Comparison of Hemodynamic Responses to Cycling and Resistance Exercise in Congestive Heart Failure Secondary to Ischemic Cardiomyopathy

Robert S. McKelvie, MD, Neil McCartney, PhD, Charles Tomlinson, MD, Robert Bauer, MD, and J. Duncan MacDougall, PhD

Recently it has been suggested that aerobic exercise training improves endurance exercise capacity in patients with congestive heart failure (CHF); however, such exercise would be expected to have only a minimal effect on the skeletal muscle weakness present in these patients. Resistance training improves muscle strength, but has been equated with isometric exercise which may produce an undesirable hemodynamic response in patients with CHF. Thus, raising the concern that resistance training may not be well tolerated by such patients. There have been no previous studies comparing the hemodynamic responses of resistance exercise and cycling in patients with CHF. The purposes of this study in patients with CHF were: (1) to examine the acute cardiovascular responses to resistance exercise, and (2) to compare them with responses during cycle ergometry.

Ten male patients with a documented history of ischemic cardiomyopathy and CHF, not limited by angina, were recruited for the study. Patients were maintained on their usual medical therapy during testing; all patients were taking angiotensin-converting enzyme inhibitors, 6 were taking diuretics, 3 digoxin, 4 nitrates, and 2 amiodarone. Mean left ventricular ejection fraction was 27 ± 2% and patients had New York Heart Association class II to III CHF. A graded incremental exercise protocol on a cycle ergometer was used to determine the peak power output of each patient. Maximal single leg press dynamic strength was determined, as previously described,6 using a Global Gym apparatus (Global Gym Inc; Downsview, Ontario, Canada). The 1 repetition maximum for single leg press was the heaviest weight that patients could lift once through a complete range of movement. Approximately 2 to 7 days after the initial testing, patients performed 5 minutes of cycle ergometry at 70% of peak power output, and 2 sets of 10 repetitions of single leg press exercise at 70% of 1 repetition maximum on the Global Gym apparatus. Continuous electrocardiographic monitoring using a V4 lead was performed during each exercise bout. The exercise bouts were randomized to prevent an order effect, and sufficient time was allowed between each exercise bout for the heart rate and blood pressure to return to baseline levels.

As previously described,6 during the testing session, brachial artery blood pressure was directly measured continuously and a Hewlett-Packard Sonos 1000 Ultrasound System (model 77030A, Hewlett Packard Inc.,
Andover, Massachusetts) with a hand-held 2.5 MHz transducer was used to perform left ventricular imaging, with video images transferred later to a cine view image analysis system (Freeland, Prism Imaging Inc., Louisville, Colorado). During the tenth repetition of lifting, a 2-chamber view was recorded during 1 of the single leg press set and a 4-chamber view was recorded during the other single leg press set; the 2- and 4-chamber views were both recorded during the fourth minute of steady-state exercise. The systolic and diastolic blood pressures measured during the recording of the 2- and 4-chamber views were matched to within 5 mm Hg of each other in order to minimize the effect of hemodynamic loading on echocardiographic dimensions. All volumes were computed using the modified Simpson’s rule method of discs, which is considered the optimal technique for calculation of volumes in patients with wall motion abnormalities. Each ventricular volume reported in our results is an average of 3 ventricular volumes separated close in time. Data analyses were performed with repeated-measures analysis of variance to compare measurements at the 2 different times and between the 2 different forms of exercise. When significant F values were obtained, a Neuman-Keuls test was used to identify the location of specific differences. All data are presented as mean ± SEM unless otherwise indicated.

There were no observed adverse symptoms, arrhythmias or ST-segment abnormalities. Systolic blood pressure increased significantly from 157 ± 7 to 189 ± 8 mm Hg during leg press exercise and to 199 ± 13 mm Hg during cycling (Table I), with no significant difference between modes of exercise. Diastolic blood pressure increased significantly from 77 ± 2 to 98 ± 4 mm Hg. Heart rate increased (p < 0.05) during both leg press and cycling, but was significantly greater during cycling. There was a significant increase in the rate-pressure product during both exercises, with the greatest increase observed during cycling. No significant change was observed for either end-diastolic or end-systolic volumes during cycling or leg press exercise. Cardiac output increased significantly from 5.2 ± 0.5 to 6.9 ± 0.5 L/min during leg press, and was greatest during cycling at 9.3 ± 0.7 L/min (Table II). Mean stroke volume increased significantly from 77 ± 5 to 87 ± 5 ml during cycling. Total peripheral resistance decreased (p < 0.05) from 23 ± 2 to 14 ± 1 mm Hg • L⁻¹ • min⁻¹ during cycling.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>Changes in Systolic and Diastolic Blood Pressure, Heart Rate, Rate-Pressure Product, and End-Diastolic and End-Systolic Volumes During Cycling and Leg Press Exercises</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rest</td>
</tr>
<tr>
<td>Systolic blood pressure (mm Hg)</td>
<td>157 ± 7</td>
</tr>
<tr>
<td>Diastolic blood pressure (mm Hg)</td>
<td>77 ± 2</td>
</tr>
<tr>
<td>Heart rate (beats/min)</td>
<td>66 ± 4</td>
</tr>
<tr>
<td>Rate-pressure product (mm Hg)</td>
<td>103 ± 6</td>
</tr>
<tr>
<td>End-diastolic volume (ml)</td>
<td>257 ± 26</td>
</tr>
<tr>
<td>End-systolic volume (ml)</td>
<td>179 ± 22</td>
</tr>
</tbody>
</table>

*p < 0.05 compared with rest; **p < 0.05 compared with leg press. Values are expressed as mean ± SEM.

There was no change in ejection fraction during either leg press or cycling. Peak systolic pressure to end-systolic volume ratio increased significantly from 0.9 ± 0.1 to 1.1 ± 0.1 during leg press, and was greatest during cycling at 1.2 ± 0.2.

This study compared the cardiovascular responses to resistance exercise with steady-state submaximal cycling using the same muscles, and at the same relative intensity, in a group of patients with CHF. Previous studies have found that even if patients develop angina during aerobic exercise, they will more than likely not develop symptoms during resistance exercise. In the present study, compared with cycling, resistance exercise produced a comparable systolic blood pressure (similar afterload), a lower rate-pressure product, reflecting a lower myocardial oxygen demand, and a slower heart rate and higher diastolic blood pressure, which at least theoretically suggests better myocardial perfusion. These findings are consistent with other studies of cardiac patients with well-maintained left ventricular function performing resistance exercise.

The results of the present study are consistent with other studies that show no change in end-systolic or end-diastolic volume during cycling in patients with heart failure. Cardiac output increased significantly more during cycling than during leg press exercise. This finding was not unexpected and, to a large extent, can be attributed to the greater oxygen cost during cycling and to the short (40 to 50 seconds) duration of the leg press exercise, which did not allow time for matching cardiac output with systemic oxygen demand. The increase in cardiac output with leg press exercise was unlike the response that has been observed with isometric handgrip exercise at 25% to 30% of maximal voluntary contraction where either no change or a decrease has been found. The lack of a large increase in stroke volume during exercise is consistent with other studies of patients with CHF and is in agreement with the suggestion that increased cardiac output during exercise is mainly related to increases in heart rate.

A decrease in total peripheral resistance was observed for both cycling and leg press exercise. These findings are consistent with those found previously for cycling but in contrast to isometric exercise. This further suggests that resistance exercise does not cause acute cardiovascular decompensation. Increases in peak systolic pressure to end-systolic volume ratio relations...
and the maintenance of ejection fraction for both cycling and resistance exercise would further suggest that resistance exercise did not adversely affect left ventricular function.

Together, these findings suggest that, in a selected group of patients with CHF, left ventricular function is well maintained during the unilateral leg press exercise. Furthermore, there appeared to be no significant difference in left ventricular response between cycling and resistance exercise performed at the same relative intensity with the same muscle groups. The findings from this study support the use of submaximal resistance training by selected CHF patients. The response of CHF patients to bilateral and upper extremity resistance exercise remains to be investigated. Further studies are required to determine the effects of resistance training on exercise capacity in patients with CHF.

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Optimal Degree of Pulmonary Artery Banding—
Adequate Circumference Ratio to Calculated Size from Normal Pulmonary Valve Dimensions

Youichi Kawahira, MD, Hidefumi Kishimoto, MD, Hidroaki Kawata, MD, Seichoito Ikawa, MD, Hideki Ueda, MD, Takayoshi Ueno, MD, Tohru Nakajima, MD, Fusoshi Kayatani, MD, Noboru Inamura, MD, Takashi Miwatanai, MD, and Takeshi Nakada, MD

Pulmonary artery (PA) banding was first performed by Muller et al in 1952. According to Trusler et al, an adequate circumference for PA banding in children with ventricular septal defects without mixing disorders is 20 mm plus an additional number of millimeters equal to the value of the body weight of the patient in kilograms. However, Albus et al reported that small infants require a band circumference that is 1 to 1.5 mm tighter than that estimated by this rule. There are no current guidelines regarding the adequate circumference for PA banding in children weighing <1 kg with excessive pulmonary flow and without evidence of a mixing disorder.

We evaluated the banding circumference in 40 children who had undergone PA banding over the past 10 years. An equation for the normal pulmonary valve dimension (16.5 × [body surface area]0.45) was assessed and attempts were made to retrospectively determine the ratio of optimal circumference to that calculated from the equation for the normal pulmonary valve dimension.

Forty-eight PA banding procedures were performed in 46 patients with a known history of progressive high PA flow at our institution between January 1981 and February 1995. The study population consisted of 40 of the 46 patients. Six patients were excluded for the following reasons: 3 had major mixing disorders, 2 had tape