Relationship between isokinetic muscle strength and exercise capacity in chronic heart failure

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Abstract

The exercise intolerance and excessive ventilatory response to exercise of chronic heart failure is associated with abnormalities of skeletal muscle function, in particular a reduction in muscle strength. Isometric and isokinetic leg muscle strength were measured in 10 patients with chronic heart failure and 10 age-matched controls. Each subject undertook maximal exercise testing to measure peak oxygen consumption ($V_{\text{O}_2}$) and the ventilatory response to exercise as measured by the slope of the relation between ventilation and carbon dioxide production ($V_{\text{E}}/V_{\text{CO}_2}$ slope). Quadriceps strength (mean (S.D.)) was reduced in heart failure as measured by isometric (444.9 (129.6) N vs. 556.0 (136.0); $P<0.01$) and isokinetic (123.6 (30.2) Nm vs. 146.8 (40.0); $P=0.04$). Hamstring strength was also reduced as measured by isokinetic testing (53.6 (15.6) Nm vs. 71.1 (28.1); $P=0.02$). Isokinetic and isometric strengths correlated, but not closely ($r=0.52$, $P<0.001$). There were negative correlations between the $V_{\text{E}}/V_{\text{CO}_2}$ slope, and isokinetic measures: with average torque, $r=-0.62$, $P<0.004$; with peak torque, $r=-0.64$, $P=0.002$. We have found evidence for reduced muscle function affecting both knee flexors and extensors. This reduction in muscle strength correlates with the ventilatory response to exercise. These observations lend support to the muscle hypothesis of the generation of symptoms in chronic heart failure. © 1997 Elsevier Science Ireland Ltd.

Keywords: Chronic heart failure; Muscle strength; Isokinetics

1. Introduction

The breathlessness and fatigue on exercise suffered by patients with chronic heart failure is associated with abnormalities of skeletal muscle function. Previous investigators have described a reduction in muscle strength [1] which correlates with exercise performance [2]. The response to repeated submaximal exercise is reduced in heart failure, with more pronounced fatigue being reported [3], which again correlates with reduced exercise capacity [4].

Muscle strength has usually been assessed by the measurement of isometric quadriceps strength. Strength is measured as a force in newtons (N). This allows a straightforward testing protocol, but is not a good representation of day-to-day activities. Measurement of muscles’ ability to generate force/torque allows identification of musculoskeletal dysfunction [5,6]. Isokinetic dynamometry provides a method of dynamically assessing muscle function which is a more physiological assessment of muscle function [7,8]. During isokinetic exercise, dynamic resistance to movement is applied to allow movement over a predetermined range at a fixed velocity. Outcome measures from isokinetic dynamometry include peak
force/torque, average force/torque, work done, and power. Torque is the product of the force measured at the point of application and the distance from the point of application to the centre of rotation of the dynamometer’s lever arm and measured as newton metres (Nm). Current research suggests that the outcome measures above are so closely related that they become interchangeable [9]. Peak torque is among the most widely reported outcome measure [10,11].

We were interested to examine the relationships between isometric and isokinetic strength in patients with chronic heart failure and their possible relationship to exercise capacity and the ventilatory response to exercise.

2. Methods

The study was approved by the local ethics committee. All subjects gave fully informed consent to the study procedures. Ten patients with chronic heart failure and 10 age-matched controls took part in the study (see Table 1). All patients were receiving angiotensin converting enzyme inhibitors (6 captopril, 3 lisinopril and 1 enalapril) and diuretics. Two patients were receiving a thiazide diuretic and the rest received an average daily dose of 85 (45) mg frusemide. Three patients received digoxin, 2 amiodarone and 3 were anticoagulated with warfarin.

All subjects attended on two occasions 1 week apart. At the first visit, each subject underwent maximal exercise testing using a Bruce treadmill protocol modified by the addition of a stage 0 (3 min at 2.7 km/h at zero gradient). The subjects breathed via a one-way valve connected to a gas analyser (Covox Fitness and Research Systems, Exeter), allowing determination of metabolic gas exchange. At the second visit, following a 5–8 min standardised treadmill warm-up, isometric and isokinetic testing was performed on the KinCom® 500H dynamometer (Chattecx Corp., Chattanooga) [12]. Right and left quadriceps were assessed both isometrically and isokinetically. Both hamstrings were assessed isokinetically. The side to be tested first was selected randomly for each subject. Tests were conducted with the subject in a seated position with a shin pad positioned ~3 cm above the ankle. Standardised verbal encouragement was given throughout.

Quadriceps were assessed isometrically with the knee in 90 degrees flexion. Each subject performed two sub-maximum voluntary contractions, followed by one maximum voluntary contraction (MVC) as a warm up. Isometric strength was then taken as the average of three MVCs each lasting 3 s, with a minimum recovery period of 15 s between.

Both quadriceps and hamstrings were assessed isokinetically at 30 degrees/s between 80 and 10 degrees knee flexion. Isokinetic data were corrected for the effects of gravity [6,13]. The initial force for knee extension was set at 50% limb weight, whilst the initiation force for knee flexion was set at 150% limb weight [14]. The test was halted if the force generated dropped below 20 N. Two sub-MVCs followed by one MVC were performed for both quadriceps and hamstrings to act both as a warm up and a familiarisation with isokinetics. A minimum recovery period of 30 s then followed. A quadriceps MVC followed by a hamstrings MVC with a 5 s delay between contractions was performed 3 times. There was a minimum of 15 s between successive quadriceps MVCs. The peak torque for each contraction was recorded and averaged. There was less than 10% variation between maximum and minimum for each measurement.

Results are given as means (S.D.). Comparisons between groups were made with Student’s unpaired t-test. Correlations were performed using the least squares method. A P value of less than 0.5 was taken to be significant.

3. Results

All subjects managed the test protocol with no complications. Exercise capacity was greater and ventilatory response to exercise was lower for controls than patients (see Table 1). Patients and controls achieved a similar respiratory exchange ratio at peak exercise suggesting similar levels of exertion.

For patients and controls no significant difference was observed between right and left sides for any of the muscle strength measurements made. The results for the isometric and isokinetic strengths are shown in Table 2. Patients had generally weaker muscles as
measured by both isokinetic and isometric testing. The time to peak during peak isometric contraction was quicker for patients. The ratio between quadriceps and hamstrings was unchanged. Quadriceps and hamstring muscle strengths correlated closely \((r = 0.74, P < 0.001)\) for both average and peak isokinetic contractions.

There was no relationship between muscle strength, however measured, and body mass index or weight. There were no relationships between measures of isokinetic muscle strength and exercise performance as assessed by peak oxygen consumption. There was a weak relationship between isometric muscle strength and peak oxygen consumption \((r = 0.47; P = 0.04)\). There was a relationship between ventilatory response to exercise, as measured by the \(\dot{V}_E/\dot{V}_{CO_2}\) slope, and isokinetic measures: with average torque, \(r = -0.62, P < 0.004\); with peak torque, \(r = -0.64, P = 0.002\) (see Fig. 1). A similar, although weaker, relationship was seen between the \(\dot{V}_E/\dot{V}_{CO_2}\) slope, and isometric muscle strength \((r = -0.51; P = 0.02)\).

### 4. Discussion

Chronic heart failure is characterised by exercise intolerance. Patients are usually limited by breathlessness and/or fatigue. The origin of the symptoms has not been clearly delineated, but does not appear to be closely related to abnormalities of central haemodynamics [15,16].

Skeletal muscle is abnormal in patients with chronic heart failure. There is reduced muscle strength and increased fatigue [1,3]. Investigators have reported abnormal biochemistry [17] and reduced muscle bulk [18]. These abnormalities appear to be related to exercise performance [2,4,19]. The ‘muscle hypothesis’ for the origin of symptoms in chronic heart failure [20] suggests that the skeletal muscle abnormalities may be responsible for generating the excessive ventilatory response to exercise via activation of work sensitive muscle receptors [21].

Previous studies have measured isometric muscle strength in large muscle groups, usually the quadriceps. Isokinetic assessment of muscle function has

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**Table 1**

<table>
<thead>
<tr>
<th></th>
<th>Patients ((n = 10))</th>
<th>Controls ((n = 10))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>54.9 (12.5)</td>
<td>52.2 (13.9)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>73.5 (9.5)</td>
<td>76.7 (9.7)</td>
</tr>
<tr>
<td>BMI (kg/m(^2))</td>
<td>25.2 (3.7)</td>
<td>25.1 (3.4)</td>
</tr>
<tr>
<td>LVEDD (cm)</td>
<td>6.35 (0.28)</td>
<td>5.19 (0.42)</td>
</tr>
<tr>
<td>LVESD (cm)</td>
<td>5.19 (0.42)</td>
<td>0.55 (0.05)</td>
</tr>
<tr>
<td>Peak (\dot{V}_{O_2}) (ml/kg/min)</td>
<td>21.3 (7.1)</td>
<td>44.7 (14.3)</td>
</tr>
<tr>
<td>(\dot{V}<em>E/\dot{V}</em>{CO_2}) slope</td>
<td>29.6 (8.2)</td>
<td>20.2 (2.1)</td>
</tr>
<tr>
<td>Peak RER</td>
<td>1.20 (0.16)</td>
<td>1.25 (0.11)</td>
</tr>
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BMI, body mass index; LVEDD and LVESD, left ventricular end-diastolic and end-systolic dimensions, respectively, as measured by two-dimensional echocardiography; CTR, cardiothoracic ratio; peak \(\dot{V}_{O_2}\), peak oxygen consumption; \(\dot{V}_E/\dot{V}_{CO_2}\) slope, the slope of the relationship between ventilation and carbon dioxide production; RER, the respiratory exchange ratio. Data are given as means (S.D.).

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**Table 2**

<table>
<thead>
<tr>
<th></th>
<th>Patients ((n = 10))</th>
<th>Controls ((n = 10))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q isometric strength (N)</td>
<td>444.9 (129.6)</td>
<td>556.0 (136.0)</td>
</tr>
<tr>
<td>Time to peak (s)</td>
<td>1.32 (0.60)</td>
<td>1.91 (0.53)</td>
</tr>
<tr>
<td>Q average torque (Nm)</td>
<td>86.3 (18.0)</td>
<td>99.4 (24.9)</td>
</tr>
<tr>
<td>Q peak torque (Nm)</td>
<td>123.6 (30.2)</td>
<td>146.8 (40.0)</td>
</tr>
<tr>
<td>H average torque (Nm)</td>
<td>42.7 (13.1)</td>
<td>56.5 (22.2)</td>
</tr>
<tr>
<td>H peak torque (Nm)</td>
<td>53.6 (15.6)</td>
<td>71.1 (28.1)</td>
</tr>
<tr>
<td>Q/H average</td>
<td>2.2 (0.6)</td>
<td>2.4 (0.6)</td>
</tr>
<tr>
<td>Q/H peak</td>
<td>2.0 (0.7)</td>
<td>2.3 (0.7)</td>
</tr>
</tbody>
</table>

Q, quadriceps; H, hamstrings. Q/H is the ratio of the two. \(P\) values refer to unpaired \(t\)-test comparisons made between patients and controls.
the advantage that it measures muscle strength over a range of movement. Although this remains an artificial setting, it is closer to the usual demands made upon exercising skeletal muscle than isometrics. There was a relationship between isometric and isokinetic measures of muscle strength ($r=0.52$, $P<0.001$). The fact that the ratio of quadriceps to hamstring muscle strength remained unchanged suggests a global change in muscle function rather than a selective process.

There was no strong relationship between muscle strength and exercise capacity, but we did find a reduction in muscle strength in patients with chronic heart failure. For the first time, the present study demonstrates a relation between skeletal muscle strength and the excessive ventilatory response to exercise, as characterised by the $V_E/V_{CO_2}$ slope. These findings lend support to the muscle hypothesis, and suggest that there may be a link between the abnormal skeletal muscle and the increased ventilatory response to exercise in chronic heart failure.

4.1. Limitations to present study

This was a small scale study designed to explore the possible use of isokinetic strength testing in patients with chronic heart failure. It is difficult to ensure that a maximal effort is being made during isokinetic muscle strength testing, and it is possible that some of our findings may be explained by reduced effort on behalf of the patients. We tried to reduce this possibility by encouraging the patients and by repeating the tests three times; there was less than 10% variation for any subject between each of the three attempts. During maximal exercise testing, each subject was able to exercise until reaching a respiratory exchange ratio greater than 1.0, demonstrating the capacity, at least in this particular setting, to produce at least near maximal exertion with encouragement.

References


