Assessing the effect of exercise training in men with heart failure

Comparison of maximal, submaximal and endurance exercise protocols

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Aims No consensus exists regarding the most appropriate exercise testing protocol for patients with congestive heart failure. This study describes the effect of exercise training on performance using three different protocols (maximal, submaximal and endurance testing) in patients with heart failure.

Methods and Results Thirty men (mean age 67 ± 8 years) with congestive heart failure in NYHA class III (mean ejection fraction 32 ± 5%) were evaluated prior to and following exercise training. A maximal exercise cycle test with gas exchange measurements, a submaximal 6 min walk test and an endurance treadmill test with blood lactate sampling were used to evaluate exercise capacity after 12 weeks of exercise training. There was a 44.6% (P < 0.001) increase in work performed during the maximal cycle test, with no significant increase in peak VO2. The distance covered by the submaximal 6 min walk test increased by 8.1% (P < 0.001). Lactate measured as area under the curve during the matched work intensity treadmill endurance test was reduced by 19.5% (P < 0.005).

Conclusion We demonstrated a significant improvement in maximal, submaximal and endurance exercise capacity following 12 weeks of exercise training in patients with congestive heart failure. Endurance tests may be more sensitive and appropriate when assessing the efficacy of intervention in this population. Specifically, demonstration of reduced lactate production at matched work intensities suggests more efficient work and decreased dependence on anaerobic metabolism following training. Although maximal cycle tests are commonly used in clinical work, submaximal and endurance testing might be preferable for evaluating new treatment regimens in this population as they are easy to perform, are reproducible, and reflect daily tasks better than the maximal cycle test in this population. (Eur Heart J 2001; 22: 684–692, doi:10.1053/euhj.2000.2286) © 2001 The European Society of Cardiology

Key Words: Test protocol, exercise training, heart failure.

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life and mortality, and may be more closely related to daily activities than maximal exercise tests\(^{[10]}\). Because exercise intolerance during daily activity is the dominant symptom, endurance protocols may be the most appropriate way to assess functional capacity\(^{[11]}\). The main objective of this study was to evaluate the relative sensitivities of maximal, submaximal and endurance protocols in the assessment of exercise performance in patients with heart failure before and after 3 months of aerobic exercise training. We evaluated men with stable congestive heart failure, using three different exercise protocols in order to compare the magnitude of improvement measured: (a) maximal cycle ergometer test with gas exchange collection and lactate sampling, (b) submaximal 6 min walk test and (c) endurance treadmill test with matched work intensities.

**Methods**

**Screening methods**

Male patients with symptomatic heart failure were screened by echocardiography to confirm the diagnosis of left ventricular dysfunction. Left ventricular ejection fraction was determined by radionucleide ventriculography and functional capacity was assessed by a 6 min walk test and a cycle exercise test with peak VO\(_2\) determination. Only patients with exercise intolerance, as confirmed by a 6 min walk test <550 m, and a peak ergometer cycle exercise test with a peak VO\(_2\) consumption <20 ml \cdot kg\(^{-1}\) \cdot min\(^{-1}\) were eligible. Patients with unstable angina pectoris, serious rhythm disturbance, significant valvular stenosis, symptomatic peripheral vascular disease or other serious concurrent illness that would reduce exercise capacity, were excluded.

**Population**

Thirty men (mean age 66.7 ± 7.7) with stable heart failure and NYHA class II–III symptoms (mean ejection fraction 32 ± 5%) were recruited (Table 1). No patients were pacemaker dependent, but two patients did have VVI back-up pacemakers prior to inclusion. In 29 patients congestive heart failure was due to previous myocardial infarction and coronary artery disease. The patients were treated with conventional medical therapy including diuretics, ACE inhibitors and digitalis (Table 1).

**Study design and training protocol**

The protocol was approved by the regional ethical committee, and written informed consent was obtained from every patient. This study was an open, unblinded trial evaluating the effect of exercise training over 3 months with three different exercise testing protocols.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Baseline characteristics (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>Males</td>
</tr>
<tr>
<td>Age (years)</td>
<td>66.7 ± 7.7</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>75.2 ± 7.6</td>
</tr>
<tr>
<td>RNV ejection fraction (%)</td>
<td>32.2 ± 5.3</td>
</tr>
<tr>
<td>Peak VO(_2) (ml \cdot kg(^{-1}) \cdot min(^{-1}))</td>
<td>15.7 ± 2.7</td>
</tr>
<tr>
<td>6 min walk distance (m)</td>
<td>517 ± 70</td>
</tr>
<tr>
<td>Diuretic</td>
<td>26</td>
</tr>
<tr>
<td>ACE-inhibitor/AT2-antagonist</td>
<td>23/4</td>
</tr>
<tr>
<td>Digitalis</td>
<td>21</td>
</tr>
<tr>
<td>Beta-blocker</td>
<td>0</td>
</tr>
<tr>
<td>Nitrates</td>
<td>11</td>
</tr>
<tr>
<td>Aspirin</td>
<td>10</td>
</tr>
<tr>
<td>Warfarin</td>
<td>14</td>
</tr>
<tr>
<td>Amiodarone</td>
<td>7</td>
</tr>
<tr>
<td>Ca-antagonist</td>
<td>2</td>
</tr>
</tbody>
</table>

RNV=radiouclide ventriculography; VO\(_2\)=oxygen consumption; ACE=angiotensin converting enzyme; AT2=angiotensin Receptor Type 2.

Patients participated in exercise training groups 3 days per week in a rehabilitation centre with an instructor specialized in cardiac rehabilitation. All exercise training techniques had been evaluated in a pilot study with patients in NYHA groups III–IV. Portable heart rate monitors (POLAR Sport Tester, Kempele Finland) were used to assess training intensity during the group sessions. After each group session, the continuously recorded heart rate pattern from each patient was downloaded, and the heart rate at 5 s intervals during the training session was analysed. The group training model consisted of 10 min of warm-up, 25 min of endurance training and 10 min of cooling down and stretching. The warm-up phase consisted of dynamic exercises to increase heart rate gradually, to prevent injuries and to prepare for higher intensity exercise. The endurance training was based on callisthenics; low impact aerobics, walking and jogging using the large muscle groups in both the upper and lower extremities at approximately 80% of maximal capacity. The training programme consisted of: 3 min of fast walking and jogging, 4 min of low impact aerobics using upper and lower limbs, 3 min of jogging, 4 min of low impact aerobics and 3 min of fast walking. The cooling-down phase after the endurance training consisted of low intensity dynamic exercise, to maintain venous blood flow in the transition from high to low intensity. Stretching exercises prevented shortening of muscle fibres and reduced muscle tone.

After 2 weeks of physical training at the cardiac rehabilitation centre, the patients were encouraged to exercise at home on a cycle ergometer 3 days per week as a supplement to the group training. They exercised for 30 min on a bicycle ergometer with a target heart rate of 80% of the peak heart rate observed during baseline bicycle exercise testing. These training sessions were performed on days when the patients were not performing group training. Following each group training session, the patients were asked to report whether the target heart rate was reached, and which of the
following symptoms were considered limiting: dyspnoea, fatigue, claudication, angina or dizziness.

**Exercise testing protocols**

**Maximal cardiopulmonary exercise test**
The patients were evaluated on an upright, electrically braked cycle ergometer (Model KEM III, Mijnhardt, S.Y. Bunnik, The Netherlands) using a 15 Watt · min⁻¹ ramp protocol. The patients were instructed to exercise maximally until symptomatic end points. Gas exchange data were collected continuously with an automated breath-by-breath system (System 2001, Medical Graphics Corporation, St.Paul, Minn.). Three sets of maximal tests were performed: an initial familiarization test not more than 3 weeks before entering the study, a baseline test, and a test following completion of the study.

Routine gas exchange measurements were made on-line. Values at rest, at respiratory exchange ratio (RER)=1 and at peak exercise were recorded. Prior to the maximal exercise test, an arterial cannula (Viggo Spectramed) was placed in the radial artery and fixed to the arm, with a continuous flush device (Abbott intra-flo II, 30 ml · h⁻¹) containing a heparinized saline solution. Blood was drawn from the cannula using a sterile closed-loop system into 2 ml tubes (Vacutainer), containing sodium fluoride and potassium oxalate for the assessment of lactate concentration. Blood was drawn with the subject seated on the cycle prior to the start of exercise testing, and every 2 min throughout the test. Immediately following the termination of the test, another blood sample was drawn for peak exercise values. After 5 min, a final blood sample was drawn for recovery values. The blood was collected in pre-chilled tubes and put into an ice bath immediately after sampling. The blood was separated and centrifuged at 4°C and 3500 rpm for 10 min.

**Submaximal exercise test (6 min walk test)**
The test was performed according to conventional criteria⁶ and all tests were monitored by the same investigator to ensure uniform instruction in a quiet exercise facility⁷. The patients were instructed to walk ‘as far as possible for 6 min’.

**Endurance exercise test**
The patients were instructed to walk on a Star Track 3028 treadmill (Unisen Inc., Tustin, CA, U.S.A.) at an initial speed of 1.0 km · h⁻¹ and an angle of 0%. The speed and angle was increased according to one of two alternative protocols, depending on the patients’ estimated exercise capacity: (a) by 0.25 km · h⁻¹ and 0.5% per minute or (b) by 0.5 km · h⁻¹ and 1% per minute, until a stable heart rate, equal to 85% of the peak heart rate, as measured during the maximal baseline bicycle test, was reached. The patient was then instructed to continue at a constant rate and angle until symptomatic end-points had been reached, or until a total test time of 30 min. The decision of which protocol to use for each patient was based on the performance during the initial maximal exercise test. We adapted the treadmill protocol according to the protocol used by Ades *et al.* on elderly deconditioned patients with coronary heart disease⁹. The intention was to reach the highest level of endurance capacity following a warming up phase of approximately 10 min and then continue at this level for the rest of the test. The 12 week test employed an identical protocol in order to ensure matched work intensities at baseline and following completion of the training. During all tests, heart rate, speed and angle were recorded at 1 min intervals. Capillary blood was collected prior to exercise, every 4 min during the test, at the end of the test and at 5 min into recovery for the assessment of lactate production during exercise. A standard micro lancet was used. Each blood sample was collected into a 100 μl capillary tube, and analysed immediately, using the YSI 1500 Sport lactate analyser (Ysi Inc., Yellow Springs, Ohio, U.S.A.). An example of the endurance test in a single patient is provided in Fig. 1.

**Statistical analysis**

All data were entered into a dBase version 5 database and prepared for analysis using a SYSTAT Version 5 software package. To evaluate the training effect in this open, unblinded trial we used the paired t-test. The values are reported as means ± SD. The t-test was used to calculate a P-value for the comparisons of means. The value of significance was set at P<0.05.

**Results**

All patients completed the study and there were no serious adverse events or requirement for therapy adjustment during the training period. The results after training according to the three different exercise testing protocols are presented in Tables 2–4. The percent difference for each of the testing protocols is presented in Table 5. Body weight was unaltered by the training programme (75.2 ± 7.6 vs 74.8 ± 7.4 kg, ns). There was no significant change in routine haematology or biochemistry. There was no change in ejection fraction measured with radionuclide ventriculography (32.2 ± 5.3 vs 32.7 ± 9.2%).

**Maximal cardiopulmonary exercise test**

Total work performed increased from 28.1 ± 11.5 to 36.9 ± 13.7 kJ (+44.6%, P<0.001). Mean exercise time increased from 584 ± 98 to 653 ± 98 s (+13-6%, P<0.001). Mean peak VO₂ increased from 15.7 ± 2.7 to 16.4 ± 2.1 ml · kg⁻¹ · min⁻¹ (+6.1%, P=ns). Minute ventilation (VE) increased by 3.82 ± 9.961 · min⁻¹ (+7.4%, P=0.048). There was no change in maximal respiratory exchange ratio (1.14 ± 0.093 vs 1.15 ± 0.085, ns). Resting heart rate while sitting on a bicycle was
unchanged (80·3 ± 16·7 vs 79·7 ± 14·8 beats·min⁻¹, ns). Maximal heart rate decreased from 133·7 ± 20·6 to 132·2 ± 21·6 beats·min⁻¹ (ns). Peak lactate was unchanged.

Submaximal 6 min walk test
The distance covered during the 6 min walk test increased from 517 ± 71 to 554 ± 56 m (+8·1%, P<0·001).

Table 2 Maximal bicycle ergometer exercise test. Results after 12 weeks of exercise training (n=30)

<table>
<thead>
<tr>
<th></th>
<th>Pre-training</th>
<th>Post-training</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise time (s)</td>
<td>584 ± 98</td>
<td>653 ± 98</td>
<td>=0·001</td>
</tr>
<tr>
<td>Work performed (kJ)</td>
<td>28·1 ± 11·5</td>
<td>36·9 ± 13·7</td>
<td>&lt;0·001</td>
</tr>
<tr>
<td>Peak VO2 (ml·kg⁻¹·min⁻¹)</td>
<td>15·7 ± 2·7</td>
<td>16·4 ± 2·1</td>
<td>ns</td>
</tr>
<tr>
<td>Peak RER</td>
<td>1·14 ± 0·09</td>
<td>1·15 ± 0·09</td>
<td>ns</td>
</tr>
<tr>
<td>Peak HR (beats·min⁻¹)</td>
<td>133·7 ± 20·6</td>
<td>132·2 ± 21·6</td>
<td>ns</td>
</tr>
<tr>
<td>Peak lactate (mmol·l⁻¹)</td>
<td>6·5 ± 1·4</td>
<td>6·7 ± 1·7</td>
<td>ns</td>
</tr>
</tbody>
</table>

VO2= oxygen consumption; RER= respiratory exchange ratio; HR= heart rate.

Table 3 Submaximal 6-min walk test. Results after 12 weeks of exercise training (n=30)

<table>
<thead>
<tr>
<th></th>
<th>Pre-training</th>
<th>Post-training</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk distance (m)</td>
<td>517±4 ± 70·8</td>
<td>554·7 ± 56·2</td>
<td>&lt;0·01</td>
</tr>
</tbody>
</table>

Endurance treadmill exercise test
Treadmill distance increased from 1435 ± 420 to 1533 ± 332 m (+6·8%, P=0·05). Lactate measured as area under the curve (Fig. 1) decreased from 45·19 ± 14·46 to 36·35 ± 14·27 (−19·5%, P<0·005). Peak lactate value at the end of the test decreased from 1·98 ± 0·58 to 1·70 ± 0·96 mmol·l⁻¹ (−14·6%, ns). Maximal lactate value for the treadmill test decreased from 2·25 ± 0·59 to 1·95 ± 0·96 mmol·l⁻¹ (−13%, ns). The lactate value at recovery (5 min after treadmill test) decreased from 1·71 ± 0·75 to 1·59 ± 0·92 mmol·l⁻¹ (−6·7%, n=20, ns).

Discussion
We evaluated three different types of exercise testing protocols. Mean exercise time and total work increased significantly. However, we did not demonstrate an increase in maximal VO2 during maximal exercise testing on the ergometer cycle after exercise training in patients with congestive heart failure. Peak respiratory exchange ratio, and peak lactate was unchanged. Distance during the 6 min walk test increased significantly. The treadmill endurance test showed an increase in the distance covered. There was no significant decrease in maximal lactate value or peak lactate value at test end. There was, however, a highly significant decrease of lactate measured as area under the curve during the
treadmill test. The percent difference for each of the testing values are presented in Table 4.

**Exercise training protocols**

Increasing exercise capacity and improving symptoms during daily living are the most important goals of intervention in patients with congestive heart failure. Previous studies have demonstrated increased work performed and increased peak VO₂ following training of large muscle groups[13]. However, mode and intensity of training necessary for achieving optimal results is still not known. In the present study the patients exercised at 85% of maximal heart rate 5 days a week during a period of 12 weeks. Three times weekly they were trained by physiotherapists experienced in cardiac rehabilitation to use the large groups of muscles in the lower extremities by walking and jogging for 25 min.

Healthy individuals are recommended a training intensity of 70–80% of estimated maximal heart rate (220-age). This approach is often not suitable for congestive heart failure patients in that they have an increased resting heart rate, reduced heart rate variability and altered chronotropic response compared to normal age-matched individuals[14].

Previous studies have demonstrated an increase in maximal VO₂ after exercise training at 40% of peak heart rate as well as after exercise training at 70–80% of peak heart rate[15,16]. The effect of training has also been demonstrated by an increase in both maximal VO₂ as well as in exercise duration after exercise training at 70% of maximal VO₂[17] and at 40–60% of peak VO₂[18]. There is no consensus as to the most beneficial type of exercise training. Until recently isotonic, dynamic exercise training involving the muscle groups in the lower extremities has been advocated. Some studies have, however, focused on local exercise training; i.e extensor strength training as an alternative to dynamic exercise training. There is an increase both in exercise capacity and strength as well as an improved ventilatory response in submaximal exercise levels and an increase in quality of life after knee-extensor training[19].

Increased oxidative enzyme activity in the vastus lateralis of the quadriceps muscle has been shown after both endurance exercise training and high intensity knee extensor strength training. The reason for local exercise training was to avoid the potentially adverse effects of systemic training on cardiac function. Previous studies indicated that exercise training could cause further myocardial damage in patients with congestive heart failure with ischaemic aetiology[20]. Recent research has not confirmed this. There is no further infarct expansion or increase in ventricular volumes unless the exercise training has been initiated too early after the myocardial infarction[21].

Exercise training increases the stroke volume in healthy subjects[22]. In congestive heart failure however, the most pronounced effect of exercise training may be found in the peripheral circulation and exercising muscle groups[23]. Dynamic exercise for large skeletal muscles and primarily the lower extremities has traditionally been the usual mode of exercise training. However, emerging data indicate an additional effect of strength-training[24].

Randomized trials are necessary to evaluate the difference between the two training techniques.

**Exercise testing protocols**

Surrogate measurements of functional capacity are used to assess therapy benefit in congestive heart failure. Maximal oxygen consumption has traditionally been used as an indicator of exercise capacity. However, recent studies have documented the value of submaximal or endurance testing for evaluating therapeutic response after exercise training[25]. The purpose of exercise testing

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**Table 4 Endurance 30-min treadmill test. Results after 12 weeks of exercise training (n=30)**

<table>
<thead>
<tr>
<th></th>
<th>Pre-training</th>
<th>Post-training</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AUC lactate</td>
<td>45.2 ± 14.5</td>
<td>36.4 ± 14.3</td>
<td>0.002</td>
</tr>
<tr>
<td>Max lactate during test (mmol. 1⁻¹)</td>
<td>2.25 ± 0.59</td>
<td>1.95 ± 0.96</td>
<td>ns</td>
</tr>
<tr>
<td>Peak lactate at termination (mmol. 1⁻¹)</td>
<td>1.98 ± 0.58</td>
<td>1.70 ± 0.96</td>
<td>ns</td>
</tr>
<tr>
<td>Lactate at 5 min recovery (mmol. 1⁻¹)</td>
<td>1.70 ± 0.75</td>
<td>1.59 ± 0.92</td>
<td>ns</td>
</tr>
</tbody>
</table>

AUC=area under the curve.

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**Table 5 Mean of individual changes in selected parameters for the three test models, prior to and following 12 weeks of exercise training (n=30)**

<table>
<thead>
<tr>
<th></th>
<th>Change (%)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal bicycle ergometer test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>13.6 ± 16.0</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Work performed</td>
<td>44.7 ± 53.4</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>VO₂</td>
<td>6 ± 1 ± 14.5</td>
<td>ns</td>
</tr>
<tr>
<td>Submaximal 6-min walk test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Distance</td>
<td>8.1 ± 9.9</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Endurance 30-min treadmill test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AUC lactate</td>
<td>−16.7 ± 26.9</td>
<td>0.002</td>
</tr>
<tr>
<td>Peak lactate at termination</td>
<td>−14.6 ± 38.4</td>
<td>ns</td>
</tr>
</tbody>
</table>

VO₂=oxygen consumption; AUC=area under the curve.
Assessing exercise training effects in CHF

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efficacy and partly by improvement in familiarity with the exercise protocol so that the same external work is achieved with less muscular effort. This finding is consistent with other trials which demonstrated that exercise training improved submaximal exercise performance in congestive heart failure patients, and that activities that were exhaustive before, became sustainable for longer periods, although the increase in maximal VO$_2$ was modest$^{[8,23]}$. Exercise intolerance in congestive heart failure patients is also characterized by slower adaptation to and from submaximal levels of exercise$^{[39]}$. This abnormally slow oxygen uptake kinetic correlates with anaerobic threshold and submaximal exercise tolerance$^{[40]}$. This might be accounted for during the endurance test.

**Comparison of testing protocols**

Many patients with heart failure find the cycle-ergometer test difficult and unfamiliar in that it requires balance and coordination. However, collection of expired gas and blood sampling is facilitated in that the patient’s upper torso is largely stationary. For assessing prognosis and for timing of heart transplantation, maximal VO$_2$ has been well documented as the exercise test of choice. Submaximal and endurance protocols may, however, be more appropriate when assessing functional capacity in this population. Treadmill exercise testing is attractive because it usually permits use of handrails, which feel safer. The patients are also more familiar with walking, and the test may therefore better reflect daily activity.

Submaximal tests are also well related to prognosis. The 6 min walk test is simple, and can easily be performed everywhere without expensive technical equipment. In the present study, the endurance protocol and the 6 min walk test demonstrate their sensitivity to changes in exercise performance after intervention in congestive heart failure patients.

**Mechanisms involved**

The limiting symptom of congestive heart failure, dyspnoea, was earlier explained as a CO$_2$-driven, lactic acid buffering reflex. Recent studies have also focused on the respiratory muscles. Selective respiratory muscle training improves submaximal and maximal exercise capacity by increased respiratory muscle strength and endurance$^{[41]}$. However, there is now evidence indicating that an altered ergo-reflex response also may contribute to hyperventilation in congestive heart failure patients at exercise$^{[42]}$. Thus, the increase in maximal work performed after exercise training is partly due to a shift toward aerobic metabolism with less lactic acidosis, which has to be buffered by the CO$_2$/HCO$_3$ system, increasing respiratory muscle strength and to a normalized ergo-reflex-response to exercise, which reduces the pathological hyperventilation which limits optimal utilization of available energy sources in congestive heart failure patients. Patients with congestive heart failure develop ultra-structural abnormalities of skeletal muscle, reflecting decreased oxidative capacity in working muscle.

The improvement in exercise tolerance after training in congestive heart failure patients seems to be related to normalization of these intracellular abnormalities, leading to improvement of oxidative capacity. This implies a more efficient aerobic metabolism resulting in less production of lactic acid, as demonstrated in the endurance test lactate area under the curve. An increase in capillary density and succinate dehydrogenase activity after exercise training in coronary patients has been documented, indicating increased aerobic metabolism$^{[43]}$.

In the treatment of patients with congestive heart failure, the main goal is to improve the quality of life. This means better endurance capacity and reduced dyspnoea, which seems to be attained by aerobic exercise training in this group of patients. The evaluation of the efficacy of exercise training is therefore perhaps best assessed by testing endurance and submaximal exercise capacity. Although maximal and submaximal performance may assess different aspects in congestive heart failure and provide valuable mechanistic information, patients may prefer the more comfortable endurance or submaximal test instead of an exhaustive, symptom-limited maximal exercise test.

**Study limitations**

This study was an open trial. This is an unavoidable design limitation in studies evaluating exercise training. Only 30 patients were included, and no control group was employed in that our focus was on the effects of training on three different exercise testing protocols.

Some of the patients were perhaps too well conditioned before entering the exercise training programme as the mean distance at the 6 min walk test was 517 m, and the mean maximal VO$_2$ before exercise training was 16 ml . kg$^{-1}$. min$^{-1}$. The population consisted of Norwegian men, a group familiar with physical activity. The programme consisted of isotonic, dynamic exercises involving the muscle groups in the lower extremities, but there was no strength training, and thereby substantial increase in muscle mass is unlikely, possibly explaining the modest increase in peak VO$_2$. There was no assessment with regard to compliance with the home-based cycle training. The training intensities may therefore have been less than intended.

**Conclusions and implications**

This study demonstrates the positive effect of moderate isotonic exercise training on a group of 30 male
congestive heart failure patients. We found that both
endurance and submaximal protocols were suitable and
sensitive methods for evaluating the effect of training in
this population.

The most sensitive test in our study for assessing the
training effect was the lactate level, measured as area
under the curve during the treadmill test. This exercise
test protocol is perhaps the most appropriate protocol
for evaluating new treatment regimens in this popula-
tion. However, the 6 min walk test, which reflects
the most frequently performed exercise in this population,
was also sensitive for assessing the effect of training
in the present study. It is simple, and can be easily
performed without special equipment.

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