Relationship between field walking tests and incremental cycle ergometry in COPD

Nia LUXTON,1 Jennifer A. ALISON,1,2 Judy WU1 AND Martin G. MACKEY1

1Discipline of Physiotherapy, The University of Sydney, and 2Department of Physiotherapy, Royal Prince Alfred Hospital, Sydney, New South Wales, Australia

Background and objective: Cycle ergometer training is an important component of pulmonary rehabilitation for patients with COPD. However, incremental cycle tests from which individualized cycle training intensity can be prescribed may not be readily available to clinicians. The aims of the study were to (i) investigate the physiological and psychophysical responses to the 6-min walk test (6MWT), incremental shuttle walk test (ISWT) and cycle ergometer test (CET); and (ii) determine whether the distance walked in either the 6MWT or the ISWT could be used to estimate peak work rate on a cycle ergometer.

Methods: A repeated measures study was undertaken in COPD patients in a stable condition. The 6MWT, ISWT and CET were performed in random order, and physiological responses, rate of perceived exertion and dyspnoea were measured.

Results: Twenty-two patients with COPD completed the study. There was no significant difference in peak oxygen uptake between the 6MWT, ISWT and CET. The significant correlation between the 6MWD and incremental shuttle walk distance with peak watts on the CET (r = 0.63, P = 0.002 and r = 0.75, P < 0.001, respectively) was strengthened by the inclusion of weight, age and gender (r = 0.89 P = 0.001 and r = 0.91, P < 0.001). Bland–Altman analysis demonstrated a strong agreement between peak work rate measured on the CET and that estimated from either the 6MWT or the ISWT.

Conclusions: The significant relationships found between the three exercise tests, and the regression equations predicting peak work rate on the CET from the 6MWT or the ISWT, may allow for the estimation of intensity of cycle exercise training from walk tests in COPD patients.

Key words: bicycle ergometry, COPD, exercise test.

INTRODUCTION

Assessment of exercise capacity and prescription of exercise training are important components of a pulmonary rehabilitation programme for individuals with COPD. Studies that have used cycle ergometry as the main mode of training for COPD patients have shown significant improvements in exercise capacity.1,2 Therefore, lower extremity training often includes stationary cycling,3 with the intensity of training determined from an exercise test.4,7 Traditionally, such exercise tests have been laboratory-based exercise tests on a cycle ergometer with the prescription for cycle training being derived from a per cent of peak oxygen uptake or work rate.1 However, such testing prior to exercise prescription may not always be possible if the laboratory facilities are not available. If an incremental cycle ergometry test is not available, the intensity for cycle ergometry training cannot be individually prescribed, potentially reducing the effectiveness of training.

Walking tests such as the 6-min walk test (6MWT) and incremental shuttle walk test (ISWT) have been increasingly used in pulmonary rehabilitation to assess exercise capacity in patients with COPD as they are simple, cheap and can be used to prescribe the intensity of a walking training programme.8,9 Although a number of studies have compared the 6MWT or ISWT with the incremental cycle ergometer...
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Methods

Study subjects

Clinically stable patients with diagnosed COPD were recruited for the study. Patients on long-term oxygen therapy or with other comorbidities such as musculoskeletal, cardiac and neurological disorders that may influence exercise performance were excluded. Written, informed consent was obtained from all patients. The study was approved by the Human Research Ethics Committees of The University of Sydney and Royal Prince Alfred Hospital, Sydney, Australia.

Study design

A repeated measures design was used in which each patient performed two 6MWT, two ISWT and one CET, with the order of the tests randomly selected using a computer-generated numbers program. Patients attended at the same time of day on a maximum of three occasions, each separated by at least 1 day, over a period of less than 10 days. Patients were requested to avoid performing exercise, drinking caffeinated drinks and eating within 2 h of the test. Spirometry (Vitalograph Spirometer Compact, Vitalograph Ltd, Buckingham, UK) was performed prior to each exercise test and was compared with predicted values. Maximum voluntary ventilation (MVV) was calculated as FEV₁ multiplied by 35.17

Physiological measures

During all exercise tests, patients wore a facemask attached to a lightweight portable gas analysis system (Kab, Cosmed, Rome, Italy). The system weighed less than 1 kg and was worn on the chest with a harness. Breath-by-breath values for oxygen uptake (VO₂), carbon dioxide output (VCO₂) and minute ventilation (Vₐ) were measured during each test. Heart rate (HR) was simultaneously measured using a portable HR monitor (Polar, Polar Electro, Oy, Finland) and oxygen saturation (SpO₂) was measured via a forehead probe (Reflectance Pulse Oximeter Sensor 8000R, Nonin Medical Inc, Plymouth, MN, USA). All values were averaged for the last 15 s of each completed minute and the last 15 s prior to the end of each exercise test.

Psychophysical measures

The modified Borg Category Ratio 0–10 scale was used to measure the rate of perceived exertion (RPE) and a 0–10 dyspnoea scale to measure breathlessness at the beginning, during each minute and at the end of each exercise test.

Exercise tests

The incremental CET to peak work capacity was performed on an electronically braked cycle ergometer (Siemens Ergomed EM 840, Siemens Medical Engineering Group, Erlangen, Germany). Patients pedalled between 50 and 60 r.p.m. throughout the test, with standardized encouragement given every minute. Work rate was increased by 5–20 W/min, depending on level of physical activity of the patients and clinical judgement, until the patients indicated they were not able to continue and this was termed peak work rate. For the 6MWT a 32-m continuous oval track was used. Standardized instructions were given to each patient prior to the test and standardized encouragement was given at each minute. The ISWT was performed around a 10-m course in accordance with the protocol described by Singh et al. Both the 6MWT and ISWT were performed twice to account for the learning effect and the furthest distance walked for each of the two tests was used for analysis. The second ISWT or 6MWT was performed after a minimum of 30-min rest or when physiological parameters returned to resting levels.

Data analysis

Based on the relationship between the distance walked in the 6MWT and the peak work in watts from a CET (r = 0.59), a sample size of 22 patients was required to find a correlation of 0.6 or larger with a power of 80% and a two-tailed α of 0.05. To account for a 10% dropout rate, 25 patients were recruited. Results are expressed in mean ± SD. All physiological and psychophysical measures for the 6MWT, ISWT and CET were compared at rest and at peak exercise using a one-way repeated measures analysis of variance. Post-hoc pairwise comparisons were made with Bonferroni correction. Pearson correlation coefficients were calculated between peak work rate achieved on the CET and 6MWD, incremental shuttle walk distance (ISWD), 6-min walk-work and incremental shuttle walk-work. Walk-work refers to the 6MWD and ISWD in metres multiplied by body mass (kg), calculated as FEV₁ and was worn on the chest with a harness. The ability to estimate an appropriate intensity for cycle training from the distance walked in the 6MWT or ISWT would be useful in clinical practice.

The aims of the present study were to (i) investigate the physiological and psychophysical responses to the 6MWT, ISWT and CET in patients with COPD; and (ii) determine whether the distance walked in either the 6MWT or the ISWT could be used to estimate peak work rate on a cycle ergometer. It was hypothesized that: (i) there would be similar physiological and psychophysical responses to the 6MWT, ISWT and CET in patients with COPD; and (ii) the distance walked in either the 6MWT or the ISWT could estimate the peak work rate on a cycle ergometer.

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The main finding of the study was that there was no significant difference in the peak VO₂ as determined by the 6MWT, ISWT or CET. The other major finding was that there was a significant correlation between the peak work rate achieved on the CET and the distance walked in both the 6MWT and the ISWT; a correlation strengthened by the addition of the anthropometric data of weight, age and gender. Thus, the distance walked during either walk test provided a good estimate of the maximal work rate in a CET in COPD patients.
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Table 2  Comparison of peak exercise parameters during the 6-min walk test (6MWT), incremental shuttle walk test (ISWT) and incremental cycle ergometer test (CET)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>6MWT (mL/min)</th>
<th>ISWT (mL/min)</th>
<th>CET (mL/min)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>VO₂ (mL/min)</td>
<td>1394 ± 404</td>
<td>1380 ± 390</td>
<td>1383 ± 437</td>
<td>0.940</td>
</tr>
<tr>
<td>VCO₂ (mL/min)</td>
<td>1069 ± 378</td>
<td>1032 ± 370</td>
<td>1208 ± 434*</td>
<td>0.001</td>
</tr>
<tr>
<td>V̇ₐ (L/min)</td>
<td>43.7 ± 12.9</td>
<td>43.0 ± 12.1</td>
<td>48.1 ± 14.6*</td>
<td>0.006</td>
</tr>
<tr>
<td>V₂/VO₂</td>
<td>103 ± 32.1</td>
<td>102 ± 34.4</td>
<td>112 ± 32.1</td>
<td>0.080</td>
</tr>
<tr>
<td>V̇ₐ/VCO₂</td>
<td>42.5 ± 8.4</td>
<td>43.4 ± 8.0</td>
<td>41.1 ± 7.4</td>
<td>0.100</td>
</tr>
<tr>
<td>V₁ (L/min)</td>
<td>1.4 ± 0.5</td>
<td>1.3 ± 0.4</td>
<td>1.4 ± 0.5</td>
<td>0.070</td>
</tr>
<tr>
<td>fR (breaths/min)</td>
<td>33 ± 6</td>
<td>34 ± 7</td>
<td>35 ± 10</td>
<td>0.080</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>121 ± 19</td>
<td>124 ± 20</td>
<td>128 ± 22</td>
<td>0.120</td>
</tr>
<tr>
<td>∆SpO₂ (%)</td>
<td>–7 ± 5</td>
<td>–7 ± 5</td>
<td>–4 ± 3†</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Dyspnoea</td>
<td>4 ± 2</td>
<td>4 ± 2</td>
<td>5 ± 2*</td>
<td>0.001</td>
</tr>
<tr>
<td>RPE</td>
<td>2 ± 2*</td>
<td>3 ± 2</td>
<td>5 ± 2‡</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*P < 0.05 CET versus 6MWT and ISWT. †P < 0.001 CET versus 6MWT and ISWT. ‡P < 0.001 CET versus 6MWT. §P < 0.05 CET versus ISWT.

Means ± SD for oxygen uptake (VO₂), carbon dioxide output (VCO₂), minute ventilation (V̇ₑ), peak minute ventilation/maximum voluntary ventilation (V₂/VO₂), ventilatory equivalent for carbon dioxide (V̇ₑ/VCO₂), tidal volume (V₁), respiratory frequency (fR) and heart rate (HR), difference between per cent oxygen saturation at rest and at peak exercise (∆SpO₂), dyspnoea and rate of perceived exertion (RPE) during the fifth–sixth minute of the 6MWT and at peak exercise for the ISWT and CET.

Table 3  Correlations between the peak work rate on the CET and the 6MWD, ISWD, 6MWORK and ISWORK

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Pearson correlation coefficient</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak work rate CET (W) and 6MWD (m)</td>
<td>0.63</td>
<td>0.002</td>
</tr>
<tr>
<td>Peak work rate CET (W) and ISWD (m)</td>
<td>0.75</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak work rate CET (W) and 6MWORK (kg-m)</td>
<td>0.78</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Peak work rate CET (W) and ISWORK (kg-m)</td>
<td>0.85</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

6MWORK, 6-min walk-work; ISWORK, incremental shuttle walk-work; ISWD, incremental shuttle walk distance.

This is the first study to measure both physiological and psychophysical responses during the CET, 6MWT and ISWT in male and female patients with COPD, and to demonstrate no significant differences in the peak VO₂ achieved during the three exercise tests. Other studies in COPD patients have also found similarities in the peak VO₂ determined by the CET and ISWT²⁰,²¹ or the CET and 6MWT²¹ but comparison of all three tests in one group of patients has not previously been reported. This important finding, together with the non-significant difference in peak HR between the three tests, suggests that patients reached their maximum exercise capacity during each test, including the 6MWT₂¹ which is often regarded as a submaximal test.²² Ventilatory constraints to exercise may have been a reason why there were no significant differences in VO₂ peak between the cycle ergometry and walk tests as the mean Vₑ/MVV was greater than 100% in all three tests. Although the use of Vₑ/MVV has shortcomings as a determinant of ventilatory constraints to exercise,²⁶ the high Vₑ/MVV in the present study is above that expected in the healthy population and would contribute to early termination of exercise, thus limiting further increases in VO₂.

This study also found significant linear relationships between the 6MWD or ISWD and the peak work rate on the CET. These relationships were strengthened by the addition of age, weight (as walk-work) and gender to the regression equation. The relationship between the CET and 6MWT,²⁵ ISWT,²⁶ or a 12-min walk test²⁸ has been previously reported but in these studies only one walk test was performed. Thus, the best performance on the walk test may not have been achieved,²⁴,²⁵ which may have reduced the accuracy of the relationship of the walk tests with the CET. Although the correlations between the 6MWD, ISWD and CET in the present study were significant, walk distance alone could not entirely explain the peak work rate on the CET. Weight, height, gender, age and lung function have been shown to influence work capacity of walking and cycling tests in both healthy and COPD populations.²²,²⁸–³¹ In this study, peak work rate on the CET was more strongly correlated with 6MWORK and ISWORK (i.e. combination of body weight and distance walked) than with distance alone, which is consistent with previous studies.²⁴,²⁵,²⁶,³² The addition of gender and age in the stepwise regression further strengthened the relationship between peak work rate on the CET and 6MWORK and ISWORK. Height was not a significant factor and may indicate that gender largely accounted for height differences.

Bland–Altman analysis for the exercise tests demonstrated a strong agreement between peak work rate (W) measured on the CET and that estimated from the walk tests. The agreement between the ISWT and CET confirms previous findings.²⁴ A useful clinical...
Implication of the developed equations is that simple walk tests, commonly used to assess exercise capacity in pulmonary rehabilitation programmes, could also be used to estimate peak work rate on a CET from which appropriate cycle training intensities could be calculated. Further validation of the equations using larger cohorts of patients with COPD needs to be undertaken.

The present study found significantly higher peak values of V\textsubscript{CO\textsubscript{2}} and V\textsubscript{E} during the CET than during either the 6MWT or the ISWT. The higher peak V\textsubscript{E} during the CET may have been in response to the higher peak V\textsubscript{CO\textsubscript{2}} during this mode of exercise as ventilation has been shown to increase in proportion to V\textsubscript{CO\textsubscript{2}}.\textsuperscript{33,34} Although the present study did not measure blood lactate, the higher V\textsubscript{CO\textsubscript{2}} may have been in response to increased blood lactate levels. Other studies, with similarly higher V\textsubscript{E} responses during cycling than walk tests, found greater levels of lactate at peak work rate during the CET compared with walk tests in patients with COPD.\textsuperscript{10,12,33} These differences were thought to be from the smaller muscle mass used during cycling compared with walking at a similar VO\textsubscript{2}. Interestingly the ratio of V\textsubscript{E}/V\textsubscript{CO\textsubscript{2}} indicated the ventilatory equivalent for carbon dioxide was lower in the CET than in either of the walk tests despite the significantly higher V\textsubscript{E} at peak CET. This was similar to the findings of Palange et al.\textsuperscript{10} and suggests that the patients were more ventilatorily efficient during the CET, possibly due to the fixed position of the arms, allowing more effective use of accessory muscles of breathing.\textsuperscript{35} The significantly higher RPE scores for the CET compared with the 6MWT or ISWT could be related to the effect of the presumed higher lactate levels during the CET on leg muscle fatigue.\textsuperscript{11,33} The peak dyspnoea score for the CET was significantly higher than for the 6MWT or ISWT and was most likely in response to the significantly higher peak V\textsubscript{E} for the CET. Factors such as dynamic hyperinflation, which also affects dyspnoea,\textsuperscript{36} was not measured in the study.

Figure 1 (a) Correlation between peak work rate on the incremental cycle ergometer test (CET) (W) and 6-min walk-work (6M\textsubscript{WORK}) (kg-m). (b) Correlation between peak work rate on the incremental CET (W) and incremental shuttle walk-work (IS\textsubscript{WORK}) (kg-m).

Figure 2 (a) Scatter plots (Bland–Altman). The difference between the estimated peak work (W) from the 6-min walk test (6MWT) and measured peak work rate (W) on the incremental cycle test (CET) against the mean values of the two tests. (b) Scatter plots (Bland–Altman). The difference between the estimated peak work (W) from the incremental shuttle walk test (ISWT) and measured peak work rate (W) on the incremental CET against the mean values of the two tests.
The present study did not include measurement of static lung volumes, single breath diffusing capacity or peripheral muscle strength, which may influence exercise capacity in patients with COPD.\textsuperscript{1,2,20,38} Despite this, through the inclusion of patient characteristics such as weight (as walk-work), age and gender, which are easily attainable in the clinical situation, a high degree of the variance in the ability of the walk tests to estimate peak cycle work rate was explained. This study only included a small number of patients with mild COPD. As pulmonary rehabilitation is recommended for all patients with COPD,\textsuperscript{3} a larger group of patients with mild disease should be included in future research in order to identify differences in responses to the three exercise tests across a range of disease severity.

In summary, this study demonstrated that peak VO\textsubscript{2} was similar for the 6MWT, ISWT and CET in patients with COPD of differing disease severity. The significant relationships between the distance walked in both the 6MWT and the ISWT with peak work rate on the CET were further strengthened by the addition of weight, gender and age. The resultant regression equations could be used to estimate peak work rate on a cycle ergometer. Thus, simple, reliable and low-cost walk tests may be useful for individualized prescription of cycle training intensity for men and women with COPD.

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REFERENCES


23 Singh S, Morgan DL, Scott S, Walters D, Hardman AE. Development of a shuttle walking test of disability in


