

# Encouraged 6-min Walking Test Indicates Maximum Sustainable Exercise in COPD Patients\*

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**Study objectives:** In patients with moderate-to-severe COPD, an encouraged 6-min walking test (6MWT) is a high-intensity submaximal exercise protocol that shows an oxygen uptake ( $\dot{V}O_2$ ) plateau after the third minute of the test. This last feature prompted the hypothesis that self-paced walking speed is set to achieve “maximal” sustainable  $\dot{V}O_2$ , namely “critical power” or “critical speed.”

**Patients and methods:** Eight patients with moderate-to-severe COPD (mean age,  $68 \pm 7$  years [ $\pm$  SD]; FEV<sub>1</sub>,  $50 \pm 13\%$  predicted; PaO<sub>2</sub>,  $69 \pm 8$  mm Hg) underwent the following tests on different days in order: (1) encouraged 6MWT; (2) standard incremental shuttle test to identify peak walking speed; (3) four different high-intensity, constant walking speed tests to exhaustion to calculate critical walking speed; and (4) timed walking test at critical walking speed (CWS) to examine sustainability of the exercise.

**Results:** 6MWT and CWS showed similar results (mean of last 3 min):  $\dot{V}O_2$  ( $1,605 \pm 304$  mL/min vs  $1,584 \pm 319$  mL/min), minute ventilation ( $47 \pm 12$  L/min vs  $48 \pm 11$  L/min), respiratory exchange ratio ( $0.89 \pm 0.1$  vs  $0.90 \pm 0.1$ ), heart rate ( $130 \pm 18$  beats/min vs  $131 \pm 16$  beats/min), Borg dyspnea score ( $5.4 \pm 1.3$  vs  $5.5 \pm 2.4$ ), and walking speed ( $1.49 \pm 0.1$  m/s vs  $1.44 \pm 0.1$  m/s, respectively).

**Conclusion:** This study supports that 6MWT indicates maximum sustainable exercise that might be related with its predictive value in COPD patients. (CHEST 2005; 128:55–61)

**Key words:** COPD; critical power; exercise testing; exercise tolerance; 6-min walking test; sustainable submaximal exercise

**Abbreviations:** ANOVA = analysis of variance; 6MWT = 6-min walking test; 6MWT-10 = 6-min walking test carried out in a 10-m course; 6MWT-90 = 6-min walking test carried out in a 90-m course; CWS = critical walking speed; GOLD = Global Initiative for Chronic Obstructive Lung Disease; HR = heart rate; L<sub>1</sub> = 90% of the peak walking speed; L<sub>2</sub> = 95% of the peak walking speed; L<sub>3</sub> = 100% of the peak walking speed; L<sub>4</sub> = 105% of the peak walking speed; RER = respiratory exchange ratio;  $\dot{V}CO_2$  = carbon dioxide output;  $\dot{V}E$  = minute ventilation;  $\dot{V}O_2$  = oxygen uptake;  $\dot{V}O_{2peak}$  = peak oxygen uptake

Impairment of exercise tolerance in COPD patients has important implications on health-related quality of life,<sup>1–3</sup> hospitalization rate,<sup>4,5</sup> and

survival.<sup>6,7</sup> Consequently, exercise testing is progressively being considered an essential component in the routine clinical assessment of functional status.

Recommendations on exercise testing in lung function laboratory settings are well established,<sup>8–10</sup> and the role of incremental cardiopulmonary cycling exercise as the “gold standard” for evaluation of exercise tolerance is acknowledged. We are facing, however, a widespread clinical use of simple exercise protocols<sup>3,11,12</sup> because of their simplicity, applicability, and low cost. Moreover, timed walking tests have been shown to predict survival<sup>6</sup> and utilization of health-care resources<sup>4,5</sup> in COPD patients. Therefore, it is suggested that simple exercise tests may be useful for staging of the disease.<sup>7</sup>

In a study<sup>13</sup> conducted in patients with moderate-to-severe COPD, we reported the 6-min walking test (6MWT) as a high-intensity, submaximal exercise protocol that shows an exponential oxygen uptake ( $\dot{V}O_2$ ) increase up to a plateau during the last 3 min

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of the test. From these results, we hypothesized that the self-paced walking speed during the test is set to achieve “maximal” sustainable exercise, which, by definition, corresponds to patient’s critical power,<sup>14</sup> or critical walking speed (CWS), defined as the maximum sustainable walking speed.

In the current study, we estimated the CWS in eight patients with moderate-to-severe COPD. The physiologic responses during the 6MWT were compared with those obtained during walking at CWS in the same patients. Identity between 6MWT and CWS may help to explain the high predictive value of 6MWT in chronic disorders.<sup>15,16</sup> An ancillary purpose of the investigation was the analysis of  $\dot{V}O_2$  profiles in four different common clinical exercise protocols performed in the same patients: incremental cycling exercise, 6MWT, incremental shuttle test, and stair-climbing test.<sup>10</sup>

## MATERIALS AND METHODS

Eight men with clinically stable COPD were recruited for the study. All of the men had a lack of exacerbations in the preceding 6 weeks. Oxyhemoglobin desaturation during exercise was an exclusion criteria. All patients were receiving inhaled, long-acting  $\beta_2$ -agonists and ipratropium bromide. Five of patients were regularly treated with inhaled steroids, but none of the eight patients had received systemic steroids in the last 3 months prior to the study. The study design included two phases: (1) comparison between 6MWT and walking at CWS, and (2) analysis of physiologic responses during the four different clinical exercise protocols.

### Comparison Between 6MWT and Walking at CWS

All patients performed, in sequence, the following timed walking tests carried out in a 10-m course to allow comparability among exercise protocols: (1) encouraged 6MWT (6MWT carried out in a 10-m course [6MWT-10]); (2) standard incremental shuttle test; (3) four high-intensity timed-walking tests at different constant speeds to calculate CWS (Fig 1), done in random order on separate days; and (4) an additional timed walking test at CWS (Fig 1), carried out to demonstrate the sustainability of the effort at least for 20 min and to compare with the physiologic responses during 6MWT-10.

### Calculation of CWS

The four different high-intensity, constant-walking, speed exercises (Fig 1) were specifically chosen at approximately 90% of the peak walking speed ( $L_1$ ), 95% of the peak walking speed ( $L_2$ ), 100% of the peak walking speed ( $L_3$ ), and 105% of the peak walking speed ( $L_4$ ) obtained during the incremental shuttle test. The CWS for a given patient corresponds to the asymptote of the hyperbolic function defined by walking speed and time to exhaustion<sup>17–20</sup> (Fig 1, center, B). This hyperbolic function is mathematically transformed into a linear relationship when the reciprocal of time to exhaustion (1/time) is used in the x-axis (Fig 1, bottom, C). CWS is defined by the y-intercept obtained using the equation proposed by Neder et al.<sup>14</sup>

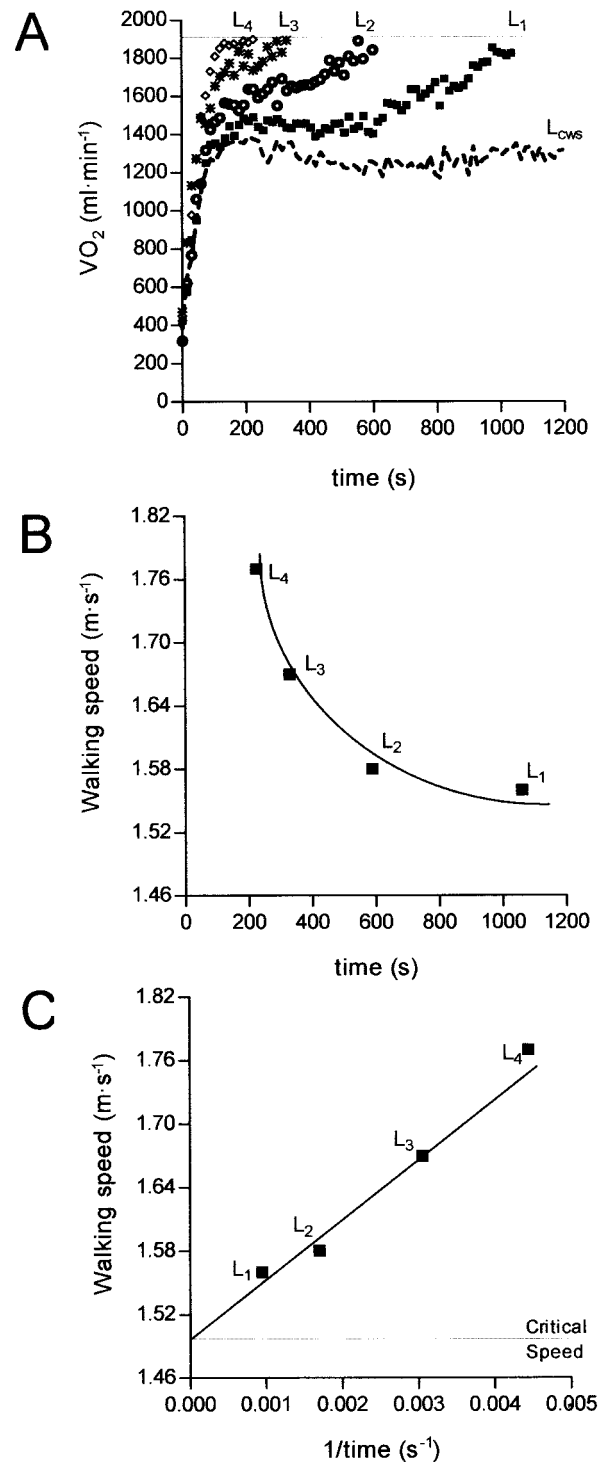


FIGURE 1. Calculation of CWS in a representative patient. *Top, A:*  $\dot{V}O_2$  profiles in four high-intensity tests at constant walking speed ( $L_1$ , 1.56 m/s;  $L_2$ , 1.58 m/s;  $L_3$ , 1.67 m/s; and  $L_4$ , 1.75 m/s, which correspond to approximately 90%, 95%, 100%, and 105% of the peak walking speed during a standard incremental shuttle test, respectively). In three of the four tests, maximum whole-body  $\dot{V}O_2$  was reached at exhaustion. The fifth constant walking speed test was done at CWS (L<sub>CWS</sub>, 1.50 m/s). *Center, B:* The asymptote of the hyperbolic relationship between walking speed (y-axis) and time to exhaustion ( $L_1$  to  $L_4$  respectively, 1,060 s, 589 s, 328 s, and 225 s) indicates the CWS in the patient. *Bottom, C:* Linear relationship between walking speed and 1/time to exhaustion. The Y-intercept corresponds to CWS.

Besides the incremental shuttle test indicated above, three additional clinical exercise protocols were done in random order on separate days, in the same patients: incremental cycling exercise, 6MWT-90, and stair-climbing test. In all instances, the time elapsed between tests ensured achievement of resting conditions before each protocol.

Measurements

Lung function at rest<sup>21,22</sup> was carried out in all patients. A telemetric portable system (K4b<sup>2</sup>; Cosmed; Pavona di Albano, Italy) was utilized for on-line exercise measurements in all exercise protocols.<sup>13,23</sup> A standard incremental shuttle test to volitional fatigue was performed according to the established protocol.<sup>24</sup> As indicated above, two types of 6MWT were performed in the present study: 6MWT carried out in a 10-m course (6MWT-10) and 6MWT-90; every 30 s, the patients were encouraged by an experienced physiotherapist to continue walking as far as possible.<sup>3,25</sup> During the stair-climbing test, patients were instructed to climb as far as possible at a brisk pace without the use of railings and to stop at their symptom-limited maximum.<sup>26</sup> Incremental cycling test was carried out following recommendations previously reported.<sup>10</sup> Before and at the end of all tests, participants were shown a modified Borg scale printed on a card and asked to indicate their current degree of shortness of breath and leg discomfort on a scale of 0 = nothing at all, to 10 = very, very severe.<sup>27</sup>

Statistical Analysis

Results are expressed as mean ± SD or as mean ± SEM. Comparisons between 6MWT-10 and CWS were done using Student paired *t* tests and Bland and Altman analyses.<sup>28</sup> One-way analysis of variance (ANOVA) for repeated measurements was carried out to examine  $\dot{V}O_2$  profiles at the different exercise protocols. A *p* value < 0.05 was considered as statistically significant.

RESULTS

The study group (mean age, 68 ± 7 years; range, 57 to 77 years) showed moderate-to-severe ventilatory dysfunction (FEV<sub>1</sub>, 1.63 ± 0.33 L; 50 ± 13% predicted; range, 32 to 67% predicted). Four patients were classified as Global Initiative for Chronic Obstructive Lung Disease (GOLD) type 2, three patients were GOLD type 3, and one patient was GOLD type 4.<sup>8</sup> Seven of the eight patients showed air trapping (residual volume, 137 ± 26% predicted; range, 80 to 169%). On average, they presented moderate hypoxemia (PaO<sub>2</sub>, 69 ± 8 mm Hg; range, 60 to 82 mm Hg) with a mean PaCO<sub>2</sub> of 41 ± 4 mm Hg (range, 38 to 49 mm Hg). Only two patients showed moderate hypercapnia (48 mm Hg and 49 mm Hg, respectively), but none of them showed exercise-induced hypoxemia. Incremental cycling exercise exhibited moderately low peak  $\dot{V}O_2$  ( $\dot{V}O_{2peak}$ ): 20.7 ± 2.4 mL/min/kg (range, 17 to 26 mL/min/kg).

Assessment of CWS

Individual relationships between walking speed and time to exhaustion during the four high-intensity, constant-walking speed tests (Fig 2, top, A) showed the expected hyperbolic function indicated in Figure 1, center, B (L<sub>1</sub> to L<sub>4</sub>). All patients presented an excellent linear correlation between constant walking speed expressed as a percentage of peak incremental shuttle and the reciprocal of time to exhaustion (Fig 2, bottom, B). Accordingly, calculated CWS was 1.44 ± 0.15 m/s, and the corresponding  $\dot{V}O_2$  plateau was 1,584 ± 319 mL/min. Sustain-

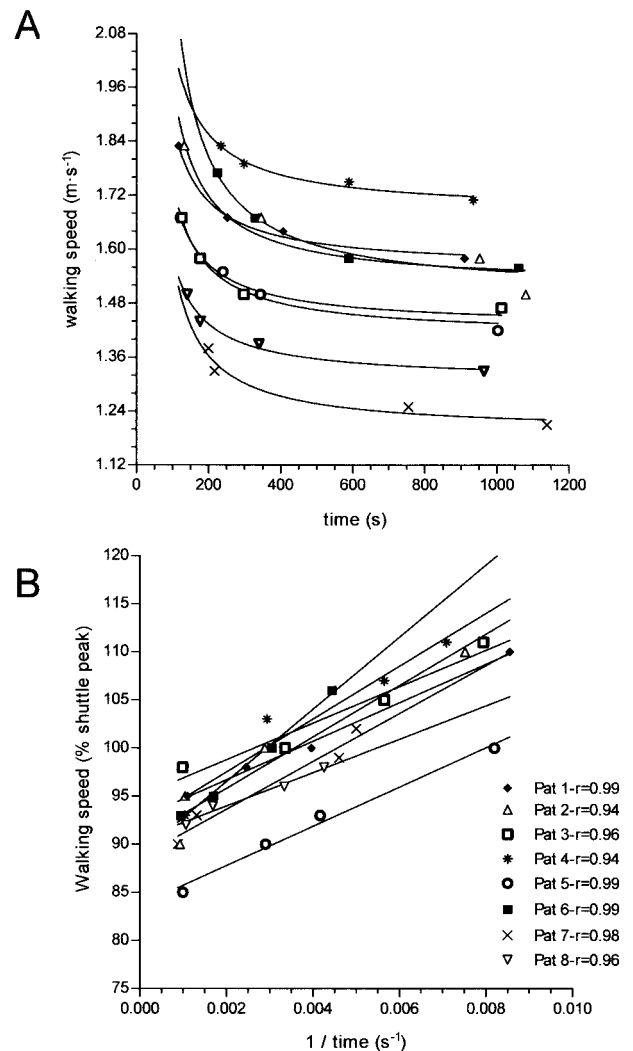


FIGURE 2. Individual relationships between walking speed and time to exhaustion for the four high-intensity tests at constant walking speed done in each COPD patient (Pat). Top, A: The hyperbolic relationship between the two variables. Bottom, B: The x-axis shows the reciprocal of time to exhaustion (1/time) that explains the linear transformation of the relationship between the two variables. In this graph, walking speed is expressed as percentage of peak walking speed measured during the incremental shuttle test. Individual coefficients of correlation are indicated.

ability of walking at CWS for at least 20 min (Fig 1, *top*, A) was confirmed in all subjects.

Three out of four high-intensity, constant-walking speed tests presented similar  $\dot{V}O_2$  values at exhaustion ( $L_2$ ,  $1,715 \pm 316$  mL/min;  $L_3$ ,  $1,655 \pm 284$  mL/min; and  $L_4$ ,  $1,660 \pm 239$  mL/min), indicating that maximum walking  $\dot{V}O_2$  (mean value,  $1,677$  mL/min), calculated as the average of the highest  $\dot{V}O_2$  for each subject regardless of the speed of the tests ( $L_2$ ,  $1.52 \pm 0.15$  m/s;  $L_3$ ,  $1.59 \pm 0.15$  m/s; and  $L_4$ ,  $1.67 \pm 0.17$  m/s), was identified in all patients.

#### Comparisons Between CWS and 6MWT-10

During the last 3 min of the 6MWT-10,  $\dot{V}O_2$  showed a plateau in all patients, as reported by

others.<sup>13</sup> Similarly, steady-state conditions ( $\dot{V}O_2$ , minute ventilation [ $\dot{V}E$ ], and heart rate [HR]) during walking at CWS were also observed in each patient. Consequently, comparisons between walking at CWS and 6MWT-10 were based on mean values of the 3 last min of each test. Figure 3, *top*, A, displays a strong correlation in  $\dot{V}O_2$  results between CWS ( $1,584 \pm 319$  mL/min) and 6MWT-10 ( $1,605 \pm 304$  mL/min), wherein all patients fell close to the identity line ( $r = 0.93$ ,  $p < 0.001$ ). Likewise, Figure 3, *bottom left*, C, indicates an excellent concordance of  $\dot{V}O_2$  between the two exercise tests ( $-21 \pm 282$  mL/min). Figure 3, *top right*, B, and *bottom right*, D, do not show statistically significant differences in walking speed ( $-0.046 \pm 0.14$  m/s) between

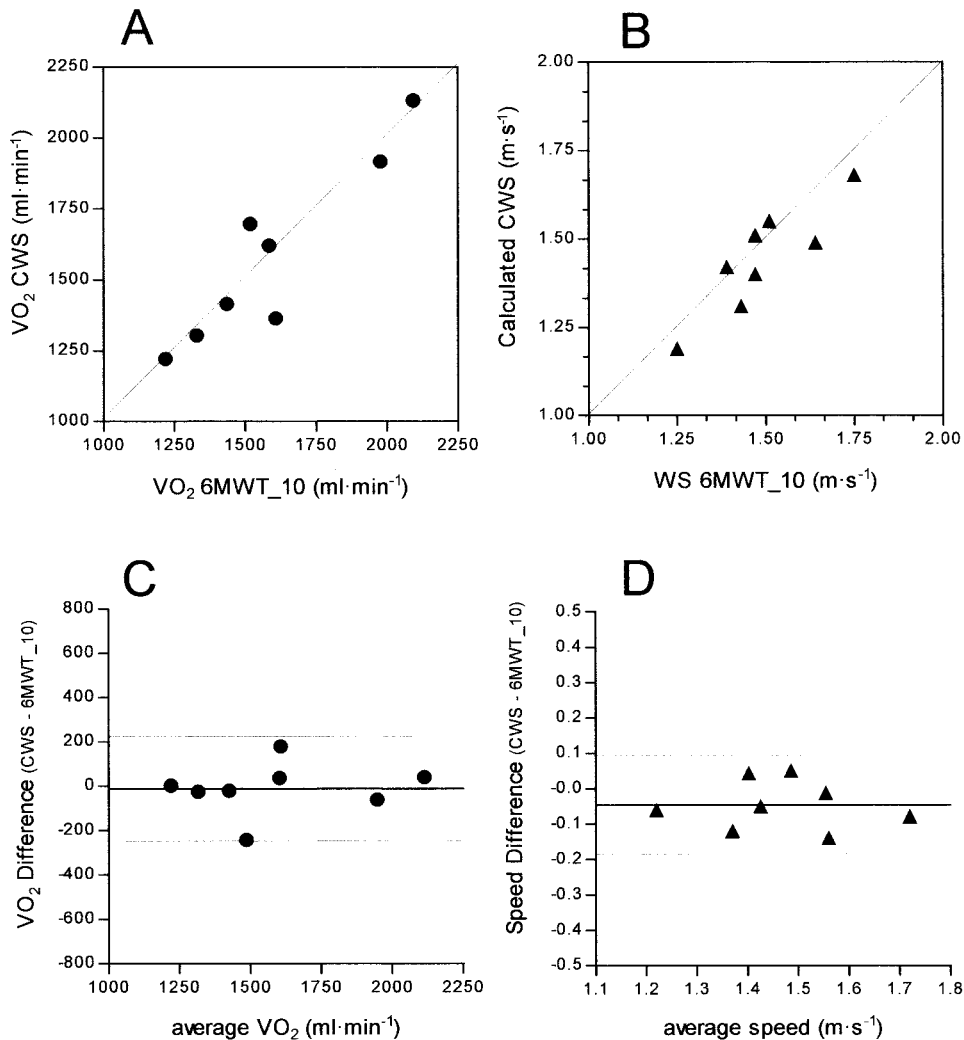


FIGURE 3. *Top left*, A: Individual relationships between  $\dot{V}O_2$  during CWS (y-axis) and  $\dot{V}O_2$  during 6MWT-10 (x-axis) [ $r = 0.93$ ,  $p < 0.001$ ]. *Top right*, B: Individual relationships between CWS (y-axis) and walking speed during 6MWT-10 (x-axis) [ $r = 0.90$ ,  $p < 0.01$ ]. Bland and Altman analyses for these two variables ( $\dot{V}O_2$  and walking speed) are shown (*bottom left*, C, and *bottom right*, D, respectively). A high concordance between 6MWT-10 and CWS was observed in all instances.



6MWT-10 ( $1.49 \pm 0.16$  m/s) and calculated CWS ( $1.44 \pm 0.15$  m/s) [ $r = 0.90$ ,  $p < 0.01$ ].  $\dot{V}_E$  ( $47 \pm 12$  L/min vs  $48 \pm 11$  L/min, 6MWT and CWS, respectively); carbon dioxide output ( $\dot{V}_{CO_2}$ ) [ $1,441 \pm 326$  mL/min vs  $1,420 \pm 292$  mL/min]; respiratory exchange ratio (RER) [ $0.89 \pm 0.1$  vs  $0.90 \pm 0.1$ ]; HR ( $130 \pm 18$  beats/min vs  $131 \pm 16$  beats/min); and symptom score were also similar between 6MWT-10 and CWS. Borg dyspnea scores at the end of the two tests were  $5 \pm 1$  (range, 4 to 8) and  $6 \pm 2$  (range, 2 to 9), respectively; likewise, the Borg leg scores were  $4 \pm 2$  (range, 2 to 6) and  $4 \pm 2$  (range, 1 to 8).

### Clinical Exercise Protocols

Figure 4 displays  $\dot{V}_{O_2}$  profiles during incremental cycling exercise, incremental shuttle test, 6MWT-90, and stair-climbing test measured in the same patients. While 6MWT-90 showed a plateau in  $\dot{V}_{O_2}$  after the third minute of the test,<sup>13</sup>  $\dot{V}_{O_2}$  increased up to the end of the test in the other three exercise protocols. The figure shows an abrupt raise in  $\dot{V}_{O_2}$  during stair climbing ( $\dot{V}_{O_2}$  at min 1 was 80% of  $\dot{V}_{O_2}$  peak) that contrasted with the steady increase of  $\dot{V}_{O_2}$  during both incremental cycling and incremental shuttle tests ( $\dot{V}_{O_2}$  at min 1 were 35% and 34% of  $\dot{V}_{O_2}$  peak, respectively). Detailed information on physiologic responses at the end of each of the four tests is provided in Table 1.

The two types of 6-min walking protocols—6MWT-10 and 6MWT-90—displayed a plateau in  $\dot{V}_{O_2}$  after the third minute of the test. 6MWT-10, however, showed higher  $\dot{V}_{O_2}$  ( $1,605 \pm 304$  mL/min vs  $1,429 \pm 227$  mL/min;  $p = 0.04$ ), lower walking speed ( $1.49 \pm 0.16$  m/s vs  $1.63 \pm 0.14$  m/s;  $p = 0.0005$ ), and shorter walked distance (mean difference,  $-54 \pm 1$  m;  $p = 0.0002$ ) than 6MWT-90.

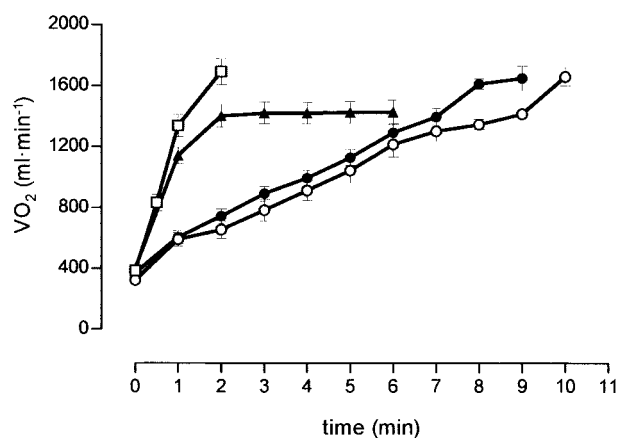


FIGURE 4. Mean  $\dot{V}_{O_2}$  profiles of the eight COPD patients during four different clinical exercise protocols (mean  $\pm$  SEM): incremental cycling (open circles), incremental shuttle (solid circles), 6MWT-90 (solid triangles), and stair climbing (open squares).

The current study showed similar physiologic responses between encouraged 6MWT-10 and walking at CWS, which indicates that patients with moderate-to-severe COPD set their walking speed during the test in order to achieve critical  $\dot{V}_{O_2}$ . The level of  $\dot{V}_{O_2}$  achieved at CWS may indicate the integrated response of the systems involved in  $O_2$  transport/ $O_2$  utilization that ultimately determine the highest sustainable level of exercise. These results might constitute the underlying explanation for the high prognostic value of the 6MWT.

As described above, the three highest constant walking speeds ( $L_2$  to  $L_4$  in Fig 1) showed similar  $\dot{V}_{O_2}$  at exhaustion (on average, 1,677 mL/min). Moreover, both stair climbing ( $1,693 \pm 256$  mL/min) and incremental shuttle tests ( $1,651 \pm 243$  mL/min) also presented similar peak  $\dot{V}_{O_2}$  results (Table 1), thereby further confirming identification of maximum  $\dot{V}_{O_2}$ max in all these patients. Maximum  $\dot{V}_{O_2}$  indicates the maximum capacity of the system for  $O_2$  transport/ $O_2$  utilization. It is of most interest that critical  $\dot{V}_{O_2}$  ( $\dot{V}_{O_2}$  at CWS, 1,584 mL/min) was reported close to 94% of maximum  $\dot{V}_{O_2}$  in the present study, as shown by other authors<sup>14</sup> in COPD patients during incremental cycling.

### Does CWS Indicate Critical Power?

While incremental cycling protocols<sup>9,10</sup> are designed to facilitate the assessment of the relationship between  $\dot{V}_{O_2}$  and work rate throughout the test, timed walking tests present important limitations in this regard. It is well accepted that the three most important factors determining energy requirements during encouraged 6MWT are walking speed, ergonomics of the test, and body weight. Since body weight remains unchanged, the other two factors modulate intrasubject variability of energy requirements during the test. The current study provides information on the relationships between these two factors (walking speed and ergonomics) and  $\dot{V}_{O_2}$ .

We observed proportionality between  $\dot{V}_{O_2}$  and walking speed during the assessment of CWS, which supports the contention that walking speed was the key determinant of work rate in our patients. This is valid provided that the analysis is done with walking tests carried out in the same corridor length (10-m course in the study), such that similar ergonomics can be reasonably assumed. Moreover, verification of steady-state conditions during exercise at CWS, alike the equivalence between 6MWT-10 and CWS, further indicates the pivotal role of walking speed modulating energy requirements in these patients. The statement requires that self-paced walking speed was constant throughout the time intervals of

**Table 1—Comparison Among Clinical Exercise Protocols\***

Variables	Stair Climbing (Peak)	Incremental Cycling (Peak)	Incremental Shuttle (Peak)	6MWT-90 (Last 3 min)
Time to exhaustion, s	88 ± 37	546 ± 95	465 ± 54	
$\dot{V}_E$ , L/m	57.7 ± 14.1	56.0 ± 8.3	48.2 ± 10.0	44.2 ± 10.0†‡
$\dot{V}O_2$ , mL/min	1,693 ± 256	1,661 ± 180	1,651 ± 243	1,429 ± 227†‡
$\dot{V}CO_2$ , mL/min	1,749 ± 359	1,687 ± 151	1,473 ± 273§	1,273 ± 220†‡
RER	1.03 ± 0.12	1.02 ± 0.06	0.89 ± 0.09§	0.89 ± 0.05†‡
HR, beats/min	131 ± 18	133 ± 15	130 ± 14	128 ± 13
O <sub>2</sub> saturation, %	91 ± 5	91 ± 4	91 ± 2	90 ± 5
Borg score (dyspnea)	8 (3–10)	7 (3–9)	5 (1–9)§	4 (1–7)†‡
Borg score (leg fatigue)	5 (3–8)	6 (3–8)	4 (1–5)§	4 (1–7)†

\*Results expressed as mean ± SD except for Borg scores, which are expressed as mean (range).

†6MWT-90 vs incremental cycling, ANOVA:  $\dot{V}O_2$  ( $p < 0.01$ ),  $\dot{V}CO_2$  ( $p < 0.01$ ),  $\dot{V}_E$  ( $p < 0.01$ ), dyspnea ( $p < 0.01$ ), leg ( $p < 0.05$ ).

‡6MWT-90 vs stair climbing, ANOVA:  $\dot{V}O_2$  ( $p < 0.005$ ),  $\dot{V}CO_2$  ( $p < 0.01$ ),  $\dot{V}_E$  ( $p < 0.01$ ), dyspnea ( $p < 0.05$ ).

§Incremental shuttle vs incremental cycling, ANOVA:  $\dot{V}CO_2$  ( $p < 0.01$ ), RER ( $p < 0.01$ ), dyspnea ( $p < 0.05$ ), leg ( $p < 0.05$ ).

||Shuttle vs stair climbing, ANOVA: RER ( $p < 0.05$ ), dyspnea ( $p < 0.05$ ).

the encouraged 6MWT, as it was proven in the present study and in previous reports.<sup>13,29</sup>

As described in the “Results” section, 6MWT-10 showed lower efficiency (higher  $\dot{V}O_2$  at lower walking speed) than 6MWT-90, which illustrates that the ergonomics of the test cannot be neglected as a determinant of energy requirements. Clearly, the 10-m course imposed a higher number of turns than 6MWT-90 during the test, which decreased the average speed and increased  $\dot{V}O_2$ . The impact of number of turns during the test on the walking distance has been also reported by Scieurba et al.<sup>30</sup> These results fully support the appropriateness of the current study design that used 6MWT-10 for comparisons with CWS, whereas 6MWT-90 was used to compare with other clinical exercise protocols. It is of note that  $\dot{V}O_2$  during 6MWT-90 (1,429 ± 227 mL/min) was approximately 85% of  $\dot{V}O_{2max}$ . Further insights on standardization of 6MWT are clearly beyond the scope of the present investigation.

#### *Exercise Protocols: Physiologic and Clinical Implications*

The most striking feature of encouraged stairs climbing (Fig 4, Table 1) was that approximately 80% of  $\dot{V}O_{2peak}$  was already achieved within the first minute of the test. This finding rises major concerns on the safety of the test. Moreover, it does not fit with a desirable smooth increase in work rate that may eventually facilitate the analysis of physiologic responses throughout the test. These considerations together with inherent problems for an appropriate standardization of this test limit the usefulness of stairs climbing as a routine clinical test. Incidentally, it has been reported<sup>26</sup> that nonencouraged stairs climbing protocols may generate a  $\dot{V}O_2$  plateau, likely indicating self-adjustment of the patient to achieve sustainable exercise.

Incremental cycling exercise and incremental shuttle test showed similar  $\dot{V}O_2$  profiles (Fig 4, Table 1). At peak exercise, however, incremental cycling showed higher  $\dot{V}CO_2$  and higher RER ( $p < 0.01$  each) than the incremental shuttle test. Likewise, symptoms score (dyspnea and leg) were also higher ( $p < 0.05$  each) during cycling exercise compared to incremental shuttle test. The differences between these two tests could be explained by higher blood lactate levels, hence ventilatory requirements, during incremental cycling compared to timed walking tests.<sup>13</sup> In the current study,  $\dot{V}O_{2peak}$  (1,661 ± 180 mL/min) during incremental cycling was similar to  $\dot{V}O_2$  at peak incremental shuttle (Table 1), despite the fact that the amount of exercising muscle mass during cycling exercise is significantly smaller than in timed walking tests and the characteristics of the exercise are different. As described above, maximum  $\dot{V}O_2$  was observed at exhaustion in most of the exercise protocols carried out in the present study (Fig 1, Table 1), irrespective of the amount of exercising muscle mass. A potential explanation for this finding is that the ceiling of whole-body  $\dot{V}O_2$  in COPD patients is mainly defined by the degree of pulmonary impairment and not by the amount of exercising muscle mass. The level of exercise is clearly below the vascular constraints to preserve systemic BP observed in healthy man, in whom the amount of exercising muscle mass modulates  $\dot{V}O_{2max}$ .<sup>31,32</sup>

The characteristics of the physiologic responses during encouraged 6MWT have been described in the current study and by others.<sup>13</sup> Standardization and clinical implications of the test are also reported.<sup>3,9,10</sup> The incremental shuttle test is properly standardized,<sup>24</sup> and it is widely used for evaluation of patients with chronic respiratory and cardiac disorders.<sup>33,34</sup>

In summary, the current study demonstrates that physiologic responses during 6MWT in patients with

moderate-to-severe COPD are equivalent to those seen walking at critical power, which corresponds to approximately 90% of maximum  $\dot{V}O_2$  in these patients. The relationship between 6MWT and CWS may likely explain the high predictive value of 6MWT that, together with its simplicity, applicability, and acceptable reproducibility,<sup>30,35</sup> prompts its recommendation as the most suitable choice for conventional clinical assessment of COPD patients, as part of the multidimensional evaluation of the disease severity.<sup>7</sup>

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