Commentary

Nontraditional Exercise Training for Patients With Cardiovascular Disease

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In patients with cardiovascular disease, there is a need for complementary strength training to maintain and/or increase muscle mass and strength. The challenge is how to stress peripheral muscles intensively without creating a cardiovascular overload. Recent research and clinical experience have expanded the use of "nontraditional" exercise training methods, such as interval training, resistance training, and eccentric exercise. These methods provide potential advantages over traditional exercise methods.

Exercise programs have traditionally emphasized aerobic exercise such as walking, cycling, and jogging. However, given the increasingly diverse (and more debilitated) population of patients in clinical exercise programs, aerobic exercise training, per se, may not necessarily remedy these functional deficits. There is an increasing need for complementary resistance exercise training to maintain and/or increase muscle mass and strength. There are several reasons to support this recommendation:

1. Skeletal muscles are the most active metabolizing organs. In patients with coronary artery disease (CAD), changes in body composition by reducing body fat and increasing muscle mass are of fundamental importance in controlling metabolic risk factors and slowing and/or stopping the progression of arteriosclerosis.
2. A hallmark of chronic heart failure (HF) is muscle wasting, which can contribute to exercise intolerance and poor prognosis.[1] Aerobic and resistance exercise training can reverse muscle and functional impairment and may help reduce cardiovascular morbidity.[2]
3. Leisure time and occupational tasks require a certain amount of muscle strength. Increased muscle mass and strength result in an attenuated cardiovascular stress response to any given load because the load now represents a lower percentage of the maximal voluntary contraction.[3]
4. Due to progress in medical treatment, patients with CAD are now living longer. Loss of muscle mass and a decline in muscle strength are among the most predictable features of aging. Maintaining muscle mass can help one to avoid immobility and dependency, and thus may help to reduce health care costs.

Accordingly, these patients require exercise training methods that: 1) provide intense exercise stimuli to peripheral muscles without producing excessive cardiovascular stress; 2) are well accepted by patients, including frail, elderly individuals; and 3) provide benefits in aerobic capacity, muscle mass, and strength within an acceptable period of time. To address these requirements, recent research and clinical experience have developed several "nontraditional" exercise training methods: interval exercise, resistance exercise, and eccentric exercise. These methods provide potential advantages as adjuncts to traditional exercise modalities or even as primary training regimens, per se.

Interval Exercise

Interval training is characterized by an alternation of work and recovery phases. In the 1990s, the concept of interval training was developed for applications in rehabilitation programs for patients with cardiovascular and other chronic diseases. In this field, the primary indication for using interval training is either pronounced peripheral exercise intolerance, a strong cardiac exercise limitation, or both. In patients with a markedly reduced exercise capacity after coronary bypass surgery, a 4-week aerobic interval training program resulted in a 20% greater rate of improvement in exercise capacity compared with conventional steady-state training.[4] In patients with stable-severe chronic

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HF, a 3-week interval training program increased oxygen consumption at the ventilatory threshold by 24% and peak oxygen consumption by 20%.[5] This improvement was comparable to that reported for steady-state exercise training regimens over much longer training periods.[2,6,7] In peripheral arterial occlusive disease (stage II)[8] and severe chronic obstructive pulmonary disease,[9] interval training enables many patients to initiate an endurance exercise regimen.

From a practical perspective, CAD patients with mild left ventricular dysfunction may employ work/recovery phases of 60 s/60 s. Intensity can be prescribed by a training heart rate of 60%–80% of peak heart rate. In chronic HF patients, work phases of 30 seconds and recovery phases of 60 seconds are often useful, and an intensity of 50% of the maximum short-term exercise capacity is preferred for the work phases. During recovery phases, patients pedal at very low work intensities (10–15 watts).[10] In chronic HF patients, when using interval work phases, the power output is usually 2–3 times greater than tolerable during steady-state exercise. Despite the high muscular power output during interval training, a number of studies have demonstrated that a well-designed interval training program is physiologically less taxing than conventional aerobic training in this patient population, and it does not evoke abnormal heart rate and blood pressure responses or signs or symptoms of left ventricular dysfunction.[10–12] Although perceived exertion was similar, blood lactate concentrations have been shown to be somewhat higher during interval training than during steady-state exercise performed at the same average power output.[10] Interval training programs have been accomplished without clinical evidence of deterioration, even in patients on a heart transplant list.[5] Thus, interval training is a potentially valuable tool with wide application in patients with cardiovascular disease, including those with significant exercise intolerance, regardless of whether it is central or peripheral in origin.

Resistance Exercise

Resistance exercise has traditionally been contraindicated for cardiac patients. The reluctance to use resistance training was probably based on the extraordinary magnitude of the blood pressure response during weightlifting in healthy, athletic individuals.[13] The pressure response is proportionate to the relative intensity (percent maximum voluntary contraction),[14] length of contraction, and muscle mass involved.[15] Thus, the cardiovascular response might be quite different from that seen with weightlifting when moderate-intensity muscle contractions are used for dynamic resistance exercise training involving small muscle groups. Numerous studies on acute cardiovascular responses to dynamic resistance exercise in coronary patients with preserved left ventricular function have shown: 1) no threatening dysrhythmias[16–18]; 2) appropriate blood pressure and heart rate increments[16–19] with peak blood pressure values lower than those measured at maximum work rates during graded exercise testing[18]; 3) no ischemic ST-segment depression.[17,18] The myocardial oxygen supply/demand relationship appears to be favorably altered by superimposing static effort on dynamic effort so that ischemic electrocardiographic responses are attenuated at rate-pressure product values that elicit significant ST-segment depression during dynamic exercise. This phenomenon may be attributed to a higher diastolic perfusion pressure, a lower heart rate, or both[20]; and 4) no evidence of left ventricular dysfunction in patients with or without heart disease.[21]

According to contemporary guidelines,[22] CAD patients without significant left ventricular dysfunction should start at a low weight and perform one set of 10–15 repetitions to moderate fatigue using 8–10 different exercises. The resistance should be increased gradually (e.g., 2–5 lb/wk and 5–10 lb/wk for arm and leg exercise, respectively). The rate-pressure product should not exceed that prescribed for aerobic exercise; perceived exertion should range from "fairly light" to "somewhat hard," and the Valsalva maneuver should be avoided.[22] By following these recommendations, resistance exercise is likely to be safe and effective in improving muscular strength and endurance. Age does not seem to be a limitation, as residents of nursing homes, including some nonagenarians, have demonstrated that resistance training markedly improves muscle size, strength, and functional mobility.[23]

Resistance Exercise in Chronic HF

Until the late 1990s, resistance exercise training was generally considered inappropriate in patients with chronic HF. This belief was largely based on central hemodynamic measurements obtained during *sustained* isometric exercise in CAD patients with moderate to severe left ventricular dysfunction. Three to 5 minutes of handgrip exercise at only 30% maximum voluntary contraction resulted in abnormal left ventricular responses.[24] Over the past few years, attitudes regarding strength training in patients with chronic HF have changed dramatically as a result of hemodynamic measurements obtained during *dynamic* resistance exercise. During a single leg press exercise performed as two sets of 10 repetitions at a load corresponding to 70% of one repetition maximum, heart rate and rate-pressure product were lower, and systolic blood pressure, left ventricular ejection fraction, diastolic volume, and systolic volume were no greater than those measured during cycling exercise at 70% of peak oxygen consumption.[25] Additionally, during dynamic double leg press exercise at loads corresponding to 60% and 80% maximum voluntary contraction and using the interval method (60 s/120 s work/rest phases), chronic HF patients demonstrated increases in left ventricular stroke work index and decreases in systemic vascular resistance, suggesting enhanced left ventricular function.[26]

More recently, echocardiographic measurements were made while chronic HF patients performed one set of 10 repetitions of leg press, shoulder press, and bicep curls at 60%–70% of one repetition maximum and cycled for 12 minutes at an intensity of 90% of their ventilatory threshold. Using the same methodology, healthy volunteers and stable CAD patients with minimal left ventricular dysfunction were assessed. Changes in left ventricular internal diameters, ejection fraction, wall thickness, blood pressure, and heart rate were similar across all three groups of subjects. Despite elevations in diastolic and mean arterial pressure during resistance exercise in the chronic HF patients, there was no evidence of significant rest-to-exercise deterioration in left ventricular systolic function (ejection fraction) during leg press (38%–37%), shoulder press (38%–35%), or bicep curls (35%–36%) vs. cycle ergometry (35%–42%).[21] These responses might be due to the rhythmic sequence of submaximal isometric muscle contractions, which helps to maintain venous return, reduce systemic vascular resistance, and maintain ejection fraction and muscle blood flow.

Eccentric Exercise

With lengthening (eccentric) muscle contractions, a muscle is capable of generating significantly higher forces compared to shortening (concentric) contractions. In daily life, muscles work eccentrically while walking downstairs or downhill and work concentrically while walking upstairs. In healthy subjects during eccentric cycle ergometer training (trying to resist the turning of the pedals), 5–7 times more force was produced compared to concentric training, whereas metabolic responses were similar during eccentric and concentric cycling.[27,28] Because the magnitude of the muscle mass and strength gained are a function of the force produced, 8 weeks of eccentric cycle ergometer training resulted in a significant increase in the cross sectional area of muscle fibers and maximal isometric knee extension strength.[28] The magnitude of observed increases in both strength and fiber area with eccentric training often exceeds that seen following a similar duration of traditional resistance strength training. How are muscles capable of producing such high forces with low metabolic demand? With eccentric exercise, the forces acting on the muscle at any time exceed the forces produced by the muscle. Thus, the muscle lengthens while absorbing mechanical energy as elastic recoil energy, which, in part, can be returned during the concentric shortening phase of the stretch-shorten cycle.[29] Additionally, because the muscles are acting as a brake to decelerate the pedals, there is little metabolic requirement.

Before eccentric training is used in cardiac rehabilitation, the cardiovascular stress produced by eccentric exercise has to be understood. During 20 minutes of cycle ergometer training at 60% peak oxygen consumption, coronary patients developed eccentrically a power output 3.6 times that produced with concentric cycling. At this workload, mean arterial blood pressure, systemic vascular resistance, pulmonary capillary pressure, and cardiac index remained, on average, in a normal range and were similar to those observed during concentric cycling. Additionally, there was no deterioration of left ventricular function after 8 weeks of eccentric training.[30] These results indicate that skeletal muscle load and cardiovascular stress are uncoupled during eccentric exercise and suggest a new approach to performing high-load muscular exercise training with minimal cardiovascular strain. Until time-specific training devices like eccentric bikes are commercially available, eccentric muscle training can be performed conventionally, by walking downhill or downstairs, for example.

These nontraditional methods offer attractive new options for muscle training in cardiovascular patients with muscle wasting and exercise intolerance. Interval training and resistance training have been shown to be both safe and effective in patients with a broad range of cardiovascular diseases. Although experience with eccentric exercise in cardiac patients is limited, this approach also appears to be promising. ■

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