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ORIGINAL RESEARCH

Reproducibility and Sensitivity of the 6-Minute Stepper Test in Patients with COPD

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Abstract

The aims of this study were to test the reproducibility of the 6-minute stepper test (6MST), and evaluate its accuracy in detecting improved functional capacity after pulmonary rehabilitation (PR) in patients with chronic obstructive pulmonary disease (COPD). Thirty-five COPD outpatients performed two 6MSTs in the same session, before ($6MST_1$ and $6MST_2$) and after ($6MST_3$ and $6MST_4$) PR. The performance, perceived exertion, heart rate and arterial oxygen saturation were measured during each 6MST. The performance was higher during the second 6MST of the same session (before PR: 514 strokes during the $6MST_2$ > 471 strokes during the 6MST1, and after PR: 559 strokes during the $6MST_4$ > 508 strokes during the $6MST_3$; $p = 0.04$). After PR, 6MST performance was higher than before PR ($6MST_3$ > $6MST_1$ and $6MST_4$ > $6MST_2$; $P < 0.01$). The bias (the difference in the number of strokes) between the two 6MSTs from the same session (before PR: $6MST_2$-$6MST_1$ = 42 strokes vs after PR: $6MST_4$-$6MST_3$ = 52 strokes) was not different ($P = 0.34$). However, both bias were greater than 0 ($P < 0.001$). The mean performances for the two 6MSTs of the same session (before PR: $6MST_1$ and $6MST_2$ and after PR: $6MST_3$ and $6MST_4$) were correlated with the bias between these performances ($P < 0.01$; $r = 0.32$). The perceived exertions were lower after PR ($P < 0.02$). The systematic improvement of performance (8–10%) during the second 6MST of the each session may be explained from the warming of hydraulic jacks of the stepper and/or learning effect. On the other hand, the 6MST seems sufficiently sensitive to detect functional capacity improvements after PR in patients with COPD.

Introduction

The 6-minute walking test (6MWT) is frequently used to evaluate functional capacity and/or the effects of pulmonary rehabilitation (PR) programme in patients with chronic obstructive pulmonary disease (COPD) (1–3). This field test is valid, reproducible and sensitive in patients with COPD (4). However, the 6MWT does have certain limitations, the main one being the environmental constraints (5). To perform a 6MWT, a corridor at least 30 meters long is recommended (6–7). Shorter corridors are inappropriate because they force patients to turn around more often, which slows the walking pace and thus reduces the distance patients are able to cover (6–7), and the functional capacity of patients with COPD might therefore be underestimated (8). Sciurba *et al.* (9), have also showed that patients with severe emphysema performed significantly longer walking distances with a continuous 6MWT (circular or oval course) than those tested with a 6MWT in a straight corridor (back and forth). The corridor length and/or layout might

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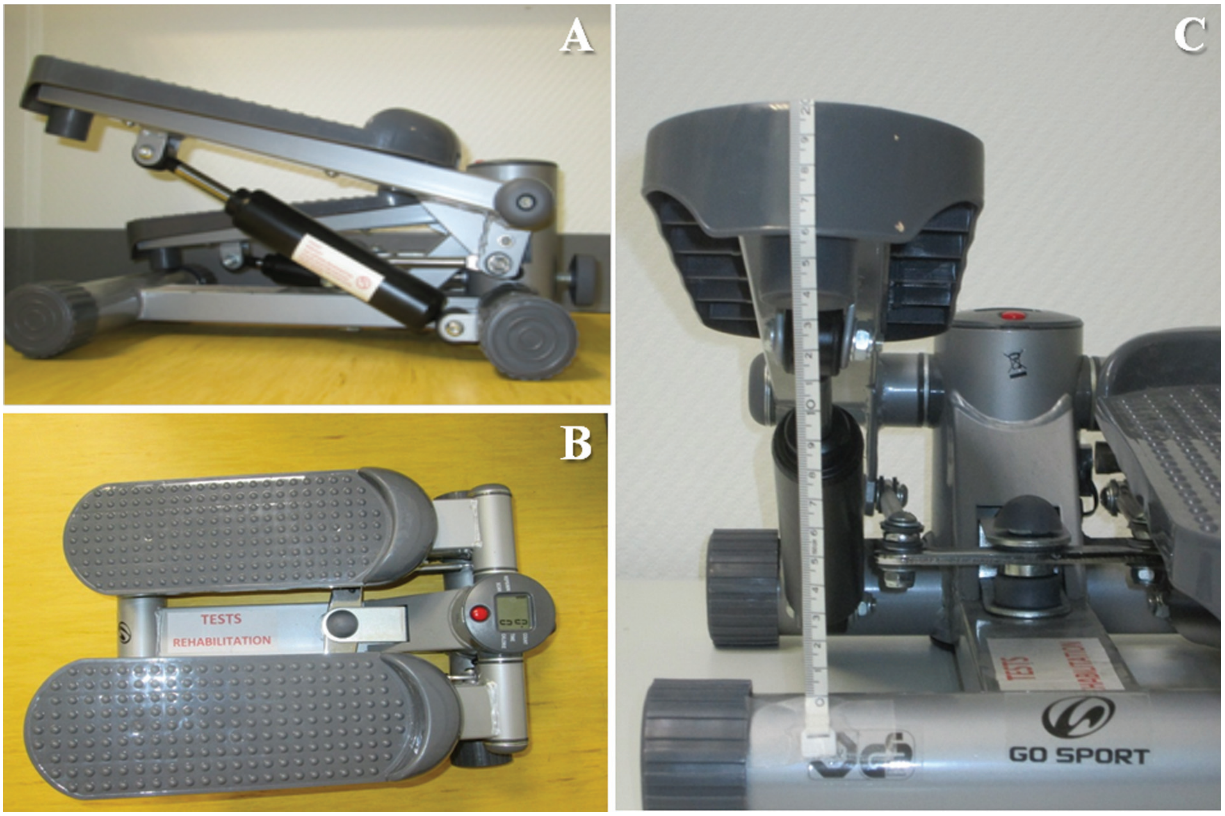

Figure 1. Photography (A: side view, B: top view, and C: back view) of the stepper (Go Sport®, Grenoble, France).

thus influence the walking distance covered during the 6MWT, thereby affecting the evaluation of patients' functional capacities.

In patients with mild-to-moderate interstitial lung disease, it is possible to use a six-minute step test (single-step device with no handle) instead of the 6MWT to assess exercise-related oxyhaemoglobin desaturation and exercise capacity (8). However, step tests are not advisable for all patients with pulmonary disease because of the risk of falling. Moreover, the joint problems frequently encountered with ageing suggest that a stepper is probably a better apparatus than a single-step device for older patients with COPD (5). In particular situations, a test on a stepper should be recommended because of safety concerns.

Recently a 6-minute stepper test (6MST; Figure 1) was proposed to circumvent the environmental constraints of the 6MWT (5). The authors noted: 1) significant correlations between the 6MWT and the 6MST for oxygen uptake and heart rate; 2) significantly higher performance during the second 6MST of each session due to a familiarization effect or to some technical issues with the stepper as the warming of the hydraulic jacks, but no significant difference between sessions (comparison of the mean performances, the bias and measure of 95% limits of agreement: 95% LoA), suggesting the reproducibility of the test; and 3) significantly higher 6MST performance in healthy subjects compared with patients with COPD, suggesting the discriminative properties of the 6MST.

The 6MST was also reported to be feasible for patients with pulmonary disease (10–11), and the number of steps completed in the 6MST was strongly correlated with the distance covered in the 6MWT (10). The 6MST thus seems to be a valid and reproducible field test (5). Moreover, the price of the stepper is low (approximately 40 €). However, no study to our knowledge has examined the 6MST performances measured before and after PR in patients with COPD. The aims of the study were therefore to: 1) assess the reproducibility of the 6MST, and 2) evaluate its capacity to detect functional capacity improvements after PR in patients with COPD.

Methods

Patients

Thirty-five sedentary outpatients (40% of women; n = 14), which were clinically diagnosed with COPD (having a ratio between the forced expiratory volume in one second and the forced vital capacity < 70%) and coming to a medical centre to participate in a PR, were volunteered to take part in this study. This study was conducted according to the ethical standards in sport and exercise science research (12), and also approved by the Authorities Concerned (CEPRO 2011-036).

Study design

Before entering the study, the patients were measured for height (in cm; model 220, Seca®, Hamburg, Germany) and body mass (in Kg; TBF 543, Tanita®, Tokyo, Japan).

The same day, spirometric data were evaluated using a spirometer (Ergocard, Medisoft, Sorinnes, Belgium). During this preliminary session, the participants were familiarised with the Borg CR10 scale (13) and a copy was provided to each participant. Two 6MSTs were performed before the six weeks of PR (first 6MST before PR: $6MST_1$ and second 6MST before PR: $6MST_2$). The PR consisted of three 30-minute sessions per week on an electromagnetically braked cycle ergometer. The intensity imposed during the training sessions corresponded to the ventilatory threshold. In addition to physical exercise, health education sessions and psychosocial follow-up were proposed. After the 6 weeks of PR, 2 6MSTs were again performed (first 6MST after PR: $6MST_3$ and second 6MST after PR: $6MST_4$).

6MST

Before each 6MST, all patients spent 2 minutes familiarising themselves with the same stepper (Go Sport®, Grenoble, France; Figure 1), as none had prior experience using one. This period was followed by a 3-minute rest period, and then the patients started the first 6MST (before PR: $6MST_1$ and after PR: $6MST_3$). For this test, we used the instructions proposed by Borel et al. (5), which were an adaptation of the instructions for the 6MWT given by the ATS (6).

The stepper was placed near a wall to permit the participants to put a hand on the wall if they became unbalanced or exhausted. For the upper position, the step height was fixed at 20 cm for all participants. Although the used stepper may display: the exercise time, the number of strokes (i.e., steps) per minute, the total number of strokes, or even the number of spent calories, only the total number of strokes is displayed during the 6MSTs. During the tests, the temperature of the air-conditioned room was always maintained between 20°C and 24°C.The participants could freely regulate their own rate of stepping.

During each 6MST, the (muscular and dyspnea) CR10, arterial oxygen saturation (SpO_2; Oximeter 3100, Nonin, MN, USA), and HR (Polar S810, Polar Electro Oy, Kempele, Finland) were measured every minute and then averaged. The number of strokes (*i.e.*, number of steps counted by the stepper) was also recorded. After the first 6MST (before PR: $6MST_1$ and after PR: $6MST_3$), a 20-minute passive recovery allowed the participants' HR to return to resting values before the start of the second 6MST (before PR: $6MST_2$ and after PR: $6MST_4$).

Statistical analysis

Data are expressed as mean ± standard deviation or standard error of measurement. Normal Gaussian distributions of the data were verified by the Shapiro-Wilk test, while the homogeneity of variance was tested by the Cochran test. A one-way (test factor) repeated measures (time factor) ANOVA was performed to compare the CR10, SpO_2, fall of SpO_2 (i.e., rest SpO2 – SpO2 at the exercise end), HR, HR at the exercise end (% maximal HR), and the number of strokes during the 6MST. The bias between $6MST_2$-$6MST_1$ and between $6MST_4$-$6MST_3$ were compared with a Student's t-test for paired data.

Moreover, the Bland and Altman method (14) was used to evaluate the agreement of the performances between the two 6MSTs of the same session (before PR: $6MST_1$ and $6MST_2$ and after PR: $6MST_3$ and $6MST_4$). This method requires the calculation of the mean difference (bias) between the performances obtained during the second and the first 6MST of each session (before PR: $6MST_2$-$6MST_1$ and after PR: $6MST_4$-$6MST_3$), as well as ± 1.96 standard deviation of these differences (95% LoA). Before using this method (14), we verified the normality of the distribution of these bias and the homoscedasticity. Moreover, we tested the null hypothesis that the bias was not different from zero with the Student's t-test. Last, the lack of significant relationship between the bias (before PR: $6MST_2$-$6MST_1$ and after PR: $6MST_4$-$6MST_3$) and the mean of the performances during the second and first 6MSTs (before PR: $6MST_1$ and $6MST_2$ and after PR: $6MST_3$ and $6MST_4$) was tested using a Bravais-Pearson test. Finally, Cronbach's α and intraclass correlation coefficients (ICC) were also assessed to attest the agreement between the performances. Statistical significance was set at $p < 0.05$. All calculations were made with SPSS software (SPSS Inc., Chicago, IL, USA).

Results

Thirty-five patients were included in the present study, but 5 of them did not complete the PR. Consequently, the data after PR included 30 patients. The patient characteristics are shown in Table 1.

Muscular and dyspnea CR10 and HR were not significantly different between the first 6MST and second 6MST (i.e., before PR: $6MST_1$ vs $6MST_2$ and after PR:

Table 1. Anthropometric and spirometric data of the chronic obstructive pulmonary disease patients

Variable (units)	
Women (%)	40.0
Age (years)	60.8 ± 8.9
Height (cm)	167 ± 10
Body mass (kg)	74.0 ± 15.3
Body mass index (kg.m^{-2})	26.5 ± 5.3
FEV_1 (L)	1.7 ± 0.6
FEV_1 (%)	63.4 ± 20.5
FVC (L)	2.7 ± 0.8
FVC (%)	74.2 ± 21.2
FEV_1/FVC (%)	62.4 ± 4.1

FEV_1: forced expiratory volume in one second; FVC, forced vital capacity.

Table 2. Perceptual and physiological data (mean ± standard error of measurement) obtained during the 6-minute stepper tests before and after pulmonary rehabilitation

	$6MST_1$	$6MST_2$	Mean	$6MST_3$	$6MST_4$	Mean
Mean muscular CR10	4.1 (0.3)	4.0 (0.4)	4.1 (0.7)	3.7 (0.5)	3.8 (0.5)	3.7 (0.5)*
Mean dyspnea CR10	3.9 (0.4)	3.6 (0.3)	3.8 (0.6)	3.3 (0.5)	3.3 (0.5)	3.3 (0.5)*
Mean SpO_2 (%)	94.7 (0.4)	94.5 (0.4)	94.6 (0.8)	94.5 (0.9)	94.1 (1.0)	94.3 (0.9)
Fall of SpO_2 (%)	3.1 (0.5)	3.3 (0.3)	3.2 (0.8)	3.7 (0.9)	3.1 (0.7)	3.4 (0.8)
Mean HR (% maximal HR)	68.5 (1.8)	71.1 (1.8)	69.8 (3.2)	65.6 (2.5)	67.9 (2.7)	66.7 (2.6)#
HR at the exercise end (% maximal HR)	69.8 (2.0)	75.0 (3.2)	72.4 (3.4)	69.0 (3.0)	71.8 (3.7)	70.4 (3.3)

$6MST_1$: first 6-minute stepper test before pulmonary rehabilitation; $6MST_2$: second 6-minute stepper test before pulmonary rehabilitation; $6MST_3$: first 6-minute stepper test after pulmonary rehabilitation; $6MST_4$: second 6-minute stepper test after pulmonary rehabilitation; CR10: (muscular or dyspnea) perceived exertion from the Borg 10-point category-ratio scale; SpO_2: arterial oxygen saturation; HR: heart rate; *significant difference between before and after pulmonary rehabilitation ($P < 0.02$); #significant difference between before and after pulmonary rehabilitation ($P < 0.01$).

$6MST_3$ vs $6MST_4$; no "test" effect; Table 2). However, no significant difference was found about the fall of SpO_2 and % maximal HR between the tests of the same session (Table 2).

The number of strokes was significantly higher during second 6MSTs in comparison with first 6MSTs (i.e., before PR: $6MST_2 > 6MST_1$ and after PR: $6MST_4 > 6MST_3$; "test" effect; $P = 0.04$; Table 3).

The performances measured during 6MSTs before PR ($6MST_1$ vs $6MST_2$) were significantly correlated ($r = 0.92$; $p < 0.01$; ICC = 0.919; Cronbach's α = 0.952). Similar results were found after PR ($6MST_3$ vs $6MST_4$; $r = 0.95$; $p < 0.01$; ICC = 0.945; Cronbach's α = 0.972). Figure 2 presents the Bland and Altman results (14) before and after PR, respectively.

Table 3. Mean (standard error of measurement) of the performances obtained during the six-minute stepper tests before and after the pulmonary rehabilitation

Performance (units)	Mean (standard error of measurement)
Before pulmonary program	
$6MST_1$ (strokes)	473 (37.1)
$6MST_2$ (strokes)	514 (40.4)
Mean ($6MST_1 + 6MST_2$ / 2; strokes)	494 (37.8)
Difference ($6MST_2 - 6MST_1$; strokes)	42 (15.6)
After pulmonary program	
$6MST_3$ (strokes)	508 (40.8)
$6MST_4$ (strokes)	559 (47.1)
Mean ($6MST_3 + 6MST_4$ / 2; strokes)	533 (43.4)#
Difference ($6MST_4 - 6MST_3$; strokes)	52 (17.9)
Before and after pulmonary program	
Mean ($6MST_1 + 6MST_3$ / 2)	489 (39.1)
Mean ($6MST_2 + 6MST_4$ / 2)	535 (43.8)*
Difference ($6MST_3 - 6MST_1$)	34 (22.5)
Difference ($6MST_4 - 6MST_2$)	45 (25.9)

$6MST_1$: first 6-minute stepper test before pulmonary rehabilitation; $6MST_2$: second 6-minute stepper test before pulmonary rehabilitation; $6MST_3$: first 6-minute stepper test after pulmonary rehabilitation; $6MST_4$: second 6-minute stepper test after pulmonary rehabilitation; *significant difference between the first and second tests ($P < 0.05$); #significant difference between before and after pulmonary rehabilitation ($P < 0.01$).

The difference (bias) in the number of strokes between the two 6MST tests of the same session (before PR: $6MST_2$-$6MST_1$ and after PR: $6MST_4$-$6MST_3$) was significantly higher than 0 ($p < 0.001$). Moreover, this bias was significantly correlated with the difference between the same two performances on the 6MST ($p < 0.01$; $r = 0.32$). However, the difference (bias) in the number of strokes between the two 6MST tests of the same session (before PR: $6MST_2$-$6MST_1$ and after PR: $6MST_4$-$6MST_3$) did not significantly differ between the two sessions ($P = 0.34$; Table 3).

Muscular and dyspnea CR10 and HR before PR were significantly higher than after PR (i.e., $6MST_3 > 6MST_1$ and $6MST_4 > 6MST_2$; "time" effect; $p < 0.02$; Table 2). No significant difference was found for the time factor (PR effect) about the fall of SpO_2 and % maximal HR (Table 2). The number of strokes was significantly higher after PR than before PR (i.e., $6MST_3 > 6MST_1$ and $6MST_4 > 6MST_2$; "time" effect; $p < 0.01$; Table 3).

Discussion

As expected and in agreement with the previous findings (5), the performance during first 6MST of each session was lower than that of the second 6MST (i.e., before PR: $6MST_2 > 6MST_1$ and after PR: $6MST_4 > 6MST_3$) because the hydraulic jacks of the stepper used in the study were more flexible once they had warmed up (which bias may not be controlled), producing significant differences between the tests of each session (Table 3). Moreover, this effect of the hydraulic jacks was confirmed by a bias significantly higher than 0 (Figure 2) during both sessions. The significant difference in the number of strokes in the two 6MSTs of the same session ($6MST_1$ vs $6MST_2$ or $6MST_3$ vs $6MST_4$) suggests that an 8–10% improvement in performance linked to warmed-up jacks for the second 6MST can be expected (i.e., during $6MST_2$ and $6MST_4$; Table 3). This systematic improvement from the stepper of the present study (Go Sport®, Grenoble, France; Figure 1) is possibly unavoidable for all commercially available steppers which hydraulic

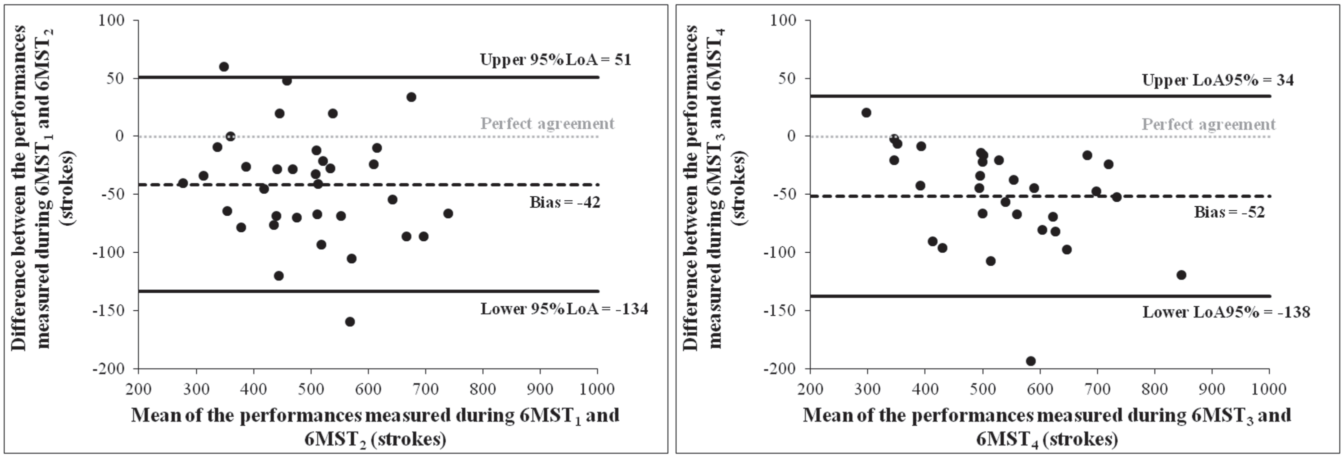

Figure 2. Bland and Altman plots for the comparison between the performances measured from the first ($6MST_1$ or $6MST_3$) and second ($6MST_2$ vs $6MST_4$) 6-minute stepper tests before (left panel) and after (right panel) pulmonary rehabilitation. The dashed line is the bias and the solid lines are the 95% limits of agreement (95% LoA).

jacks. Nevertheless, this bias is perhaps not the same between the different steppers, and is probably influenced by the mechanic characteristics of the hydraulic jacks. However, further studies must be performed to confirm this hypothesis.

In addition to the effect of the hydraulic jacks during the second 6MST, a learning effect might be suggested. Indeed, although the 6MWT is a reproducible test in COPD patients, several authors have suggested a learning effect to explain why patients achieve a considerably greater walking distance when a second test is performed (4, 9, 15). For example, Leach et al. (15) found an increase of approximately 9% in the distance walked when a second 6MWT was performed in the same session in pulmonary patients. Sciurba et al. (9) then reported an increase in performance during the second 6MWT (+7%) in patients with severe and very severe COPD. More recently, Hermandes et al. (4) confirmed this result in a larger sample of patients with COPD (+7%). Based on these findings for the 6MWT and the previous findings (5), it might be hypothesised that a learning effect would also explain the performance increase during the second 6MST in the present study. However, from our data, it is not possible to identify if the warming of hydraulic jacks of the stepper and/or learning effect explain(s) this systematic improvement of performance. To differentiate between these two possibilities, it would be interesting to familiarize the patients with the stepper. Moreover, waiting to explain the systematic improvement of performance during the second 6MST (warming of hydraulic jacks of the stepper and/or learning effect), we recommend to perform two 6MST, and to use the performance on the second 6MST.

The 6MWT is frequently used to evaluate functional capacity improvements during and after PR in patients with COPD. For example, Rejbi et al. (3) examined the impact of 12 weeks of PR on the iterative weekly measurement of performance during a 6MWT in 32 patients with moderate-to-severe COPD. The PR consisted of three 45-minute sessions of physical exercise per week. The results showed a significantly higher performance during the 6MWT after PR (+23%). Moreover, the dyspnea CR10 and HR at the end of the 6MWT decreased significantly after PR ($p < 0.05$). However, no significant change in SpO_2 at the end of 6MWT was noted. These results are similar to those of the present study because decreases in muscular and dyspnea CR10 and HR were identified after PR, whereas no significant change was noted for SpO_2 (Table 2).

The study of Rejbi et al. (3) also revealed that, although patients with COPD and healthy subjects presented improved 6MWT performances after the same PR, this response differed quantitatively and qualitatively. Quantitatively, the increase in 6MWT performance was significantly higher in the controls than patients. From a qualitative point of view, PR induced a logarithmic increase in 6MWT performance in the patients with COPD, whereas the healthy subjects showed a linear increase. As has already been indicated, this linear increase could be explained by a linear rise in peak oxygen uptake during PR over 10–12 weeks in the healthy subjects (3, 16). In contrast, the patients with COPD seemed to reach a plateau in their performance improvement before eight weeks probably because many factors such as baseline structure and biochemical status in COPD muscles or oxidative stress induced by exercise (3). To our knowledge, no study has examined the PR programme effects on stepper performance for a period longer than 8 weeks, yet these studies in COPD patients are needed.

Recently, Marrara et al. (17) evaluated the PR programme effects on 6MST performance using 20-cm-high step (rather than stepper) in patients with COPD who were randomised into two groups. One group followed a PR (i.e., 30 minutes of walking on a treadmill, with three sessions per week for 6 weeks at approximately 70% of the maximal walking velocity), whereas the other group remained untrained. From their results (+27% only in the trained group), the authors concluded that the 6MST permits to detect physical fitness improvements linked to treadmill PR (17).

Similarly, Rammaert et al. (18) used the same 6MST as in the present study and evaluated the impact of a 6-week, home-based PR on cycle ergometer in patients with idiopathic pulmonary fibrosis. These authors found a significant increase in the number of strokes after PR (+42%; $p = 0.03$), which agrees with the present finding of a significant improvement in 6MST performance after PR (i.e., $6MST_3 > 6MST_1$ and $6MST_4 > 6MST_2$). Moreover, these results were more recently confirmed by Grosbois et al. (11) in patients with different pulmonary diseases.

The results of the present study showed that the mean 6MST performances for the two tests of the same session were slightly but significantly correlated with the differences between the same two performances (i.e., the bias) on the 6MST. This suggests that the differences varied in a systematic way over the range of measurement (14). In other words, the scatter of the differences increased when the performance increased. Consequently, this result suggests that the LoA, which were rather enough large in general ($6MST_1$ vs $6MST_2$: $-134 < 95\%$ LoA < 51 and $6MST_3$ vs $6MST_4$: $-138 < 95\%$ LoA < 34), would be wider apart than necessary for low performances and narrower than they should be for high performances (14). However, because of weak sample size in the present study, we suggest that further studies are needed to confirm this hypothesis.

Previously, authors have proposed equations to evaluate the functional capacity (i.e., peak oxygen uptake) from 6MWT in patients with moderate to very severe COPD (19). However, no study to our knowledge has developed equations to predict the peak oxygen uptake from our 6MST. Consequently, similarly to 6MWT, it might be proposed shortly to develop regression equations for estimating peak oxygen uptake for men and women with COPD from the 6MST.

Conclusion

This study shows that a systematic improvement of performance (8–10%) during the second 6MST of the each session (i.e., before PR: $6MST_2 > 6MST_1$ and after PR: $6MST_4 > 6MST_3$) may be expected. It is hypothesized that this systematic bias may be explained from the warming of hydraulic jacks of the stepper and/or learning effect explain(s). However, the 6MST seems permit to detect functional capacity improvements after PR in patients with COPD.

Declaration of Interest Statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

1. Dolmage TE, Evans RA, Hill K, Blouin M, Brooks D, Goldstein RS. The effect of pulmonary rehabilitation on critical walk speed in patients with COPD: a comparison with self-paced walks. Chest 2012; 141:413–419.
2. Rasekaba T, Lee AL, Naughton MT, Williams TJ, Holland AE. The six-minute walk test: a useful metric for the cardiopulmonary patient. Intern Med J 2009; 39:495–501.
3. Rejbi IB, Trabelsi Y, Chouchene A, Ben Turkia W, Ben Saad H, Zbidi A, Kerken A, Tabka Z. Changes in six-minute walking distance during pulmonary rehabilitation in patients with COPD and in healthy subjects. Int J Chron Obstruct Pulmon Dis 2010; 9:209–215.
4. 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;38:261–7.
5. Borel B, Fabre C, Saison S, Bart F, Grosbois J-M. An original field evaluation test for chronic obstructive pulmonary disease population: the six-minute stepper test. Clin Rehabil 2010; 24:82–93.
6. American Thoracic Society. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002; 166:111–117.
7. Rabinovich RA, Vilaro J, Roca J. Evaluation exercise tolerance in COPD patients: the 6-minute walking test. Arch Bronconeumol 2004; 40:80–85.
8. Dal Corso S, Duarte SR, Neder JA, Malaguti C, de Fuccio MB, de Castro Pereira CA, Nery LE. A step test to assess exercise-related oxygen desaturation in interstitial lung disease. Eur Respir J 2007; 29:330–336.
9. Sciurba F, Criner GJ, Lee SM, Mohsenifar Z, Shade D, Slivka W, Wise RA. 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; 167:1522–1527.
10. Delourme J, Stervinou-Wemeau L, Salleron J, Grosbois JM, Wallaert B. Six-minute stepper test to assess effort intolerance in interstitial lung diseases. Sarcoidosis Vasc Dif 2012; 29:107–112.
11. Grosbois J-M, Le Rouzic O, Monge E, Bart F, Wallaert B. La réhabilitation respiratoire : évaluation de deux types de prise en charge, ambulatoire versus domicile. Rev Pneumol Clin 2013; 69:10–17.
12. Harriss DJ, Atkinson G. Update-ethical standards in sport and exercise science research. Int J Sports Med 2011; 32:819–821.
13. Borg G. Psychophysical bases of perceived exertion. Med Sci Sports Exer 1982; 14:377–81.
14. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 8:307–310.
15. Leach RM, Davidson AC, Chinn S, Twort CH, Cameron IR, Bateman NT. Portable liquid oxygen and exercise ability in severe respiratory disability. Thorax 1992; 47:781–789.
16. Hickson RC, Bomze HA, Holloszy JO. Linear increase in aerobic power induced by a strenuous program of endurance exercise. J Appl Physiol 1977; 42:372–376.
17. Marrara KT, Marino DM, Jamami M, Oliveira Junior AD, Di Lorenzo VA. Responsiveness of the six-minute step test to a physical training program in patients with COPD. J Bras Pneumol 2012; 38:579–587.
18. Rammaert B, Leroy S, Cavestri B, Wallaert B, Grosbois JM. Home-based pulmonary rehabilitation in idiopathic pulmonary fibrosis. Rev Mal Respir 2009; 26:275–282.
19. Carter R, Holiday DB, Stocks J, Grothues C, Tiep B. Predicting oxygen uptake for men and women with moderate to severe chronic obstructive pulmonary disease. Arch Phys Med Rehabil 2003; 84:1158–1164.