Reproducibility of Cadence-Free 6-Minute Step Test in Subjects with COPD

Joyce NF da Costa PT, Juliano F Arcuri MSc, Ivana L Gonçalves MSc, Simone F Davi PT, Bruna V Pessoa PhD, Mauricio Jamami PhD, and Valéria AP Di Lorenzo PhD

BACKGROUND: Six-minute step test (6MST) has been used to assess functional capacity in chronic conditions; however, its reproducibility in the COPD population has not been evaluated. Our study objective was to evaluate 6MST reproducibility. METHODS: The test was performed in a single 20-cm height step, and subjects were instructed to step up and down (cadence-free) for 6 min. Subjects underwent three tests. The first and second were controlled by the same assessor with a 30-min interval. The third test was controlled by a different assessor one week later. For intra-rater comparison, the first and second performances of the test were used, and for inter-assessor comparison, the better performance of the first two tests was compared with the third test. RESULTS: Excellent intra-rater and inter-rater relative reproducibility was observed (intraclass correlation coefficient > 0.8), and there was no statistical difference (repeated measures of analysis of variance) among the performances of the three tests. Intra-rater error values were acceptable (mean error of 5.7 steps and limits of agreement between −7 and 18 steps). Inter-rater error values were not acceptable (mean error of 4.4 steps and limits of agreement between −20 and 29 steps. CONCLUSIONS: 6MST proved to be reproducible in the COPD population when performed by the same assessor. *Key words: chronic obstructive pulmonary disease; COPD; exercise test; reproducibility*. [Respir Care 2014;59(4):538–542. © 2014 Daedalus Enterprises]

Introduction

COPD is characterized by chronic air-flow limitation, pulmonary function deterioration, significant weight loss, and decreased strength and endurance of respiratory muscles and lower and upper limbs,[1] in addition to a decreased functional capacity and intolerance of physical efforts.[2]

Exercise intolerance in COPD subjects has important implications regarding quality of life, number of hospitalizations, and survival.[3] Thus, functional physical tests have been considered to be essential components in the routine clinical assessment of exercise capacity in these subjects.[3] The most accurate way of assessing physical state and determining the cause of exercise intolerance is maximal cardiopulmonary exercise testing[3,4] with measurements of exhaled gases. However, the complexity of the equipment, the high operating costs, and the need for trained technicians make its use limited in clinical practice.[5]

Alternatives to the maximal tests are the 6-min walk[6] and step[7] tests because they are practical and easy to perform in a clinical routine.[2,3,7] The walk test has good reproducibility, reliability, and low cost;[4,6,8,9] is a predictor of morbidity and mortality;[10,11] and reflects the exercise capacity of COPD subjects to perform the physical activities of daily living.[12] However, the physical space required for its execution often limits its use.[6,7] Moreover, one step test protocol, the 6-min step test (6MST), is considered to be a good alternative for assessing exercise capacity in chronic subjects.[7,13]

Ms da Costa, Mr Arcuri, Ms Gonçalves, Ms Davi, Dr Jamami, and Dr Di Lorenzo are affiliated with the Universidade Federal de São Carlos, São Carlos, São Paulo, Brazil. Dr Pessoa is affiliated with the Universidade do Sagrado Coração, Bauru, Brazil.

This work was supported by scholarships from the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). The authors have disclosed no conflicts of interests.

Correspondence: Joyce NF da Costa PT, Spirometry and Respiratory Physiotherapy Laboratory, Universidade Federal de São Carlos (UFSCar), Rod, Washington Luis, Km 235, Caixa Postal 696, CEP 13565-905, São Carlos, SP, Brazil. E-mail: joy.nog@bol.com.br.

DOI: 10.4187/respcare.02743

Recently, 6MST has been validated in subjects with interstitial lung disease.[7] It was reproducible, safe, and sensitive to oxygen desaturation induced by exercise, proving it to be easy to use, economical, and portable.[7] Although there are studies showing the physiological responses to 6MST,[14,15] we did not find reproducibility studies of this test in subjects with COPD, justifying this study. Therefore, the objective of this study was to evaluate the reproducibility of 6MST in subjects with COPD. We hypothesized that 6MST would be reproducible in either intra-rater or inter-rater analysis, which would make it the perfect choice for use in large-sample analysis of exercise capacity.

QUICK LOOK

Current knowledge

The 6-min walk test is the standard test for evaluating exercise intolerance in patients with COPD. The 6-min step test has been used to assess functional capacity in chronic conditions; however, its reproducibility in COPD has not been evaluated.

What this paper contributes to our knowledge

The cadence-free 6-min step test is a reproducible test for the population of COPD subjects when performed by the same examiner.

Methods

Study Design and Participants

This study is part of a larger prospective, cross-sectional, observational study being conducted by the Spirometry and Respiratory Physiotherapy Laboratory at the Federal University of São Carlos in Brazil. The goal of this larger study was to verify the clinimetrics of 6MST and the 6-min walk test in three different populations (COPD patients, young adults, and elderly adults); the study was registered at clinicaltrials.gov (Identifier NCT01298661). Here, we have concentrated on the reproducibility of 6MST in patients with COPD.

The enrollment period for participants was January 2011 to June 2012, and the participants were invited using posters distributed in the university and its neighborhood, local radio and television, and newspapers. In addition, patients referred for treatment to the Special Unit of Respiratory Physiotherapy at the Federal University of São Carlos were invited to participate. All subjects willing to participate were asked via telephone if they matched the inclusion criteria for participation in the study. The inclusion criteria adopted were: subjects with clinical and spirometric COPD diagnosis[16] who did not show associated diseases that would prevent them from performing the proposed tests. The exclusion criteria adopted were: subjects who had already performed 6MST before this study and those with COPD exacerbation. Moreover, subjects who could not complete the first assessment day were not included in any analysis, and those who missed the second assessment day were not included in the inter-rater reproducibility analysis. All accepted patients signed a consent form for the larger study, which was approved by the Human Ethics Committee of the university (decision 009/2011). The consent and the ethics committee-approved project included all of the objectives and measurements used here.

Experimental Procedure

Subject assessment was conducted in 2 days with a one-week interval. On the first day, the subjects' history and their anthropometric and spirometric characteristics were collected. On that same day, they performed two 6MSTs with a 30-min interval between them. On the second day, a body composition analysis and a third 6MST by a different assessor were performed.

6MST

Two assessors conducted each of the tests, one to command the test and the other to count the number of steps the subject climbed. A 20-cm height step was used as an ergometer.[7] The same standardized verbal incentives for each 6-min walk test[6] were used. Prior to the beginning of the test, the subjects received standard instructions, which are described in Figure 1.

Throughout the test, heart rate (Vantage NV, model 1901001, Polar, Kempele, Oulu, Finland) and pulse oximetry (Nonin, model 2500, Minneapolis, Minnesota) were monitored, and if the individual heart rate presented higher than the submaximal heart rate or if pulse oximetry was $< 85\%$, the assessor asked the individual to rest until the heart rate was down by 10 beats/min under the submaximal heart rate or until pulse oximetry increased to 88% or higher. Submaximal heart rate (SubHR) was calculated using the following equations: SubHR (beats/min) = [220 − age (y)] × 0.85 for men and SubHR (beats/min) = [210 − age (y)] × 0.85 for women. The participant could also choose to stop the test to rest, but in either case, the chronometer was not stopped during the interruption.

Statistical Analysis

Initially, the normality of the data was verified using the Shapiro-Wilk test, and parametric data were expressed us-

Mr. (s) Name of the individual

This is the 6-minute step test. The objective of this test is to climb the greatest number of steps you can in 6 minutes. The more steps you climb, the better your exercise capacity. You need to go up the step and then back down again to the place you started, with your feet on the floor. You can use either of your legs to begin, and you can change to the other whenever you want.

(Demonstrate one step up and down, starting with one leg, and then climb one more starting with the other leg.)

You cannot use your arms to help you climb, but if you feel that you might fall, you can use them to regain your balance. You need to stop using your arms as soon as possible.

Six minutes is a long time to climb stairs, so you will be exerting yourself. You can slow down, stop, and even rest in the chair provided, but you should resume climbing as soon as you can. If your heart beats too fast, or the oxygen in your blood becomes too low, I will ask you to stop for a moment, and I will let you know when you can start again. Even if you stop, the countdown timer will not be stopped. Are you ready to start? Start now or whenever you are ready.

Fig. 1. Instructions given before six-minute step test.

ing mean ± SD. P values $< .05$ was considered as significant. To verify the intra-rater reproducibility, first and second 6MSTs were compared, and the inter-rater reproducibility was verified by comparison of the third test with the others and the choice of the better test.

Relative reproducibility was analyzed by the intraclass correlation coefficient (ICC), and reproducibility was considered to be excellent when the ICC values were higher than 0.75.[17] Absolute reproducibility was verified by comparison of the tests using repeated measures analysis of variance, standard error of measurement (SEM = SD $\times$ $\sqrt{}$(1 − ICC)) and its 95% CI (SEM − 95% CI = SEM $\times$ 1.96), and minimal detectable difference (MDD = 1.64 $\times$ $\sqrt{}$(2) $\times$ SEM).[18] Furthermore, the mean error and limits of agreement were calculated to construct Bland-Altman plots.

The sample size required to perform the proposed reliability analysis was at least 19 subjects,[19] considering $\alpha < 0.05$ and $\beta < 0.2$, two test repetitions, the null hypothesis of ICC < 0.7, and the expected hypothesis of ICC > 0.9. The expected ICC value used was consistent with the mean value of ICC found in 6 min walk test reproducibility studies: 0.88−0.94.[20-22]

Results

This study included 34 subjects, two of whom were excluded for not completing the first assessment day. Of the 32 subjects included in the analysis, 2 presented FEV_1 > 80% of the predicted value, 9 presented FEV_1 < 80% and > 50% of the predicted value, 15 presented FEV_1 < 50% and > 30% of the predicted value, and 6 presented FEV_1 < 30% of the predicted value.[16] Sample characteristics are shown in Table 1. Three subjects did not appear on the second day of evaluation, so they were included only in the intra-rater analysis.

Table 1. Demographic, Anthropometric, and Spirometric Characteristics of the 32 Evaluated Subjects with COPD

Characteristic	COPD (n = 32)
Age, y	68.5 ± 10.3
Weight, kg	67.1 ± 11.5
Height, m	1.64 ± 0.07
BMI, kg/m^2	25 ± 4.4
FVC, %	62.7 ± 19.3
FEV_1, %	45.8 ± 17.7
FEV_1/FVC	0.54 ± 0.13

Values are expressed as mean ± SD.
BMI = body mass index
FVC = forced vital capacity

Table 2. Relative Reproducibility of 6-min Step Test in COPD Subjects Evaluated

Comparison	ICC	95% CI
T1 × T2	0.94	0.89–0.97
T1 × T3	0.80	0.62–0.89
T2 × T3	0.79	0.62–0.89
T1 or T2 × T3	0.80	0.63–0.89

ICC = intraclass correlation coefficient
T1, T2, and T3 = first, second, and third tests, respectively
T1 or T2 = choose the better of both tests

Intra-rater and inter-rater relative reproducibilities were excellent in COPD subjects (Table 2). There were no statistically significant differences among the tests (T1/T2/T1 or T2 and T3) (Table 3), which indicates that 6MST has

Table 3. Performance on 6-min Step Test Assessed in Subjects with COPD

Test	6MST (steps)
T1	76.6 ± 19.6
T2	82.4 ± 20.7
T1 or T2	83.1 ± 20.2
T3	87.0 ± 21.6

Values are expressed as mean ± SD.
T1, T2, and T3 = first, second, and third tests, respectively.
T1 or T2 = choose the better of two 6-min step tests (6MST) (analysis of variance for repeated measures; $P > .05$).

Table 4. Absolute Reproducibility of 6-min Step Test assessed in subjects with COPD

Comparison	SEM	95% CI	MDD
T1 × T2	4.8	9.3	11.1
T1 × T3	9.8	19.3	22.8
T2 × T3	9.9	19.3	23.0
T1 or T2 × T3	9.0	17.6	20.9

SEM = standard error of measurement
MDD = minimal detectable difference
T1, T2, and T3 = first, second, and third tests respectively
T1 or T2 = choose the better of both tests.

absolute reproducibility as well. Error analysis, verified by a Bland-Altman plot (Fig. 2), the standard error of measurement, and the minimal detectable difference (Table 4), showed acceptable error in the intra-rater comparison. However, they were unacceptably high in the inter-rater comparison.

Discussion

6MST is a reproducible test in COPD subjects when performed by the same assessor. Furthermore, it presents an excellent inter-rater relative reproducibility,[17] but with high error values that are too high, which does not encourage the comparison of two 6MSTs performed by different assessors.

Relative reproducibility values (ICC) were > 0.8 in the intra-rater comparison, and there were no statistical differences in the first two tests (means of T1 = 76 and T2 = 82 steps). This indicates that, for this population, the test is reproducible with reproducibility values similar to those obtained using other clinical exercise tests, such as 6-min walk test, which presents an ICC of 0.88–0.94,[20-22] and shuttle-walk test, which presents an ICC of 0.87.[23]

Moreover, the error value for this comparison was acceptable, presenting a mean error of 5.7 steps and limits of agreement ranging from −7.1 to 18.6 steps. Dal Corso and colleagues[7] also concluded that this test is reproducible in subjects with interstitial pulmonary fibrosis with even lower error values (mean error of one step and limits of agreement ranging from −0.5 to 2.5 steps). Furthermore, standard error of measurement and the minimal detectable difference were 4.1 and 11 steps, respectively, which confirms previous results from a study[24] in which 6MST was used to determine an 11-step difference between two groups of COPD subjects, one group of which was included in an aerobic physical training protocol and the other was not. Standard error of measurement as a percentage of the mean was 5%, which was similar to the same error analysis using the 6-min walk test in other studies that also represented ~5% of the mean performance of the test.[21,25]

These results show that the performance in this test was not influenced by the learning effect in the COPD population, which leads to the affirmation that this test can be done without a familiarization test, spending only 15 min of assessment time. This characteristic could be an advantage over the 6-min walk test, which requires at least one previous test and a recovery time between them, totaling a time expenditure of at least 50 min.[20] However, since the 6-min walk test has been largely used, and it has already been validated and related to morbidity/mortality in COPD subjects, we suggest that 6MST should substitute for the walk test only under certain circumstances. The 6MST should be used when there is not an adequate area in which to perform it or when the time is too short to allow a

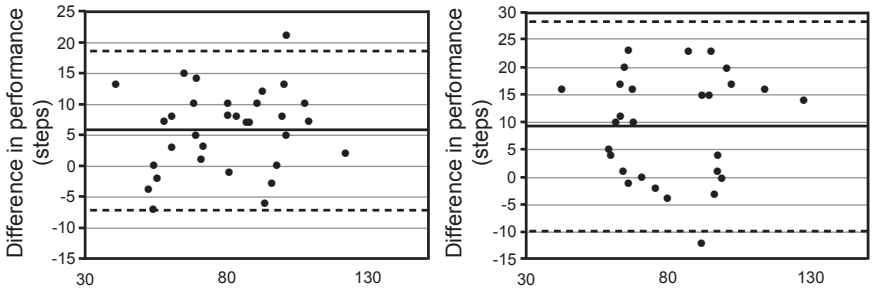

Fig. 2. Reproducibility in COPD patients. Left: Intra-rater six-minute step tests. Mean error = 5.75 steps. Right: Inter-rater six-minute step test (best of first 2 tests). Mean error = 9.25 steps.

familiarization test or an adequate recovery interval because of large sample sizes.

Inter-rater relative reproducibility was also excellent, and there were no significant differences among the comparisons, but it presented higher limits of agreement and standard error of measurement and the minimal detectable difference, which were considered above acceptable. Thus, we believe that performances in two tests controlled by different assessors should not be compared. Taking this into consideration, questions should be raised whether other functional tests, such as the 6-min walk test, should be performed by different assessors.

The extrapolation of this study could be limited because of the use of a convenience sample. Moreover, subjects could already being in physical training, but since one week is not enough to change exercise capacity, one can affirm that it did not influence the differences between the first two tests and the third test.

Conclusions

We conclude that cadence-free 6MST is a reproducible test in the population of COPD subjects when performed by the same examiner.

REFERENCES

1. Fromer L, Cooper CB. A review of the GOLD guidelines for the diagnosis and treatment of patients with COPD. Int. J. Clin. Pract. 2008;62(8):1219-1236.
2. Dourado VZ, Tanni SE, Vale SA, Faganello MM, Sanchez FF, Godoy I. Systemic manifestations in chronic obstructive pulmonary disease. J Bras Pneumol 2006;32(2):161-171.
3. Casas A, Vilaro J, Rabinovich R, Mayer A, Barbera JA, Rodriguez-Roisin R, et al. Encouraged 6-min walking test indicates maximum sustainable exercise in COPD patients. Chest 2005;128(1):55-61.
4. Leung AS, Chan KK, Sykes K, Chan KS. Reliability, validity, and responsiveness of a 2-min walk test to assess exercise capacity of COPD patients. Chest 2006;130(1):119-125.
5. Cataneo DC, Cataneo AJ. Accuracy of the stair climbing test using maximal oxygen uptake as the gold standard. J Bras Pneumol 2007; 33(2):128-133.
6. 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):111-117.
7. Dal Corso S, Duarte SR, Neder JA, Malaguti C, de Fuccio MB, de Castro Pereira CA, et al. A step test to assess exercise-related oxygen desaturation in interstitial lung disease. Eur Respir J 2007;29(2):330-336.
8. Dourado VZ, Antunes LC, Tanni SE, de Paiva SA, Padovani CR, Godoy I. Relationship of upper-limb and thoracic muscle strength to 6-min walk distance in COPD patients. Chest 2006;129(3):551-557.
9. Enright PL, Sherrill DL. Reference equations for the six-minute walk in healthy adults. Am J Respir Crit Care Med 1998;158(5 Pt 1): 1384-1387.
10. Casanova C, Cote C, Marin JM, Pinto-Plata V, de Torres JP, Aguirre-Jaíme A, et al. Distance and oxygen desaturation during the 6-min walk test as predictors of long-term mortality in patients with COPD. Chest 2008;134(4):746-752.
11. Cote CG, Pinto-Plata V, Kasprzyk K, Dordelly LJ, Celli BR. The 6-min walk distance, peak oxygen uptake, and mortality in COPD. Chest 2007;132(6):1778-1785.
12. Pitta F, Troosters T, Spruit MA, Probst VS, Decramer M, Gosselink R. Characteristics of physical activities in daily life in chronic obstructive pulmonary disease. Am J Respir Crit Care Med 2005;171(9): 972-977.
13. Neder JA, Nery LE. Clinical Exercise Physiology. São Paulo: Artes Médicas; 2003.
14. Schnaider J, Karsten M. Tolerance tests to the exercise in a hospital physical therapy program in the exacerbation of the chronic obstructive pulmonary disease. Fisioter Mov 2006;9(4):119-126.
15. Pessoa BV, Jamami M, Basso RP, Regueiro EMG, Di Lorenzo VAP, Costa D. Step test and sit-to-stand test: behavior of metabolic, ventilatory and cardiovascular responses in patients with COPD. Fisioter Mov 2012;25(1):105-115.
16. Global Initiative for Chronic Obstructive Lung Disease (GOLD) 2014. Global Strategy for the Diagnosis, Management and Prevention of COPD. Updated 2014. http://www.goldcopd.org/guidelines-global-strategy-for-diagnosis-management.html. *Accessed on March 5, 2014.*
17. Fleiss JL. The design and analysis of clinical experiments. New York: John Wiley;1986.
18. Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L. Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. J Orthop Sports Phys Ther 2011;41(9):644-650.
19. Walter SD, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Stat Med 1998;17(1):101-110.
20. Hernandes NA, Wouters EF, Meijer K, Annegarn J, Pitta F, Spruit MA. Reproducibility of 6-minute walking test in patients with COPD. Eur Respir J 2011;38(2):261-267.
21. Andersson M, Moberg L, Svantesson U, Sundbom A, Johansson H, Emtner M. Measuring walking speed in COPD: test-retest reliability of the 30-metre walk test and comparison with the 6-minute walk test. Prim Care Respir J 2011;20(4):434-440.
22. Sciurba F, Criner GJ, Lee SM, Mohsenifar Z, Shade D, Slivka W, et al. 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):1522-1527.
23. Elías Hernández MT, Fernández Guerra J, Toral Marín J, Ortega Ruiz F, Sánchez Riera H, Montemayor Rubio T. [Reproducibility of a shuttle walking test in patients with chronic obstructive pulmonary disease]. Arch Bronconeumol 1997;33(2):64-68.
24. Marrara KT, Marino DM, Jamami M, de Oliveira AD Jr, Pires Di Lorenzo VA. Responsiveness of the six-minute step test to a physical training program in patients with COPD. J Bras Pneumol 2012; 38(5):579-587.
25. Stevens D, Elpern E, Sharma K, Szidon P, Ankin M, Kesten S. Comparison of hallway and treadmill six-minute walk tests. Am J Respir Crit Care Med 1999;160(5 Pt 1):1540-1543.