of the level surface on which the participants walk seems to have little influence on the results (the shape of the circuit seems to be more relevant), as was reported in a study conducted by the National Emphysema Treatment Trial Research Group.[25] Two professionals are necessary in order to carry out the 6MWT, regardless of the standards used (6MWT or E6MWT). No complications (such as the incidence of significant symptoms, arrhythmias or nonphysiological alterations in blood pressure) were detected in either test, although both were maximal or close to maximal performance tests, and SpO_2 tolerance was as high as 80%. We concluded that both tests had good applicability in this sample of patients. However, it is important to highlight the fact that all patients, despite having moderate or severe COPD, were considered normal in a previous ergometric evaluation, which was an inclusion criterion for this study.

In our COPD study sample, mean distance walked on the SWT was 307 meters, higher than the 195 meters reported in a study carried out by the authors who developed the test.[9] In another study conducted by the same group, the mean distance walked was 375 meters, similar to that found in the present study.[15] We found a weak correlation between the distance walked on the SWT and the forced expiratory volume in one second (r = 0.42), a value similar to that reported in a previous study (r = 0.31).[15] It is important to emphasize that the sample in the original SWT study included patients diagnosed with various etiologies causing bronchial obstruction, rather than COPD patients exclusively.[9]

Since 1997, a change in the type of encouragement used during the 6MWT has been proposed in order to increase reproducibility and make the test more closely approximate the maximum patient effort.[16] In fact, when we compare the distance walked on the 6MWT by the patients with COPD in this study to that walked by normal individuals, the mean distance in both cases is similar - 515 meters and 580 meters, respectively.[7] The mean distance walked by patients with moderate to severe COPD ranges from 264 to 403 meters in the literature.[2,26] In a previous study conducted at our center, 59 patients with COPD (forced expiratory value in one second, 47.9 ± 16.5%) were evaluated, and the mean distance walked on the E6MWT was 499.7 ± 83.6 meters.[27] This showed that modifying the type of encouragement given during the 6MWT induced patients to put forth greater effort, approaching their maximum capacity, during the test.

The hypothesis that both tests induced effort close to maximum predicted values can be justified by the post-test analysis of the parameters, most of which were, from the clinical and statistical viewpoint, similar, except for the significantly higher values for dyspnea and HR obtained after the E6MWT (Table 2). This is confirmed in most studies in the literature, in which incremental tests such as the SWT have been shown to induce greater increases in cardiovascular variables when compared to the 6MWT.[9-10] In a recent study, similar results in the cardiovascular parameters were reported for the SWT and the 6MWT. However, the study sample was composed of patients with COPD recovering from exacerbations, and the unencouraged form of the 6MWT was used. The similar behavior of physiological variables in that study was credited to a reduction in exercise tolerance found in patients with COPD exacerbations.[28] The findings in the present study are considered unique since they are related to patients in a stable phase of the disease. In our study, there was a good correlation between the SWT and the E6MWT (r = 0.80), better than those reported in classical studies,[9,11] but similar to that found in another study (r = 0.85).[28]

Traditionally, the SWT is characterized as an incremental test that assumes values close to maximum when compared to maximal incremental tests using ergometry. Modifying the stimulus given during the E6MWT might have led patients to walk at a speed approximating the maximum for a prolonged period of time (six minutes for this test). This concept is similar to that known as critical potency, in which the load tolerated by patients with moderate to severe COPD during high-intensity exercise would be limited to the dynamic ventilatory response.[29] Endurance was strongly associated with the level of ventilatory stress, resulting in an increase in the sensation of

dyspnea.[29] This would explain, therefore, the finding of higher levels for the sensation of dyspnea and HR on the E6MWT than on the SWT, since the latter is an incremental test that is interrupted immediately after reaching maximum load, thereby submitting patients to very high workloads over a shorter period of time. It has been reported that, three minutes after the beginning of the 6MWT, patients reach a walking speed plateau, accompanied by the maximum sustainable ventilatory level, which is said to be close to 90% of maximum voluntary ventilation. It has been shown that, on a 6MWT involving standardized external encouragement, patients will assume the maximum sustainable speed.[30]

Based on the principal findings of the present study, we concluded that the SWT can be used to evaluate exercise tolerance in patients with COPD in Brazil. This test in an incremental field test, is easily performed and requires no sophisticated equipment. The comparison between the SWT and the E6MWT showed that both tests present similar post-test values, although HR and sensation of dyspnea were higher after the E6MWT. The clinical implication of the differences between the use of these two tests, as a proposal for the training load in more simplified rehabilitation programs, should be evaluated in future studies, which should also include a more detailed evaluation of the differences between the standard 6MWT and the E6MWT in terms of the metabolic changes occurring during their performance.

REFERENCES

1. Celli BR, MacNee W; ATS/ERS Task Force. Standards for the diagnosis and treatment of patients with COPD: a summary of the ATS/ERS position paper. Eur Respir J. 2004;23(6):932-46.
2. Celli BR, Cote CG, Marin JM, Casanova C, Montes de Oca M, Mendez RA, et al. The body-mass index, airflow obstruction, dyspnea, and exercise capacity index in chronic obstructive pulmonary disease. N Engl J Med. 2004;350(10):1005-12. Comment in: ACP J Club. 2004;141(2):53; N Engl J Med. 2004;350(10):965-6; N Engl J Med. 2004;350(22):2308-10; author reply 2308-10.
3. Jardim JR, Camelie, AC, Miki, D. Pulmonary rehabilitation: the Latin American perspective. In: Hodgkin JE, Celli BR, Connors GL, Hodgkin C, editors. Pulmonary rehabilitation: guidelines to success. Philadelphia: Lippincott Williams & Wilkins; 2000. p.661-8.
4. Gallagher CG. Exercise limitation and clinical exercise testing in chronic obstructive pulmonary disease. Clin Chest Med. 1994;15(2):305-26.
5. Palange P, Carlone S, Forte S, Galassetti P, Serra P. Cardiopulmonary exercise testing in the evaluation of patients with ventilatory vs circulatory causes of reduced exercise tolerance. Chest. 1994;105(4):1122-26.
6. Elias Hernández MT, Ortega Ruiz F, Fernandez Guerra J, Toral Marín J, Sanchez Riera H, Montemayor Rubio T. [Comparison of a shuttle walking test with an exertion test with cycloergometer in patients with COPD]. Arch Bronconeumol. 1997;33(10):498-502. Spanish.
7. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS Statement: guidelines for the six minute walk test. Am J Respir Crit Care Med. 2002;166(1):111-7. Comment in: Am J Respir Crit Care Med. 2003;167(9):1287.
8. Montes de Oca M, Ortega Balza M, Lezama J, López JM. [Chronic obstructive pulmonary disease: evaluation of exercise tolerance using three different exercise tests]. Arch Bronconeumol. 2001;37(2):69-74. Spanish.
9. Singh SJ, Morgan MD, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax. 1992;47(12):1019-24.
10. Elias Hernández MT, Fernandez Guerra J, Toral Marin J, Ortega Ruiz F, Sanchez Riera H, Montemayor Rubio T. [Reproducibility of a shuttle walking test in patients with chronic obstructive pulmonary disease]. Arch Bronconeumol. 1997;33(2):64-8. Spanish.
11. Onorati P, Antonucci R, Valli G, Berton E, De Marco F, Serra P, Palange P. Non-invasive evaluation of gas exchange during a shuttle walking test vs. a 6-min walking test to assess exercise tolerance in COPD patients. Eur J Appl Physiol. 2003;89(3-4):331-6.
12. Bestall JC, Paul EA, Garrod R, Garnham R, Jones RW, Wedzicha AJ. Longitudinal trends in exercise capacity and health status after pulmonary rehabilitation in patients with COPD. Respir Med. 2003;97(2):173-80.
13. Aalbers R, Ayres J, Backer V, Decramer M, Lier PA, Magyar P, et al. Formoterol in patients with chronic obstructive pulmonary disease: a randomized, controlled, 3-month trial. Eur Respir J. 2002;19(5):936-43. Erratum in: Eur Respir J. 2002;20(1):245.
14. Hernandez MT, Rubio TM, Ruiz FO, Riera HS, Gil RS, Gomez JC. Results of a home-based training program for patients with COPD. Chest. 2000;118(1):106-14.
15. Singh SJ, Morgan MD, Hardman AE, Rowe C, Bardsley PA. Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. Eur Respir J. 1994;7(11):2016-20.
16. Cavalheiro LV, Cendon SP, Ferreira IM, Ribeiro AS, Gastaldi A, Jardim JR. Six minute walking test accompanied by a physiotherapist assess better the physical capacity of patients with COPD [abstract]. Am J Respir Crit Care Med. 1997;155:A167.
17. Wasserman K, Hansen JE, Sue DY, Stringer WW, Whipp BJ, editors. Principles of exercise testing and interpretation. 3rd ed. Baltimore: Lippincott Williams & Wilkins, 1999.
18. Lung function testing: selection of reference values and interpretative strategies. Am Rev Respir Dis. 1991;144(5):1202-18. Comment in: Am Rev Respir Dis. 1992;146(5 Pt 1):1368-9.

19. Sousa TC, Jardim JR, Jones Paul. Validação do Questionário do Hospital Saint George na Doença Respiratória (SGRQ) em pacientes portadores de doença pulmonar obstrutiva crônica no Brasil. J Pneumol. 2000;26(3):119-28.
20. Mahler DA, Weinberg DH, Wells CK, Feinstein AR. The measurement of dyspnea. Contents, interobserver agreement, and physiologic correlates of two new clinical indexes. Chest. 1984;85(6):751-8.
21. Wedzicha JA, Bestall JC, Garrod R, Garnham R, Paul EA, Jones PW. Randomized controlled trial of pulmonary rehabilitation in severe chronic obstructive pulmonary disease patients, stratified with the MRC dyspnoea scale. Eur Respir J. 1998;12(2): 363-9.
22. Singh SJ, Smith DL, Hyland ME, Morgan MD. A short outpatient pulmonary rehabilitation programme: immediate and longer-term effects on exercise performance and quality of life. Respir Med. 1998;92(9):1146-54.
23. Neder JA, Nery LE, Castelo A, Andreoni S, Lerario MC, Sachs A, et al. Prediction of metabolic and cardio-pulmonary responses to maximum cycle ergometry: a randomised study. Eur Respir J. 1999;14(6):1304-13. Comment in: Eur Respir J. 2000;15(5):982.
24. Oga T, Nishimura K, Tsukino M, Sato S, Hajiro T. Analysis of the factors related to mortality in chronic obstructive pulmonary disease: role of exercise capacity and health status. Am J Respir Crit Care Med. 2003;167(4):544-9.
25. Sciurba F, Criner GJ, Lee SM, Mohsenifar Z, Shade D, Slivka W, Wise RA; National Emphysema Treatment Trial Research Group. Six-minute walk distance in chronic obstructive pulmonary disease: reproducibility and effect of walking course layout and length. Am J Respir Crit Care Med. 2003;167(11):1522-7.
26. Carter R, Holiday DB, Nwasuruba C, Stocks J, Grothues C, Tiep B. 6-minute walk work for assessment of functional capacity in patients with COPD. Chest. 2003; 123(5):1408-15.
27. Mayer AF, Cavalheiro L, Jardim JR. A critical analysis of the current reference equations for the walked distance in a six minute walking test (6WT) when applied for chronic obstructive lung disease (COPD). Am J Respir Crit Care Med 2001;163:A151.
28. Vagaggini B, Taccola M, Severino S, Marcello M, Antonelli S, Brogi S, et al. Shuttle walking test and 6-minute walking test induce a similar cardiorespiratory performance in patients recovering from an acute exacerbation of chronic obstructive pulmonary disease. Respiration. 2003;70(6):579-84. Comment in: Respiration. 2005;72(3):331; author reply 332.
29. Neder JA, Jones PW, Nery LE, Whipp BJ. Determinants of the exercise endurance capacity in patients with chronic obstructive pulmonary disease. The power-duration relationship. Am J Respir Crit Care Med. 2000;162 (2 Pt 1):497-504.
30. Troosters T, Vilaro J, Rabinovich R, Casas A, Barbera J, Rodriguez-Roisin, R, et al. Physiological responses to the 6-min walk test in patients with chronic obstructive pulmonary disease. Eur Respir J. 2002;20(3):564-9.