Exercise Prescription of Patients with Heart Failure Before and After Heart Transplantation

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Introduction

While the mortality from stroke and heart attack is declining in industrialized countries, the incidence and prevalence of heart failure is growing dramatically without reduction in annual mortality [1,2]. Many patients worldwide are also undergoing orthotopic heart transplantation which is now an accepted treatment for patients with end-stage heart disease. As a result cardiac rehabilitation programs in the 21st century face the challenge of having to accommodate a growing number of more complex and severely ill patients.

Patients with heart failure were traditionally excluded from formal cardiac rehabilitation programs on the basis that they were at a much higher risk of sudden death during exercise activity, even though supervised, and that exertion could adversely affect the natural history of ventricular dysfunction precipitating or accelerating the decompensation of the left ventricle.

It is only recently that studies demonstrated the benefits of exercise training in this population. Earlier observational studies [3-6] showed that patients with left ventricular dysfunction could achieve improvements in maximal and submaximal exercise capacity without improvement in ejection fraction. More recent randomized trials [7-13] confirmed earlier findings in a controlled manner and contributed to provide a better understanding of the effects of aerobic exercise training in reverting intrinsic muscle abnormalities produced by heart failure. It has also been demonstrated that the improvement in functional capacity seen in patients with heart failure can lead to an improvement in quality of life and a reduction in hospital readmission and mortality rate [14].

Heart transplantation is now an accepted mode of treatment for selected patients with end-stage heart failure. At major teaching hospitals in the United States these patients are routinely referred for cardiac rehabilitation following hospital discharge. The beneficial effects of exercise training in patients who underwent orthotopic heart transplantation have been previously reported in observational studies [15, 16] and more recently in a randomized trial [17].

Specific practical guidelines regarding the assessment, counselling and exercise prescription of patients with heart failure before and after heart transplantation during their participation in cardiac rehabilitation programs will be provided.

Exercise Prescription for patients with heart failure

All patients need to be medically evaluated before enrolling in a cardiac rehabilitation program. Whether patients will be assessed on site or by their referring doctors will depend on the facilities and staff structure of the rehabilitation center. Ideally, the medical assessment would consist of a complete medical history of the patient, a comprehensive examination, a fasting lipogram and blood glucose determination, a resting electrocardiogram (ECG), anthropometric measurements, a cardiopulmonary exercise test and measurement of left ventricular (LV) function. The functional capacity of the patient as well as any abnormal responses to exercise testing including myocardial ischemia, are determined. In selected cases, the diagnosis of ischemia may require radionuclide perfusion imaging procedures. Through echocardiography or radionuclide ventriculography the left ventricular function of patients is evaluated. An appraisal of the coronary risk profile of patients is performed with a view to lifestyle modification strategies. Patients are subsequently categorized into low, moderate and high risk of exercise-related cardiac events, and the patient's level of risk will determine the extent of the supervision and monitoring of the patient during exercise sessions. Using the guidelines for risk stratification developed by the American Association for Cardiopulmonary Rehabilitation [18], patients with heart failure are categorized as high risk, thus requiring more intense monitoring during their participation in cardiac rehabilitation programs.

The general exercise prescription principles applied to low risk patients can also be used in patients with heart failure [19,20]. The exercise recommendation should be treated with the same seriousness and caution which is used in prescribing drug therapy and should always be under the control of the medical health care team. It
should take into consideration several factors such as age, gender, medical status, previous physical activity, orthopedic and musculoskeletal integrity and should be based on the physiological responses to a symptom-limited graded exercise test. The important parameters determined from the test are peak heart rate and oxygen uptake (either measured directly or estimated from the exercise load), ventilatory threshold, rating of perceived exertion (RPE), limiting signs or symptoms, any ischemic ST-segment displacement, dysrhythmias and an abnormal blood pressure response.

A balance must be achieved between the patient's optimal improvement and his cardiac and orthopaedic safety, while the activity is made enjoyable enough for him to want to continue. The format for the exercise session should include a warm-up period (10 minutes), a conditioning phase which should involve aerobic exercise (30-45 minutes), an optional muscle-conditioning program and a cool-down period (5 minutes). The prescription of endurance exercise should take into account the type of activity, intensity, duration, frequency and progression.

Because various activities have been previously related to oxygen consumption and extensive data are available on these relationships, it becomes practical to state the training exercise loads in terms of oxygen consumption as opposed to heart rate. The oxygen consumption level for training can either be measured directly from the exercise test data, or estimated from the work rate of the protocol, at the appropriate training heart rate. The optimal level of intensity for exercise when related to oxygen consumption occurs at a level which lies between 57 and 78% of the maximal oxygen uptake. Once the training level is expressed in terms of oxygen consumption, standard tables can be used to set an appropriate walking, walk/jog or jogging program. These tables usually express the energy requirements of activities in terms of the basal oxygen uptake by giving a MET rating. Each patient is given his/her training heart rate and the speed and distance which he/she should walk, walk/jog or jog. Both patients and staff must monitor heart rate, speed and distance.

Table 1: Exercise prescription differences between recent randomized exercise training trials.

<table>
<thead>
<tr>
<th>Locat.</th>
<th>Dur. (wks)</th>
<th>Intens.</th>
<th>Freq. (wks)</th>
<th>Time (min)</th>
<th>M</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hambrecht*</td>
<td>Hosp/H</td>
<td>3/21</td>
<td>70% PVO₂</td>
<td>6/4</td>
<td>40</td>
</tr>
<tr>
<td>Keteyian**</td>
<td>S</td>
<td>24</td>
<td>60-80% HRR</td>
<td>3</td>
<td>43</td>
</tr>
<tr>
<td>Kilavuori†</td>
<td>S/unS</td>
<td>12/12</td>
<td>50-60% pVO₂</td>
<td>3</td>
<td>30</td>
</tr>
<tr>
<td>Dubach‡</td>
<td>S</td>
<td>8</td>
<td>70-80% HRR</td>
<td>7/4</td>
<td>120/40</td>
</tr>
<tr>
<td>Belardinelli§</td>
<td>S/unS</td>
<td>8.52</td>
<td>60% pVO₂</td>
<td>3/2</td>
<td>60</td>
</tr>
</tbody>
</table>

As can be seen in the table above, there are significant differences in exercise intensity between some of the most recent randomized studies evaluating the effects of exercise training in patients with heart failure. As previously described, the classical intensity is between 60 to 80% of peak oxygen uptake. Kilavuori et al. [10] expressing the intensity in terms of oxygen uptake set his patients at an intensity between 50 and 60% of peak oxygen uptake, which would be considered moderate, whereas Dubach et al. [12] using the heart rate reserve method designed by Karvonen, set his patients at an intensity which could be considered in the upper range.

An alternative method is to set the intensity slightly below the ventilatory threshold which is defined as the point at which during incremental exercise the subject's ventilation deviates from linearity. The threshold usually occurs close to the middle of the prescribed range of optimal intensity for exercise training (60-80% of peak oxygen uptake) and about 75% of maximal heart rate. Once again, the intensity can be expressed below the ventilatory threshold in terms of oxygen uptake or heart rate. The major advantage of prescribing exercise below the ventilatory threshold is to prevent a catecholamine rise during exercise which could be
very deleterious in patients with heart failure.

The RPE could also be a useful adjunct to the heart rate to guide the intensity of training [19]. The RPE response to graded exercise correlates highly with cardio-respiratory and metabolic variables such as oxygen uptake, heart rate and ventilation. Using the 15-point scale which ranges from 6 to 20, a perceived exertion rating of 12 to 13 corresponds to approximately 60% of the heart rate range. A rating of 16 corresponds to approximately 85% of heart rate range. Consequently most participants with heart failure should exercise within the RPE range of 11 and 15.

Figure 1 shows how exercise is prescribed at the Johannesburg Cardiac Rehabilitation Center [24]. It is our experience that exercise prescribed at an intensity below the ventilatory threshold is well tolerated and still enhances fitness. Each patient is given his training heart rate and the speed and distance which he must walk or walk/jog. Starting with 2 km of walking at a pace aimed at 10 min/km, the distance is increased to 3.5 km after 2 weeks and to 5 km after a further 2 weeks. Once up to 5 km, the pace is increased by means of a faster walking speed or the addition of brief periods of jogging. The load for the bicycle ergometer is calculated according to the following formula:

$$\text{Watts} = \frac{\text{VO}_2 \text{ (mL/kg/min)} - (5.8 \times \text{body mass (kg)}) - 151}{10.5}$$

Depending on the patient’s physical condition he/she is asked to cycle for 5-8 minutes at the prescribed load and is progressed by 1 minute each time he/she attends the class, until he/she is able to cycle for 30 minutes. Further increases in load are achieved via 5 watts increments every week, never exceeding the patients’ heart rate at the ventilatory threshold.

**EXERCISE PRESCRIPTION**

*HR < Ventilatory Threshold*

**WALKING**

2 km / 2 weeks → 3.5 km / 2 weeks → 5 km

Increase speed or add period of jogging

**STATIONERY BYCYCLE**

5-8 min → + 1 min / session → 30 min

+ 5 watts / week

$$\text{Watts} = \frac{\text{VO}_2 \text{ ml/min} - (5.8 \times \text{body weight in kg}) - 151}{10.5}$$

*Figure 1: Exercise prescription at the Johannesburg Cardiac Rehabilitation Center*

**Interval training**

Meyer et al. [22] have recently introduced a new exercise training procedure for patients with chronic heart failure. The procedure includes interval exercise training for 3 weeks on a cycle ergometer (30s work phases alternating with 60s recovery phases) or on a treadmill (60s work alternating with 60s recovery phases) (Figure 2).
The authors designed a specific steep ramp test to derive exercise intensity for the work phases. The rationale behind this new training modality is that short bouts of exercise allow for intense stimuli of 50% of maximum work rate achieved during the steep ramp test to be applied to the working muscles with minimal cardiac strain. The authors stated that it is possible that the intermittent nature of the interval training allows the left ventricle to accommodate to an enhanced venous return associated with the high muscle work rates. This new training modality proved safe since no ST segment depression or serious ventricular arrhythmias occurred during testing or training and the clinical results suggested that there is no worsening of heart failure.

The authors observed that higher work rates with significantly lower cardiac stress were achieved during interval training than during conventional steady-state exercise training at intensity levels of 75% of peak VO\(_2\) and ventilatory threshold \((22, 23)\) (Table 2). A higher intensity stimulus might be more beneficial in reversing the alterations in skeletal muscle ultrastructure, biochemistry and fibre type as well as in peripheral perfusion that occurred in patients with heart failure.

### Exercise prescription for heart transplant recipients

The exercise prescription of patients after orthotopic heart transplantation is even more challenging. The denervated heart lacks vegetative control and relies on the concentration of circulating catecholamines to increase its heart rate in response to exercise.
The table below shows that during an exercise test, patients post heart transplantation have a higher resting heart rate, reach a lower maximal heart rate and achieve a lower functional capacity compared to the predicted norms for their age and gender. Typically, the heart rate continues to increase beyond peak exercise reaching its peak after exercise was stopped.

Table 3: Data collected from Vanderbilt University Cardiac Rehabilitation Program [24]

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting HR (bpm)</td>
<td>100 ± 9</td>
<td>78 - 120</td>
</tr>
<tr>
<td>VT (ml/kg/min)</td>
<td>10.8 ± 2.4</td>
<td>6.8 - 16.7</td>
</tr>
<tr>
<td>VT %</td>
<td>64 ± 5</td>
<td>55 - 74</td>
</tr>
<tr>
<td>HR at VT (bpm)</td>
<td>110 ± 11</td>
<td>87 - 139</td>
</tr>
<tr>
<td>Peak VO₂ (ml/kg/min)</td>
<td>16.9 ± 4.0</td>
<td>10.1 - 28.0</td>
</tr>
<tr>
<td>% Pred. Normal</td>
<td>55 ± 15</td>
<td>30 - 87</td>
</tr>
<tr>
<td>% Pred. Heart Tx</td>
<td>91 ± 22</td>
<td>56 - 151</td>
</tr>
<tr>
<td>MHR (bpm)</td>
<td>137 ± 16</td>
<td>100 - 175</td>
</tr>
<tr>
<td>RQ</td>
<td>1.22 ± 0.11</td>
<td>0.99 - 1.48</td>
</tr>
</tbody>
</table>

Since heart rate methods are unreliable in this type of patient, the determination of ventilatory threshold could be particularly useful for exercise prescription. In this regard, Kavanagh and colleagues [16] demonstrated the use of the ventilatory threshold along with RPE in prescribing exercise in this group. Oxygen uptake determinations are however not widely available so current methods utilize a combination of resting heart rate plus 20 to 40 beats and RPE.

At the Vanderbilt University Cardiac Rehabilitation Program we compared several commonly used exercise prescription methods against the heart rate at the ventilatory threshold (Fig. 3) to determine which method could provide the best alternative to a target heart rate derived from metabolic-based methods, in patients after orthotopic cardiac transplantation [24].

Figure 3: Best alternative to ventilatory threshold (Deviations from ventilatory threshold are expressed in SD units)

HRR: heart rate reserve; E: estimated from formula 220-age; M: calculated from maximal exercise test; RHR: resting heart rate; RPE: rates of perceived exertion; MHR: maximal heart rate; SD: standard deviation; VT: ventilatory threshold
Our results showed that heart rates computed using the heart rate reserve method (estimated or calculated from an exercise test), the resting heart rate plus 20-40 beats method, heart rate at 85% of maximal heart rate and heart rate at RPEs above 12 were significantly higher than the heart rate at the ventilatory threshold. Furthermore heart rates computed at 70 and 75% of the maximal heart rate were significantly lower than the heart rate at ventilatory threshold. In the absence of expiratory gas measurements, heart rate at 80% of maximal heart rate, determined during exercise testing, as well as an RPE of 11-12 provided the closest alternative to ventilatory threshold measurements in patients after a heart transplant. In the absence of exercise testing, resting heart rate plus 10 beats used in conjunction with RPE provided the closest alternative to heart rate at 80% of maximal heart rate.

Conclusions
Rest is an essential component in the management of an acute episode of heart failure, but once the heart failure has been stabilized and the fluid overload and edema have been adequately controlled, the patient should be mobilized.

Any potentially deleterious role of exercise training for patients with heart failure has not been substantiated and several studies have now demonstrated the benefits of exercise training in patients with moderate or even severe left ventricular dysfunction without evidence of clinically manifest congestive heart failure. A small increase in exercise performance in these patients may have a profound effect on their quality of life.

Extra benefit could be derived in these patients from the close medical surveillance available in the context of a formal rehabilitation program and from the lifestyle changes normally induced by these programs (Table 4).

<table>
<thead>
<tr>
<th>Primary Prevention</th>
<th>Control of coronary risk factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nutritional counseling</td>
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<td></td>
<td>Lipid management</td>
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<td>Hypertension management</td>
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<td>Smoking cessation</td>
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<td>Psychosocial management</td>
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<td></td>
<td>Physical activity counseling</td>
</tr>
<tr>
<td></td>
<td>Exercise training</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Secondary Prevention</th>
<th>Control of coronary risk factors with an emphasis on nutritional and psychological support</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Exercise training</td>
</tr>
<tr>
<td></td>
<td>Adherence to medication: angiotensin converting enzyme inhibitors, beta-blockers, diuretics, digoxis.</td>
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</table>

Table 4: Role of cardiac rehabilitation in the management of heart failure patients

Cardiac rehabilitation, including exercise training and coronary risk factor intervention strategies, can complement the limited therapeutic options available for patients with heart failure.

References


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