Hallway Versus Treadmill 6-Minute-Walk Tests in Patients With Chronic Obstructive Pulmonary Disease

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INTRODUCTION: The 6-min-walk test is widely used for functional evaluation of patients with chronic obstructive pulmonary disease (COPD), but the test requires a 30-m unobstructed hallway, which is not available in all institutions. A treadmill 6-min walk test might be more practical. METHODS: In a crossover study, we compared the results from hallway and treadmill 6-min-walk tests by 19 patients with moderate to very severe COPD. Each patient did 3 hallway tests and 3 treadmill tests. The hallway tests were according to the American Thoracic Society guidelines. RESULTS: The mean hallway walk distance was significantly (102 m, 95% confidence interval 65–139 m) greater than the mean treadmill walk distance. Between the hallway and treadmill tests, agreement was very poor via Bland-Altman analysis, correlation was low (r = 0.48, *P* = .04), and those differences were not explained by differences in patient effort. The differences between the 3 treadmill tests were greater than those between the 3 hallway tests, and in both the hallway and treadmill tests patient effort progressively diminished, indicating a learning effect. CONCLUSIONS: The hallway and treadmill walk tests are not interchangeable. We need further study and standardization of the treadmill 6-min walk test. *Key words: chronic obstructive pulmonary disease, COPD, 6-min walk test, treadmill.* [Respir Care 2009;54(12):1712–1716. © 2009 Daedalus Enterprises]

Introduction

Reduced exercise capacity greatly impacts quality of life in patients with moderate to severe chronic obstructive pulmonary disease (COPD).[1-4] Dynamic hyperinflation and respiratory and skeletal muscle inefficiency cause exercise limitation and dyspnea.[5] Evaluating exercise capacity is important in initial assessment, prognosis, and treatment of COPD.[3,6,7] The 6-min-walk test is simple, inexpensive, correlates with activities of daily living, and measures response to pulmonary rehabilitation.[8] The American Thoracic Society (ATS) guidelines provide a standardized method for the 6-min-walk test, which reduces inter-examiner variability.[9,10] The patient is informed that the objective is to measure the distance walked in 6 minutes and that he or she can slow down or stop for rest if needed. There are standard encouragement phrases at the end of each minute. As a submaximal test, limited by the patient, the 6-min walk test is considered safe, if there are no contraindications.[9,11,12]

The 6-min-walk test requires a 30-m hallway that is free of obstructions or interruptions (eg, intersecting hallways with passersby), and such a hallway is not available in all institutions. Performing the test on a treadmill would obviate the hallway. The ATS recommended against using a treadmill for the 6-min-walk test,[9] but that recommendation was based on just one study,[13] which, although well designed, was carried out before the ATS guidelines were published and technical aspects, such as standardized encouragement phrases, were set.

With patients with COPD, we compared the hallway and treadmill 6-min-walk tests, conducted per the ATS guidelines,[9] and watched for learning effect.

Methods

We conducted a randomized crossover study with subjects who had moderate, severe, or very severe COPD,[14]

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and who regularly attended the out-patient pneumology clinic at the Hospital das Clínicas, which is a teaching hospital of the Federal University of Pernambuco, Brazil. The protocol was approved by our institutional review board, and written informed consent was obtained from all subjects.

The exclusion criteria were history of coronary heart disease, unstable pulmonary disease (reported worsening respiratory symptoms in the last 7 days), musculoskeletal conditions that affect physical performance, inability to walk on a treadmill, change of medicines in the preceding 30 days, and high blood pressure (systolic $\geq$ 180 mm Hg or diastolic $\geq$ 110 mm Hg).

Sample size was calculated based on 2 previous studies. With a group of 21 patients, Stevens et al[13] found a mean $\pm$ SD 6-min walk-distance-difference of 55 $\pm$ 92 m between the hallway and treadmill 6-min-walk tests. Redelmeir et al[15] studied 112 COPD patients and found that the smallest 6-min-walk-distance difference that was significantly associated with clinical differences was 54 m (95% confidence interval 37–71 m). Based on those findings, a 2-tailed paired *t* test, and alpha and beta errors of .05 and .2, respectively, we found that a sample size of 18 subjects was required to detect a difference of 71 m. We used the upper Redelmeier confidence limit to guarantee that only clinically relevant differences would be considered discordant.

With consecutive patients who met the inclusion criteria we used simple randomization to allocate subjects to 2 groups. The first group performed the hallway 6-min-walk test first, then, 3–15 days later, performed the treadmill 6-min-walk test. The second group was evaluated in the opposite order. All the tests were performed in the morning. Each subject took the hallway and treadmill walk tests 3 times each, with a 30–60-min rest between each test, per the ATS guidelines.[9] One researcher, who has extensive experience in administering the 6-min-walk test, supervised all the tests.

Per the recommendation of the Brazilian Pneumology Society,[16] all subjects had spirometry (MicroQuark, Cosmed, Rome, Italy) at the beginning of each test day. We used the predicted pulmonary-function values for Brazilians.[17] We classified body mass index and obesity per the World Health Organization's criteria.[18] We measured heart rate, arterial oxygen saturation (S_{pO_2}) via pulse oximetry (M1000, JG Moriya, São Paulo, Brazil), and Borg dyspnea rating[19] immediately prior to and 2 minutes after each walk test. We calculated the percent-of-predict maximum heart rate (220 minus patient's age).

The hallway 6-min-walk test was performed in a 30-m flat hallway delineated with traffic cones, and with marks every 3 m. The treadmill 6-min-walk test was conducted on an electric treadmill (EG700X, Ecafix, São Paulo, Brazil) that has no inclination. Before the treadmill test the subject learned to operate the treadmill's start, stop, accelerate, and decelerate buttons. Other treadmill buttons and the treadmill's distance, time, and speed monitors were hidden.

There was no warming up before tests. Oral commands and coaching were the same for both methods, according to ATS guidelines.[9] The initial treadmill speed was zero, and the treadmill test began when the patient activated the treadmill and started walking. The patient controlled the treadmill speed during the test and could stop to rest at any time, as in the hallway test. We calculated the treadmill 6-min-walk distance by multiplying the number of complete treadmill-belt revolutions in 6 minutes by the length of the belt (308 cm).

Before, during, or after any walk test, the walk testing was discontinued[9] if the patient had thoracic pain, intolerable dyspnea, cramps, dizziness, staggering, diaphoresis, pallor, or an $S_{pO_2} < 90\%$.

Statistical Analysis

We analyzed the longest walk distances. We used the Shapiro-Wilk test to analyze data distribution, the Bland-Altman[20] method to analyze agreement between the walk tests, and Pearson's correlation coefficient to analyze the correlation between the walk tests. We used the paired Student's *t* test to compare the longest walk distances from each test day, the final exercise heart rate, differences between pre-test and post-test heart rate, and forced expiratory volume in the first second (FEV_1) on each test day. We used the Wilcoxon test for paired samples to compare the Borg dyspnea ratings. We made the calculations with statistics software (SPSS 10.0, SPSS, Chicago, Illinois, and Excel, Microsoft, Redmond, Washington).

Results

Table 1 describes the 19 subjects. There were no statistically significant differences between the test days in baseline FEV_1 (P = .45), heart rate (P = .71), or S_{pO_2} (P = .051).

The mean hallway 6-min-walk distance (509 $\pm$ 66 m) was 102 m greater than the mean treadmill 6-min-walk distance (407 $\pm$ 86 m) (95% confidence interval 65–139 m, $P < .001$). Only one patient walked further on the treadmill than in the hallway. The Bland-Altman plot (Fig. 1) shows poor agreement between the tests. The difference between the hallway and treadmill walk distance tended to decline as the mean distance increased, as shown by the regression line. Ten (53%) of the 19 subjects had hallway-versus-treadmill walk-distance differences $>$ 71 m (the difference that Redelmeier et al[14] decided was clinically relevant).

The correlation between the maximum walk distances in the hallway versus treadmill tests was low to moderate

Table 1. Study Subjects (n = 19)

Age (mean ± SD y)	63.4 ± 10.5, range 46–80
Male (n)	14
Female (n)	5
Weight (mean ± SD kg)	63.3 ± 16.2, range 33.5–90.0
Height (mean ± SD cm)	160.5 ± 7.9, range 148–175
Body mass index (mean ± SD kg/m^2)	24.4 ± 5.3, range 15.3–33.5
Underweight (n)	2
Normal (n)	10
Overweight (n)	2
Obese (n)	5
COPD Severity	
Moderate	11
Severe	6
Very severe	2
FEV_1 (mean ± SD L)	
Before hallway 6-min walk test	1.26 ± 0.39, range 0.35–1.78
Before treadmill 6-min walk test	1.25 ± 0.41, range 0.32–1.76

COPD = chronic obstructive pulmonary disease
FEV_1 = forced expiratory volume in the first second

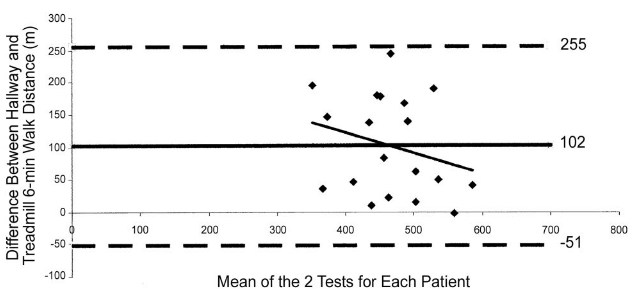

Fig. 1. Bland-Altman plot of the agreement between the hallway 6-min-walk test and the treadmill 6-min-walk test. The dashed lines represent the limits of agreement. The solid horizontal line represents the mean difference. The diagonal is the regression line.

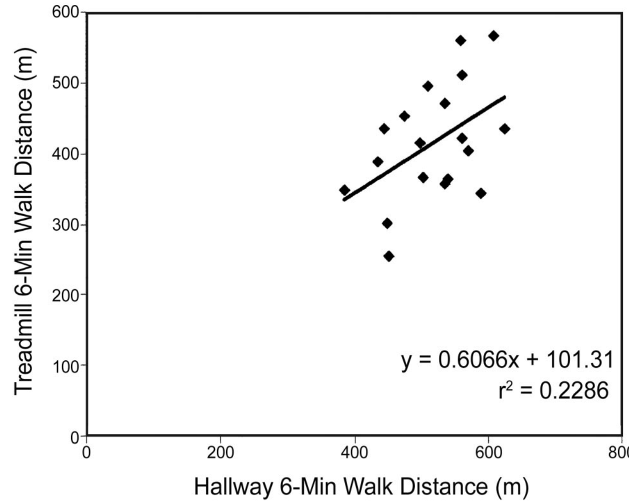

Fig. 2. Correlation between the hallway 6-min walk distance and the treadmill 6-min walk distance.

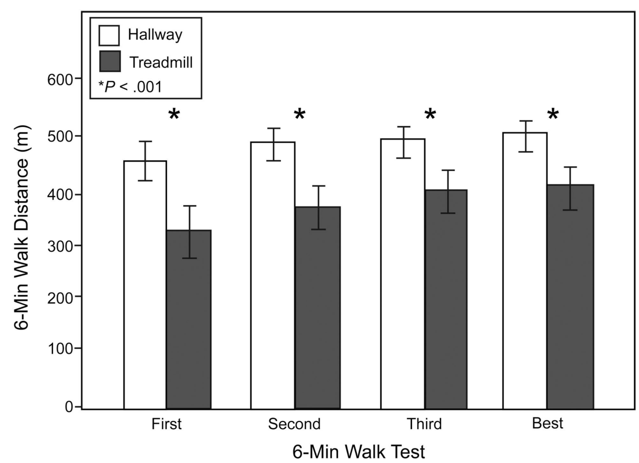

Fig. 3. Mean walk distances in the first, second, third, and best hallway and treadmill 6-min walk tests.

(r = 0.48), and the difference was statistically significant (P = .04) (Fig. 2), so the probability of accurately predicting the hallway walk distance from the treadmill walk distance is only 23%, which is not acceptable.

There was a strong learning effect. In the hallway tests there was a significant difference between the first test and the 2 subsequent tests collectively, though not between the second and the third tests. In the treadmill tests there were significant differences between all 3 tests. In the hallway test the greatest walk distance was in the third test in 10 subjects, in the second test in 7 subjects, and the first test in 2 subjects. In the treadmill test the greatest walk distance was in the third test in 15 subjects, in the second test in 3 subjects, and the first test in 1 subject. The walk-distance difference between the hallway and treadmill tests diminished from the first to the third test (Fig. 3).

Post-test heart rate was not significantly different (P = .48). Eleven subjects (58%) reached their highest heart rate after the treadmill test, 7 (37%) following the hallway test, and 1 subject had the same heart rate following both tests. There were no significant differences in the percent-of-predicted maximum heart rate after each test (P = .44), which suggests a similar effort level during the treadmill and hallway tests.

There was also no statistically significant difference in post-test Borg dyspnea rating (P = .47). Eight subjects reported greater dyspnea after the treadmill test, 6 after the hallway test, and 5 reported no difference in post-test dyspnea.

Discussion

There was a significant walk-distance difference between the hallway and treadmill tests. Fifty-two percent of the individual differences between tests were above the value considered clinically relevant.[15] The low correlation between the test methods does not allow prediction of hallway walk distance from treadmill walk distance. A high correlation would be expected between methods that measured the same variable in the same patients.[20] Age, weight, height, motivation, and cognitive level can affect walk distance,[10,21] but we don't think those factors affected our results, because we compared tests by the same patient.

There were no significant differences in post-test heart rate and dyspnea, which suggests that our subjects made similar efforts in the hallway and treadmill tests. Since the 6-min-walk test does not provide specific information about the systems involved in carrying out physical exercise, we could not evaluate whether the walk-distance differences were due to: greater energy expenditure during treadmill walking; the use of muscles that are not used in hallway walking; or greater anxiety or difficulty caused by unfamiliarity with the treadmill. Another possibility is that the subjects spent the first few treadmill minutes ramping up to the speed at which they would begin the hallway walk, despite the standardized encouragement phrases delivered at 1-minute intervals up to the end of the test. One way to study this issue would be to start the treadmill test at a low belt speed, as did Stevens et al,[13] who found a smaller mean walk-distance difference than we did (55 m vs 102 m).

The patient's skill in walking on the treadmill is crucial to the treadmill walk distance, but there have been no studies done with the aim of optimizing patients' treadmill walking skill. We don't know the number of treadmill walk tests that would be needed to minimize the walk-distance difference between the hallway and treadmill tests.

There was a clear learning effect with both the hallway and treadmill tests, but the effect was larger in the treadmill test. The decreasing difference between the treadmill and hallway walk distance might be explained by increasing familiarity with the treadmill. We did not test whether the walk-distance difference decreased further with more treadmill walk tests. In the hallway test, 3 tests minimized the walk-distance improvement effect.[12,22] A future study should evaluate the number of treadmill tests needed to get beyond the learning effect and achieve reproducibility. However, more than 3 walk tests per session could fatigue a patient with COPD. Training sessions should be done at greater intervals, probably on different days.

Previous studies found a poor correlation between FEV_1 and exercise capacity in patients with COPD.[23] Large exercise-capacity differences on different test days might have influenced our results, but we do not think that was the case, and we do not know the cause of the hallway-versus-treadmill walk-distance differences. Disease severity might also affect walk-distance differences, but our study was not powered to answer to that question. Excluding the 2 patients who had very severe COPD from the analysis did not change the results.

The 6-min-walk test is an important instrument for functional evaluation of patients with cardiorespiratory disease.[1,3,7-11,15,24-29] Stevens et al[13] also found a substantial hallway-versus-treadmill walk-distance difference (55 ± 92 m), which, like our results, indicates that the hallway and treadmill tests are not interchangeable. But Stevens et al[13] emphasized the advantages of the treadmill test and did not discount its potential utility. However, Stevens et al[13] did not use the standardized ATS protocol[9] for the hallway test, and they included patients with other diseases than COPD.

Swerts et al[30] also found hallway walk distances (after 2, 6, and 12 min) significantly greater than treadmill walk distances. The hallway-versus-treadmill differences at 2 min and 6 min were similar (10.2% and 9.2%, respectively), and larger than that at 12 min (7.8%), which suggests some patient adaptation to the treadmill. They did not find any difference in heart rate or dyspnea between the hallway and treadmill tests and therefore concluded there was no significant difference in patient effort. They concluded that the hallway test is preferable.

The ATS guidelines[9] are an important instrument for standardization of the 6-min-walk test and promote comparable walk-test administration among investigators. The guidelines explicitly recommend against treadmill use, based on the results of only one, albeit well designed, study.[13] The ATS statement encouraged further studies on controversial topics, to contribute to guideline updates,[9] which was our motivation to reproduce the Stevens et al[13] study with the walk tests conducted per the ATS guidelines. We believe ATS should standardize a treadmill 6-min-walk test.

Conclusions

There is a poor correlation between the hallway and treadmill 6-min-walk tests, so they are not interchangeable. There were no significant differences in dyspnea or heart rate (which we assumed to be proxies for patient effort) between the hallway and treadmill tests. The influence of the learning effect in the walk-distance differences and improvements requires further investigation. Issues of test standardization, reproducibility, and minimum clinically important improvement after repeated treadmill tests need to be addressed to determine the treadmill test's role in patient assessment. We think the treadmill test may become a valuable tool.

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