Assessment of functional capacity in chronic heart failure: time-limited exercise on a self-powered treadmill

Jane Sparrow, Jayan Parameshwar, Philip A Poole-Wilson

Abstract

Objectives—To assess the efficacy of a 9-minute walking test on a self-powered treadmill in a group of patients with various degrees of heart failure, to investigate the reproducibility of the technique, and to establish the safety of the technique.

Patients and methods—24 controls and 37 patients with various grades of heart failure were studied. Peak oxygen consumption was measured in patients and controls. The distance walked in 9 minutes on a self-powered treadmill was measured in all groups and the test was repeated to assess reproducibility.

Results—The distance walked in 9 minutes correlated with peak oxygen consumption in patients, controls, and both groups combined. There was a significant difference in the distance walked by controls and patients and in the distance walked by patients with severe rather than with mild or moderate heart failure. There was no significant difference between the results of successive 9-minute walking tests in any group. No serious adverse reaction was seen in any patient during or after the test.

Conclusion—The 9-minute walking test on a self-powered treadmill is a sensitive, reproducible, safe, and inexpensive method of assessing functional capacity in patients with all grades of heart failure.

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The past decade has seen the gradual acceptance of the need for objective assessment of functional capacity in patients with chronic heart failure. The measurement of respiratory gas exchange during a maximal exercise test is established as an objective and reproducible method of assessing exercise capacity, but is not widely used because the equipment required is expensive and the procedure needs staff, training, and time. The 6-minute walking test was devised as an inexpensive and simple alternative method. The distance walked during a 6-minute walking test has been shown to discriminate between patients with severe chronic heart failure but there was little variation in the distance walked between patients with mild heart failure and normal subjects. The 6-minute walking test requires a corridor that should ideally be temperature controlled.

The self-powered treadmill was introduced to overcome the disadvantages of the 6-minute walking test. The distance walked in 12 minutes on a self-powered treadmill was shown to correlate with maximum oxygen consumption in a small group of patients with mild heart failure and in normal subjects. The conclusion of that study was that 9 minutes might be preferable to 12 minutes.

We report here a study of a 9-minute walking test on a self-powered treadmill. The objectives were to study a larger group of patients with various grades of heart failure, to establish the reproducibility of the technique, and to assess its safety.

Patients and methods

We studied 37 patients with heart failure (mean age 52±1) (range 24–75); 33 men) and 24 controls (mean age 34 (range 20–54). The controls were believed to be free of cardiac disease. The cause of heart failure was coronary artery disease in 18 patients, idiopathic dilated cardiomyopathy in 16 patients, and ventricular dysfunction secondary to valvar heart disease in three. The mean duration of heart failure was 30±5 (range 1–144) months. Ten patients were in atrial fibrillation; these patients and one in sinus rhythm were taking digoxin. Twenty seven patients were taking frusemide (mean dose 77 mg); the remaining 10 patients were taking other diuretics including thiazides and bumetanide. Twenty six patients were taking an angiotensin converting enzyme inhibitor, 10 were taking anticoagulants, and eight received nitrates. The mean (SD) left ventricular ejection fraction of the patients (assessed by radionuclide ventriculography) was 24 (11-7%). The mean (SD) peak oxygen consumption of the 37 patients was 15±4 (4-2) ml/kg/min (range 6-5–23-9). Exclusion criteria were myocardial ischaemia on exercise, significant pulmonary disease, or inability to exercise for any reason other than dyspnoea or fatigue.

Peak oxygen consumption was measured...
on a conventional treadmill by an argon dilution technique and a mass spectrometer. The anaerobic threshold and extrapolated maximum oxygen consumption were obtained by computerised analysis with a curve fitting model as previously described. A modified Bruce protocol was used for 34 patients and a modified Naughton protocol for three patients.

The study groups exercised on a Tunturi Jogger 2 self powered treadmill. The treadmill consists of a conveyor belt that slides over an underplate by the force of the subject walking on the belt. A liquid crystal display can show the distance travelled, the current speed, or time elapsed, or can scan between these three. The distance walked was recorded by a Trumeter surveyor’s wheel attached to the belt of the treadmill. The slope of the belt is adjustable (there are three possible settings) but, by contrast with a conventional motorised treadmill, cannot be varied during a test.

The 37 patients were asked to walk for 9 minutes on the self-powered treadmill set at a gradient of 6.7% (6°) an hour after performing a symptom-limited maximal exercise test to measure peak oxygen consumption. They were asked to walk the greatest distance possible at any speed they chose and the distance achieved at the end of each 3-minute interval was recorded. When necessary, patients were allowed periods of rest within the 9 minutes. The 9-minute walking test was repeated the next day in 23 patients and a third test was performed in 15 patients within 2 weeks. The mean interval between test 2 and test 3 was 9 days.

The 24 controls performed two 9-minute walking tests within 2 weeks of their peak oxygen consumption being measured. Results are expressed as means (SD). Differences were analysed by analysis of variance and Student’s t test.

### Results

#### Peak Oxygen Consumption

Peak oxygen consumption was limited by symptoms in patients and controls. The mean peak oxygen consumption was 36.9 (4.1) ml/kg/min in controls and 15.4 (4.2) ml/kg/min in patients with heart failure. The mean extrapolated oxygen consumption was 38.2 (5.2) ml/kg/min in controls and 19.5 (5.8) ml/kg/min in patients. The mean anaerobic threshold was 22.3 (2.9) ml/kg/min in the controls and 13.2 (3.2) ml/kg/min in the patients. All the patients and controls reached respiratory quotient > 1.0 by the end of exercise.

#### 9-Minute Walking Test

In the 24 normal subjects the mean distance walked in 9 minutes on the self-powered treadmill was 704.2 (147) m and 703.9 (144) m in the successive tests. By contrast the patients with heart failure walked 318 m (153-4), 385 m (165-6), and 354-6 m (127-5) in the three tests carried out (table 1). There was a significant difference between the distance walked by patients and controls (p < 0.0001). The figure shows the relation between the distance walked in 9 minutes and the peak oxygen consumption. The distance walked in 9 minutes correlated with the peak oxygen consumption in controls (r = 0.57, p < 0.005), patients (r = 0.85, p < 0.0001), and both groups combined (r = 0.9, p < 0.0001). The distance walked in 9 minutes correlated with the extrapolated maximal oxygen consumption in controls (r = 0.57, p < 0.005), patients (r = 0.48, p < 0.005), and both groups combined (r = 0.83, p < 0.0001). Although the anaerobic threshold did not correlate with the distance walked in controls there was a significant correlation in patients (r = 0.64, p < 0.0001), and in both groups combined (r = 0.76, p < 0.0001).

Table 2 shows the results of the 9-minute walking test according to severity of heart failure. There was a significant difference between the distance walked by patients with severe heart failure and those with mild to

### Table 1: Nine minute walking test in patients with heart failure and controls

<table>
<thead>
<tr>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Controls (n = 24)</td>
<td>Patients (n = 24)</td>
<td>Controls (n = 24)</td>
</tr>
<tr>
<td>Mean (m)</td>
<td>704</td>
<td>318</td>
</tr>
<tr>
<td>Range (m)</td>
<td>525-1038</td>
<td>71-3-706</td>
</tr>
<tr>
<td>SD</td>
<td>147</td>
<td>153-4</td>
</tr>
</tbody>
</table>

Note: The table shows the mean and range of distance walked in meters for patients and controls in 9-minute walking tests. The tests were performed to assess oxygen consumption and physical capacity in patients with heart failure. The results are compared with controls to determine the impact of heart failure on walking ability.
Table 2: Mean (SD) results of 9 minute walking test in patients with different degrees of heart failure and controls

<table>
<thead>
<tr>
<th>Group</th>
<th>Test 1 (m)</th>
<th>Test 2 (m)</th>
<th>Test 3 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe heart failure</td>
<td>200-2 (75-1)</td>
<td>200-9 (99-2)</td>
<td>245-3 (70-3)</td>
</tr>
<tr>
<td>Peak ( \dot{V}O_2 ) &lt; 15 ml/kg/min</td>
<td>(n = 18)</td>
<td>(n = 10)</td>
<td>(n = 7)</td>
</tr>
<tr>
<td>Mild to moderate heart failure</td>
<td>429-6 (83-2)</td>
<td>473-5 (93-1)</td>
<td>450-3 (81-0)</td>
</tr>
<tr>
<td>Peak ( \dot{V}O_2 ) &gt; 15 ml/kg/min</td>
<td>(n = 19)</td>
<td>(n = 13)</td>
<td>(n = 8)</td>
</tr>
<tr>
<td>Controls</td>
<td>704 (147)</td>
<td>704 (144)</td>
<td>(n = 24)</td>
</tr>
</tbody>
</table>

Peak \( \dot{V}O_2 \), peak oxygen consumption on exercise.

In patients with mild heart failure, however, there was considerable overlap between the distance walked by patients and by controls. Functional state has also been assessed by the use of sensors of limb movement that provide a guide to the level of everyday physical activity in patients with chronic heart failure.17

The time of limited exercise on a self-powered treadmill where the patient chooses the speed at which he or she walks was initially explored as an alternative in patients with mild heart failure.4 The test may be more representative of normal activity than a conventional maximum exercise test as the patient chooses the speed of walking. Considerable effort is required to overcome the friction of the belt and inertia of the rollers, making it more strenuous than a 6-minute walk along a corridor. It is also more convenient and allows better supervision of the patient. The characteristics of the treadmill were established in a preliminary study and the distance travelled in 12 minutes was shown to correlate with peak oxygen consumption.6

The current study set out to explore the use of this technique in a larger group of patients with various degrees of heart failure. As a result of our earlier experience we chose to shorten the test to 9 minutes, which is an adequate challenge even in patients with mild heart failure and avoids boredom being a determinant of the end point. The distance walked in 9 minutes correlated with the peak oxygen consumption in controls, patients, and both groups combined. There was a significant difference in the distance walked by controls and patients with heart failure. Although the controls were not age matched it is unlikely that this accounted for the difference in walking distance. The test is also able to discriminate between patients with mild to moderate heart failure (peak oxygen consumption >15 ml/kg/min) and severe heart failure (peak oxygen consumption <15 ml/kg/min, table 2).

The correlation between extrapolated maximal oxygen consumption and distance walked in 9 minutes was also significant in this group of patients and controls. The correlation of distance walked with anaerobic threshold was poor in controls but was seen in patients and in both groups combined. Although the anaerobic threshold was initially introduced as an objective, effort-independent measure of capacity to exercise, the validity of the concept has been challenged in recent years.5,10

The friction between the belt and the underplate is considerable and may vary from day to day. The distance travelled during a time-limited test will also depend on the ability of the subjects to pace themselves optimally. Despite these potential limitations we found that the technique was reproducible in controls and in patients with heart failure. It may therefore be used as an alternative to conventional exercise testing with measurement of respiratory gas exchange.

Conventional exercise testing has been

moderate heart failure (p < 0.0001) and between the severe heart failure group and controls (p < 0.0001). In patients with severe heart failure there was a progressive increase in the distance walked in the three tests. There was no significant difference in the severity of heart failure between patients who performed one, two, or three 9-minute walking tests, the peak oxygen consumption in the three groups was 15-1 (4-2) ml/kg/min, 16-0 (4-3) ml/kg/min, and 15-9 (4-3) ml/kg/min.

REPRODUCIBILITY
There was no significant difference in the distance walked in successive tests in the normal subjects (mean (SD) of the difference between the two measurements = 13 (68) m) or in the patients with heart failure (mean (SD) = 8 (50)m).

SAFETY
The 37 patients who participated in this study did a total of 74 9-minute walking tests on the self-powered treadmill. Exercise had to be ended early in one patient because of symptomatic bradycardia and hypotension.

Discussion
One of the main problems in the evaluation of heart failure is that symptoms are a poor guide to the severity of the condition.7,10 Haemodynamic variables at rest or exercise are known not to correlate with symptoms or exercise capacity.11,12 This accounts for the increasing use of objective measures of exercise capacity in these patients. The peak oxygen consumption on exercise has been shown to be more reproducible than exercise duration,10 and to be an independent predictor of prognosis.15,16 A knowledge of the respiratory quotient at peak exercise provides information as to whether function of the cardiovascular system limits exercise. The main disadvantages of the measurement of peak oxygen consumption are expense, the requirement for considerable technical expertise, and discomfort to the patient.

Performance assessed from a maximal exercise test may not correlate with the symptoms of the patient or the ability to perform tasks in everyday life. Although submaximal tests may be useful for this, the most appropriate exercise protocol has not been established. The 6-minute walking test has been found to be an inexpensive and sensitive method in patients with severe heart failure.5
established as a safe technique in large cohorts of patients in trials of heart failure. These procedures have usually been carried out in tertiary care centres with considerable expertise on hand. The use of a self-powered treadmill is inexpensive and does not require much technical expertise. Consequently it may be applied to patients in all settings including primary care and may have particular value in trials of treatment in such a setting. Although our study included patients with severe heart failure we did not experience serious adverse events and the use of a self-powered treadmill seems safe in these patients.

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