original article

BJPT Brazilian Journal of Physical Therapy

Chester step test: assessment of functional capacity and magnitude of cardiorespiratory response in patients with COPD and healthy subjects

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ABSTRACT | **Background:** the assessment of functional capacity in patients with chronic obstructive pulmonary disease (COPD) has been performed by simple and easy to apply methods that mimic everyday activities, such as the Chester step test (TChester). **Objectives:** to investigate whether TChester is able to differentiate functional capacity and the magnitude of cardiorespiratory response of patients with COPD from healthy subjects; and to compare it with the cardiorespiratory response induced by shuttle test (TShuttle) and six-minute walk test (6MWT). **Method:** 10 patients with COPD (64±10 years, and forced expiratory volume at the first second - FEV1 38.1±11.8% predicted) and 10 healthy subjects (63±7 years, and FEV1 of 95.8±18.0% predicted) underwent evaluation of pulmonary function, functional status and capacity (6MWT, TShuttle and TChester). **Results:** COPD patients had worst performance in all tests, when compared to healthy subjects (TChester 2,1±0,9 vs. 4,1±1,1 completed levels; TC6min: 435±105,1 vs. 593±87,3 m; TShuttle 251±84,6 vs. 436±55,4 m; $p<0.05$). TChester correlated with TShuttle and 6MWT ($r=0.67$ and 0.83, respectively, $p<0.05$). There were no differences in heart rate and dyspnea in TChester levels between groups ($p>0.05$). SpO2 was lower in COPD patients since the first TChester level ($p<0.05$). **Conclusion:** TChester is valid in the assessment of functional capacity of COPD patients, being able to distinguish them from healthy subjects, inducing similar cardiovascular demand and greater desaturation in COPD patients.

Keywords: rehabilitation; evaluation; functional capacity; exercise tolerance; chronic obstructive pulmonary disease.

HOW TO CITE THIS ARTICLE

Karloh M, Corrêa KS, Martins LQ, Araujo CLP, Matte DL, Mayer AF. Chester step test: assessment of functional capacity and magnitude of cardiorespiratory response in patients with COPD and heatlhy subjects. Braz J Phys Ther. 2013 May-June; 17(3):227-235. http://dx.doi.org/10.1590/S1413-35552012005000087

Introduction

Peripheral muscle dysfunction is considered a main systemic change in chronic obstructive pulmonary disease (COPD) and contributes to the loss of exercise capacity, which interferes with the activities of daily living (ADL) of the patients[1,2]. Currently, the search for functional capacity evaluation methods that are simple and easy to apply in clinical practice has gained prominence once laboratory evaluations are not available to all professionals and often do not faithfully mimic real-life situations[3,4]. Clinical trials aimed at evaluating functional capacity usually consist of reproducing the common daily activities of these patients by imposing a constant or incremental load. The six-minute walking test (6MWT), the Glittre ADL test (TGlittre) and the shuttle test (TShuttle) reflect the functional limits and exercise limits in patients with COPD[2,5-7]. However, these tests require a large space, making clinical practice difficult. The Chester step test (TChester) was originally developed by Sykes et al.[8] to evaluate the aerobic capacity of healthy adults and to prescribe physical activity[9]. TChester consists of a submaximal test for healthy subjects, which is easy to perform, does not require a large space, is inexpensive and has a pace that is determined by a sound signal[8]. Although simple and familiar to patients, going up and down stairs is a task that usually causes great strain in patients with COPD[2]. Recently, TChester

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Received: 04/27/2012 Revised: 10/08/2012 Accepted: 11/23/2012

was shown to be reproducible and to significantly correlate with the 6MWT in patients with COPD[10]. The 6MWT is a submaximal test with constant load defined by the patient[11]. However, it is still unknown whether TChester is able to differentiate the functional capacity between healthy subjects and COPD patients, or whether there are differences in the overload imposed on the cardiorespiratory system of these subjects. Additionally, it is necessary to know whether TChester induces cardiorespiratory adaptations similar to other well-accepted tests. Thus, the present study aims to investigate whether TChester is able to differentiate the functional capacity and the magnitude of the cardiorespiratory response between patients with COPD and healthy subjects and to compare cardiorespiratory responses induced by TChester, 6MWT and TShuttle.

Method

Sample

Ten patients with COPD (Global Initiative for Obstructive Lung Disease (GOLD) scale 2 to 4)[1] were recruited from the database of the Hospital de Clínicas da Universidade Federal de Uberlândia – HC-UFU, and 10 healthy subjects paired by gender, age and body mass index (BMI) were recruited from the community. The inclusion criteria for the COPD group were the following: COPD diagnosis based on clinical and spirometric criteria[1], minimum smoking history of 20 pack-years, clinical stability in the month prior to the beginning of the protocol and more than 40 years of age. Sedentary individuals, with normal spirometry, no history of smoking and over 40 years of age were included in the control group. The study excluded patients on home oxygen therapy; those with cardiomyopathy, musculoskeletal diseases, rheumatic diseases, obesity, cancer, diabetes mellitus, tuberculosis or asthma; orthopedic prosthesis users; patients unable to perform any of the evaluations; and those who displayed an exacerbated clinical condition during the study period. The patients who freely signed an informed consent form participated in the study. It was approved by the Human Research Ethics Committee of the Triangle University Center (Centro Universitário do Triângulo - UNITRI), Uberlândia, state of Minas Gerais - MG, Brazil (protocol No. 618161).

Procedure for data collection

The protocol was conducted over a three-day period. Initially, anamnesis, anthropometric and lung function evaluation and TShuttle were performed. The modified Baecke questionnaire was applied to the group of healthy subjects. On the second day, all individuals performed the 6MWT, and patients with COPD completed the London Chest Activity of Daily Living scale (LCADL) questionnaire. On the third day, the participants performed TChester.

Pulmonary function

A previously calibrated EasyOne spirometer (NDD, Switzerland) was used to assess lung function. The methods and criteria used were those recommended by the American Thoracic Society/ European Respiratory Society (ATS/ERS)[12]. The spirometric measurements were obtained before and 15 minutes after the inhalation of 400 μg of salbutamol. The forced expiratory volume in one second (FEV_1), the percentage of the predicted FEV_1 value (FEV_1%pred), forced vital capacity (FVC) and FEV_1/FVC ratio were evaluated. The predicted values were those established by Pereira et al.[13].

Functional capacity

Six-minute walking test

The 6MWT was performed according to the recommendations of the ATS[5], in a 30-m-long flat corridor, with interval markings every meter. Subjects were instructed to walk as far as possible and received standardized verbal encouragement. Two tests were performed with a 30-minute interval between them. The longest distance walked and the distance as a percentage of the predicted value were considered for the analysis[14].

Shuttle test

TShuttle consists of walking on a flat 10-m course. The subject follows a pace imposed by a sound signal, completing laps (shuttles) around cones on the course. The test velocity is increased at each level, with a total of 12 levels and velocity ranging from 0.5 m/s in the first level to 2.37 m/s at the last level[6,14]. The test was stopped if the signal sound was emitted when the patient was more than 0.5 meters away from the cone for three consecutive shuttles. The number of shuttles performed at each level, the number of completed levels and the full distance walked were calculated.

The predicted distance for TShuttle was calculated using the equations proposed by Probst et al.[15].

Chester step test

TChester is a test validated for healthy subjects, which consists of going up and down a step that is up to 30 cm in height at a pace set by a signal sound, which progressively increases in speed up to five levels. In the first minute, patients go up and down the step 15 times, and this is increased by 5 every 60 seconds. The maximum test time is 10 minutes. The step height used depends on the study population. The minimum height is 15 cm, and the maximum is 30 cm[9]. For the present study, a 17-cm-high step was used for both the COPD group and the control group. A height of 17 cm was selected because it is the same step height standardized by Skumlien et al.[2] for TGlittre and because COPD patients are usually quite limited in their functional capacity. The test was stopped when the subject could no longer keep the pace or displayed any limiting symptom (dizziness, strong dyspnea or headache). The subjects were instructed to report any limiting symptom to the researchers as soon as it was perceived. The test was also stopped by the examiner if the subject reached 90% of the predicted maximum heart rate (HRmax)[9]. The number of completed levels (TChester level) and the number of steps (TChester step) were considered for the analyses.

HR, blood oxygen saturation (SpO_2) and dyspnea (modified Borg scale) were measured before, immediately after and at the end of each level of the test. Blood pressure (BP) was measured only before and after the test with the subject still standing. HRmax was calculated using the equation HRmax=210–(0.65*age)[16]. Desaturation was considered when SpO_2 decreased below 90% or when the baseline SpO_2 decreased 4% or more and remained between 90 and 94%[17].

Functional status

The functional status was assessed by the Brazilian version of the LCADL questionnaire[18]. The instrument consists of four domains related to personal care, household activities, leisure and physical activities, allowing the interviewer to evaluate the degree of dyspnea of the patients and their response to a therapeutic intervention. The LCADL scale addresses common ADL, such as putting on a shirt, putting on shoes with socks and making the bed, among others activities, totaling 15 quantitative questions in which patients must select scores from 0 to 5, which together add up to a maximum total of 75 points (LCADL score)[19]. The percentage of the total score ($LCADL\%_{total}$) was also calculated, excluding items where the answer was 0[18].

Physical activity level

The physical activity level of the control group was assessed by the Modified Baecke Questionnaire for Older Adults[20]. A score lower than 9.4 classifies the individual as inactive[21]. The questionnaire was applied to the control group to ensure a sample of sedentary individuals.

Outcomes studied

The outcomes of the present study were as follows: the performance in TShuttle, 6MWT and TChester and the HR, SpO_2 and dyspnea sensation measured in TChester.

Statistical analysis

The Shapiro-Wilk normality test was used, and depending on the nature of the variables, the corresponding parametric or nonparametric test was applied. For comparisons between the COPD and control groups, the t-test for independent samples or the Mann-Whitney U test was used. One-way analysis of variance (ANOVA) or the Kruskal-Wallis test with the Tukey's *post-hoc* test was used to compare HR, SpO_2 and dyspnea index within groups. The variation in cardiorespiratory variables between test levels and between groups was compared using two-way ANOVA or the corresponding nonparametric test, with a *post-hoc* paired t-test or Wilcoxon test. The association between the variables was verified by the Pearson's or the Spearman's correlation coefficient. Data are presented as the mean±standard deviation or median and interquartile range. The significance level for the analyses was 5%.

Power of the study

The power of the study was calculated based on the difference in performance between the COPD and control groups. Using the sample of the present study and α=0.05, the power to detect TChester's potential to identify a greater limitation of the functional capacity of patients with COPD was greater than 95%.

Results

Table 1 shows the features of the two study groups. The groups were similar regarding age, weight, height and BMI but differed regarding the pulmonary function variables and smoking history ($p<0.05$).

All subjects with COPD displayed worse performance ($p<0.05$) than the control group in the functional capacity tests (Table 2). The COPD group achieved, on average, a 26.6% lower performance in the 6MWT, 42.4% lower in TShuttle and 48.8% lower in TChester. In the COPD group, TChester level correlated with the last completed level on TShuttle (TShuttle level). The 6MWT also showed a strong correlation with TShuttle. The number of steps in TChester correlated with the distance walked in the 6MWT. The Physical Activity domain of the LCADL scale showed a strong negative correlation with TChester level (Figura 1).

In the COPD group, all three tests indicated similar variation (post-test level minus pre-test level) in dyspnea as well as similar variation in SpO_2 ($p>0.05$ for both). The variation in HR was significantly higher in the 6MWT compared to TShuttle, and it was also greater in TChester compared to the TShuttle ($p<0.05$ for both) (Table 3). The HR variation showed no significant differences between groups in any of the three tests. Dyspnea varied significantly between groups only in the 6MWT ($p<0.05$), and the variation in SpO_2 was significantly larger for the COPD group according to the 6MWT and TChester ($p<0.01$ in each test) (Table 3). No differences were observed in dyspnea between the COPD and control groups according to TChester. The percentage HRmax achieved was higher in the control group ($p<0.04$, Table 3), and SpO_2 was significantly lower in the COPD group from the first level of the test until the end (Figure 2).

Discussion

The present study aimed to investigate whether TChester was able to differentiate the performance of COPD patients from healthy individuals as well as to identify the magnitude of the cardiorespiratory response induced by TChester by comparing it with two other, widely used functional and exercise tests.

TChester, as well as the 6MWT and TShuttle, identified the functional limitations of patients with COPD, who presented a performance 48.8% lower than that of healthy subjects. This greater limitation in TChester may have resulted from the fact that

Table 1. Characteristics of the sample.

	Control group	COPD group	p
Age (years)	63±7	64±10	0.86
Sex	7(F) e 3(M)	7(F) e 3(M)	
Pack-years smoked		63±42	<0.01
Body mass (kg)	61.0±7.9	59.1±12.2	0.68
Height (m)	1.57±5.85	1.57±8.83	0.86
BMI (kg/m^2)	24.5±3.1	23.7±5.1	0.67
FEV_1(liters)	2.8±0.5	0.9±0.2	<0.01
FEV_1 (%pred)	95.8±18.0	38.1±11.8	<0.01
FVC (liters)	2.8±0.7	1.9±0.4	<0.01
FVC (%pred)	96.4±20.4	61.1±12.5	<0.01
FEV_1/FVC (%)	85.0±4.4	48.4±7.8	<0.01
LCADL	-	22.6±4.6	-
$LCADL_{\%total}$	-	33.3±5.7	-
LCADL	-	22.6±4.6	-
Baecke	4.9±1.8	-	-

Mean±SD; p: level of significance; F: female; M: male; BMI: body mass index; FEV_1 = forced expiratory volume in one second; %pred= percentage of the predicted value; FVC = forced vital capacity; LCADL = total score of the London Chest Activity of Daily Living scale; $LCADL_{\%total}$ = percentage of the total score of the London Chest Activity of Daily Living scale; Baecke: modified version of Baecke questionnaire.

TChester is a test of incremental nature[6,8], where the progression of the load is imposed by a signal sound and not selected by the patient, as in the 6MWT, which allows for physiological adjustments that ensure the sustainability of the activity throughout the test[11].

Table 2. Performance on functional capacity tests.

	Control group	COPD group	p
6MWT (m)	593±87.3	435±105.1	<0.01
6MWT (%pred)	113±13.6	83.2±19.4	<0.01
TShuttle (m)	436±55.4	251±84.6	<0.01
TShuttle (%pred)	69.4±9	40.1±13.9	<0.01
TShuttle (level)	6.7±0.7	4.6±1.3	<0.01
TChester (level)	4.1±1.1	2.1±0.9	<0.01

Mean±SD; p: level of significance; %pred: percentage of the predicted value; 6MWT (m): distance walked during the six-minute walking test in meters; TShuttle (m): distance walked during the shuttle walking test; TShuttle (level): completed levels in the shuttle walking test; TChester (level): completed levels in the Chester step test.

Casas et al.[11] demonstrated that in a step test, the oxygen consumption (VO_2) value achieved is similar to the value achieved in TShuttle and in a maximal incremental exercise test, but with an abrupt increase, reaching 80% of the peak VO_2 in the first minute of the test. When specifically studying TChester, Camargo et al.[10] estimated the VO_2 peak achieved in this test in six patients with COPD and found that it was higher than the VO_2 peak reached in the maximal incremental exercise test. Going up and down the step, in addition to inducing a higher VO_2, generates a larger energy expenditure in patients with COPD compared to other everyday activities, such as sitting down and standing up, walking on a flat surface, walking on a flat surface carrying weight and moving objects with the upper limbs[22]. This increased effort may explain the greater limitation of patients in the present study when evaluated by TChester compared to healthy subjects.

In addition, the TChester level showed a strong association with the distance walked in the 6MWT and with the TShuttle level in patients with COPD,

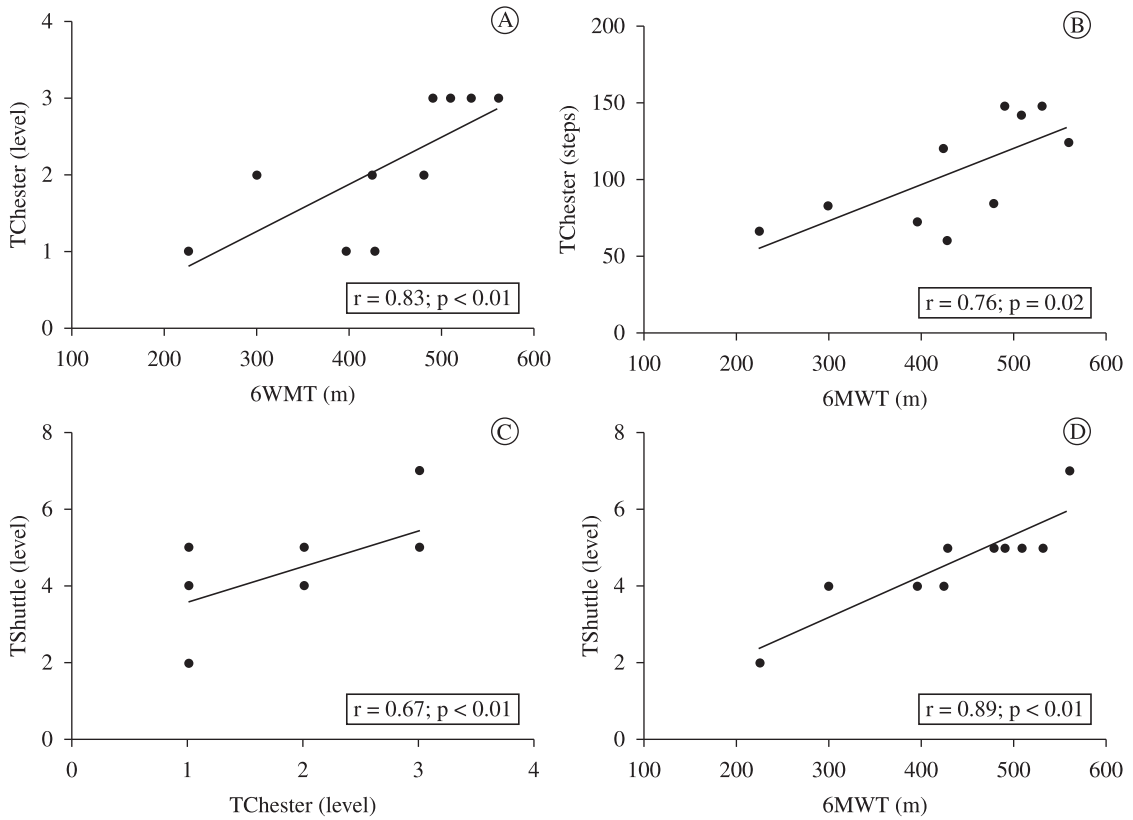

Figure 1. Correlations between TChester, 6MWT and TShuttle in the COPD group. A: Correlation between the last level completed in TChester and 6MWT distance (m), r=0.85, p<0.01. B: Correlation between the number of steps taken in TChester and 6MWT distance (m), r=0.76, p<0.02. C: Correlation between the last completed level in TShuttle and the last completed level in TChester, r=0.76, p<0.01. D: Correlation between the last completed level in TShuttle and 6MWT distance (m), r=0.89, p<0.01.

Table 3. Comparison of cardiorespiratory variables (HR, SpO_2 and Borg) in functional capacity tests between control and COPD groups.

	Control group	COPD group	p (between groups)
6MWT (m)			
ΔHR	39.1±17.3	25.7±11.3 *	0.08
HR %max	73.6±11.8	67.5±10.1	0.22
ΔSpO_2	–1.8±1.4	-8.0±7.4	0.01
Desaturation, n	0	9	-
ΔBorg	1.3 ±0.9	3.7±2.6	0.02
TShuttle (level)			
ΔHR	30.6±22.2 #	17.2±7.4 †	0.09
HR %max	67.5±16.7	65.6 ±8.3	0.75
ΔSpO_2	–2.2±3.5	-5.7±5.3	0.10
Desaturation, n	2	10	-
ΔBorg	2.6±0.8	3.1±1.4	0.33
TChester (level)			
ΔHR	42.3±24.6	31.7±14.2	0.25
HR %max	83.5±14.9	70.5±10.5	0.04
ΔSpO_2	–0.1±1.6	–8.1±7.4	<0.01
Desaturation, n	0	9	-
ΔBorg	2.6±2.1	4.4±2.7	0.11

Mean±SD of the change between final and rest value of heart rate, oxygen saturation, and Borg dyspnea score; HR%max: percentage of predicted maximum heart rate; Desaturation, n: number of individuals who had desaturation; * $p < 0.01$ 6MWT vs. TShuttle (COPD group); # $p < 0.05$ TShuttle vs. TChester (control group); † $p < 0.01$ TShuttle vs. TChester (COPD group).

which confirms the applicability of TChester to assess the functional capacity of patients with COPD. TChester and TShuttle, although they involve different activities, are similar in nature because both progressively increase the load imposed, which is announced by a signal sound, and are limited by the symptoms of the patient.

Camargo et al.[10] considered TChester an exercise protocol that is difficult for COPD patients to perform because most of their patients stopped the test during the second level. According to the authors, this might have been due to the high pace and load increase of the test. However, in the present study, almost all of the patients reached the third level, although no subjects from the COPD group reached the end of the test, indicating that TChester may be better tolerated by patients with COPD. Furthermore, although COPD patients of the present study displayed greater airflow obstruction than those of Camargo et al.[10] (38.1±11.8% vs. 46.0±15.0% of the predicted value[10]), they showed better functional capacity, as evidenced by their performance in the 6MWT (435±105.1 vs. 398±110 m[10]), which may explain the greater tolerance of our patients to TChester (104.6±35.2 vs. 68±41 steps)[10]. In addition, the divergence in the results of these two studies might be explained by the difference in the height of the steps, as the present study used a 17-cm-high step, while Camargo et al.[10] used a step with a height of 20 cm. Although Buckley et al.[9] have studied TChester with four different step heights (15, 20, 25 and 30 cm), the 17 cm height was chosen because it was the height standardized by Skumlien et al.[2] in TGlittre, a test validated for patients with COPD. In addition, the Brazilian Technical Standards Association[23] recommends that the height of the steps of a ladder range between 16 and 18 cm, and thus, our goal was to evaluate the patients in a condition similar to the activities that they perform every day.

The HR in TChester increased linearly and similarly between the test levels in both groups, confirming that it increases proportionally to the load increment[24]. SpO_2 remained lower in the COPD group in the first three TChester levels. There was also an apparent recovery of SpO_2 in the last two levels completed in the COPD group, but this might have

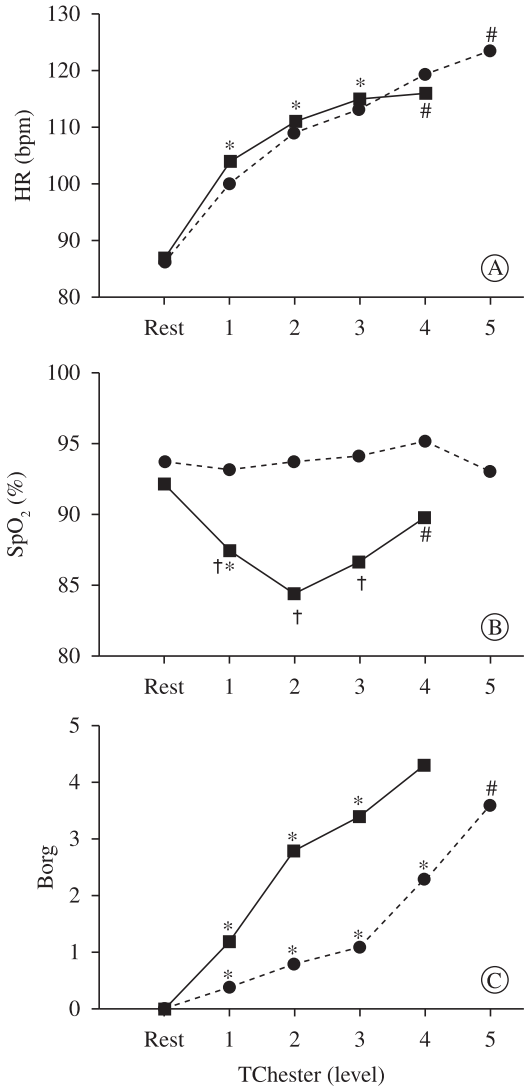

Figure 2. Cardiorespiratory variables measured during the Chester step test (TChester) in the COPD and control groups. ● Control Group; ■ Group COPD. A: Heart rate (HR). B: Saturation of peripheral oxygen (SpO_2). C: Sensation of dyspnea (Borg). † p<0.05 vs. control, * p<0.05 vs. previous level in either group, # p<0.05, final level vs. pre-test.

occurred because patients with lower SpO_2 stopped the test at the second level, and only those with higher SpO_2 continued. There was no significant difference in the subjective perception of dyspnea between the groups. Since patients with COPD have ventilatory limitation during exercise, higher levels of dyspnea were expected in these patients, once the increased ventilatory demand and effort of breathing associated with the reduction in the ventilatory capacity intensify the respiratory distress in COPD patients[25]. Moreover, the dyspnea scores may have been similar between groups because COPD patients stopped the tests early, while the control group reached more intense exercise stages and hence had dyspnea scores close to the ones of the COPD group. However, there was also no difference in dyspnea after the same exercise load (TChester level).

Although the tests differ regarding the activities performed (walking or going up and down steps), loads imposed (incremental or defined by the patient) and stimulus (verbal or a signal sound), patients with COPD had a similar cardiorespiratory performance in all three tests, except for a smaller ΔHR in TShuttle (Table 3). Previous studies have reported similar responses in HR, SpO_2 and dyspnea between incremental and non-incremental tests[11,26], and therefore, we did not expect the smaller ΔHR in TShuttle compared to TChester and the 6MWT.

Some factors could be identified as limitations of the study. No instruments were used to assess muscle fatigue, which could have contributed to the early interruption of the exercise in both groups. Although determining the mechanism of exercise tolerance was not the focus of the present study, further studies should be conducted to determine the role of peripheral muscle fatigue in exercise limitation during TChester. Moreover, another limitation may have been the fact that tests were not performed in a randomized order. Rather, all participants of the study always conducted the protocol in the same order, after familiarization with all of the tests.

Significant associations were found between TChester, an assessment tool that is still little used in the evaluation of the functional capacity and exercise tolerance in patients with COPD, and two instruments that are already well accepted. In addition, the COPD group showed worst performance in all tests, including TChester. To our knowledge, this is the first study to compare the performance of COPD patients and healthy subjects in TChester. Although the results of TChester were associated with the results of the main tests used to assess the functional capacity of patients with COPD, its responsiveness to the therapeutic interventions in this population needs to be studied to determine whether it can be recommended to assess functional capacity in clinical rooms that do not have the physical space required for other tests.

In summary, this study demonstrated that TChester is valid in assessing the functional capacity of patients with COPD and is able to differentiate them from healthy individuals. The cardiorespiratory response induced by the test is similar in the COPD and control

groups regarding HR and dyspnea and is different regarding peripheral oxygen saturation. In addition, the cardiorespiratory response induced is similar in TChester, 6MWT and TShuttle, except for the ΔHR in TShuttle.

Acknowledgments

The authors thank the Minas Gerais Research Foundation (Fundação de Amparo à Pesquisa do Estado de Minas Gerais - FAPEMIG) for the support provided by the Programa Jovens Doutores [Young Doctors Program], public notice number 019/060, and Vinícius Pafume de Oliveira for his help in patient selection.

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