Resistance Exercise in Cardiac Rehabilitation

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OVER THE PAST 30 YEARS there has been a significant trend toward the acceptance of more aggressive treatments in cardiac rehabilitation programs. Before 1960 many cardiac patients with acute myocardial infarction (MI) were restricted to bed rest for as long as 2 months after a cardiac event, and some were advised to limit physical activity for a year (13).

Presently cardiac patients are encouraged to begin restricted low-intensity activities (2 to 3 METs) as soon as 1 to 3 days after a cardiac event. They may be encouraged to begin short duration (5 to 10 min) treadmill walking or cycle ergometry within 3 to 5 days. Patients are now typically released from the hospital by the 2nd or 3rd week after MI or open heart surgery, and are advised to participate in a program of supervised exercise (1).

The American College of Sports Medicine (1) recommends that supervised low-level resistance exercise begin as early as 7 to 8 weeks after an event, as long as a symptom-limited exercise test has been performed and no contraindications are present. ACSM lists contraindications for entry into inpatient and outpatient exercise programs as follows:

- Unstable angina
- Resting systolic blood pressure >200 mm Hg, or resting diastolic blood pressure >100 mm Hg
- Orthostatic blood pressure drop of ≥20 mm Hg
- Moderate to severe aortic stenosis
- Acute systemic illness or fever
- Uncontrolled atrial or ventricular dysrhythmias
- Uncontrolled sinus tachycardia (>120 bpm)
- Uncontrolled congestive heart failure
- 3rd degree A-V heart block
- Active pericarditis or myocarditis
- Recent embolism
- Thrombophlebitis
- Resting ST displacement (>3 mm)
- Uncontrolled diabetes
- Orthopedic problems that would prohibit exercise.

The American College of Sports Medicine lists specific contraindications for a resistance training program as follows:

- Abnormal hemodynamic responses or ischemic changes on the electrocardiogram during graded exercise
- Poor left ventricular function
- Peak exercise capacity <6 METs
- Uncontrolled hypertension or dysrhythmias.

Cardiac rehabilitation programs have traditionally used aerobic activities as an accepted mode of therapy. For improving and maintaining cardiovascular fitness, aerobic exercises such as walking, jogging, and stationary cycling are typically prescribed.

However, the addition of resistance exercise is gaining popularity in cardiac rehabilitation programs for the added benefits of increased muscular strength and endurance in patients (51). Many activities of daily living, as well as

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vocational and recreational activities, place demands on the cardiovascular and muscular systems that more closely resemble resistance exercise than aerobic exercise. To fully prepare the patient for returning to work and leisure-time activities, it is important to rehabilitate muscular strength and local muscular endurance in the patient after a cardiac event (15, 40).

Early research suggested that coronary patients who engage in isometric resistance exercise were more prone to developing arrhythmias, angina pectoris, and left ventricular dysfunction (3, 9, 33, 36, 37, 41). In addition, it had been reported that, even in healthy populations, both systolic blood pressure (SBP) and diastolic blood pressure (DBP) showed a dramatic rise during heavy isotonic resistance training (30). Therefore physicians and cardiac rehabilitation clinicians were skeptical of the safety of using resistance exercise in their cardiac rehabilitation programs.

However, recent evidence suggests that isotonic resistance exercise is hemodynamically safe for selected individuals with cardiovascular impairment, not only at low to moderate workloads of 30 to 60% of 1-RM (5, 17, 18, 26, 45, 46, 50) but also at relatively high workloads of 75 to 80% of 1-RM (8, 14). Resistance exercise has been shown to increase muscular strength, muscular endurance, and lean body mass, and it may decrease risk factors for coronary artery disease (51). Furthermore, a cardiac rehabilitation program that offers resistance exercise in addition to aerobic activities may result in patients performing daily strength tasks more safely, efficiently, and with greater confidence (7).

- **Physiological Responses to Resistance Exercise**

When cardiac patients begin physical activity and exercise after a cardiac event, in the interest of safety it is important to monitor them closely monitored. In addition to the electrocardiographic responses (ECG) of the heart, two important areas of physiological responses are monitored to judge the stress placed on the heart and cardiovascular system during exercise: (a) blood pressure, and (b) heart rate and oxygen consumption.

**Blood Pressure Responses**

In earlier studies with healthy populations, it was reported that significant elevations in systolic and diastolic blood pressures may occur with heavy weight training and isometric exercise (2, 30, 32). Other studies on cardiac patients showed that elevated systolic blood pressures could increase the rate pressure product (heart rate × systolic blood pressure) (25) and may increase the likelihood of dysrhythmias, myocardial ischemia, or left ventricular dysfunction in patients with heart disease (47).

However, in some more recent studies, relatively small elevations in blood pressure have been reported during circuit weight training using 8 to 16 reps at 30 to 50% of measured and predicted 1-RM values in selected cardiac and high-risk patients (5, 11, 17, 18, 26, 45, 46, 50).

In a study by Vander et al. (50) that employed resistance loads of 40 to 60% of 1-RM, patients with coronary artery disease had lower peak systolic blood pressures and rate pressure products during circuit weight training than during maximal graded exercise testing. Peak diastolic blood pressures exceeded those during maximal exercise testing 100 to 136%, but the mean diastolic blood pressure reported was only 100 mm Hg during the circuit weight training sessions.

Squires et al. (46) also found acceptable blood pressure responses (systolic ≤220 mm Hg or diastolic ≤110 mm Hg) (1) during chest and leg press exercises in patients 17 to 60 days after myocardial infarction or coronary artery bypass graft surgery. The greatest systolic blood pressure measured for any subject during resistance exercise was 150 mm Hg during the leg press.

> **... the addition of resistance exercise is gaining popularity in cardiac rehabilitation programs for the added benefits of increased muscular strength and endurance ...**

Acceptable blood pressure responses have also been reported in studies using higher intensity weight training. Falgenbaum et al. (8) reported peak systolic and diastolic blood pressures and rate pressure products all within normal limits at an exercise intensity of 75% of 1-RM for 2 sets of 7 reps on 7 upper-body isotonic machines. Ghilarducci et al. (14) observed acceptable blood pressure responses in aerobically trained cardiac rehabilitation patients who performed resistance exercise using 80% of 1-RM. Subjects were continuously monitored for ECG, heart rate, and blood pressure during testing and throughout the 10-week resistance training program. No signs of ischemia or abnormal heart rate or blood pressure were observed during 1-
RM testing or during the exercise program.

It should be noted that blood pressure responses observed indirectly may not accurately reflect actual arterial pressures generated during the effort. Wieck et al. (53) demonstrated that both systolic and diastolic pressures decrease rapidly immediately after weight training efforts at 40 to 60% of 1-RM in patients with coronary artery disease.

However, Haslam et al. (19), using the more accurate intra-arterial pressure techniques of monitoring blood pressure, also reported acceptable blood pressure responses with acute resistance exercise in cardiac patients after myocardial infarction and coronary artery graft surgery. These investigators monitored patients by intra-arterial pressure and ECG monitoring as the patients performed single arm curls and single and double leg presses at 20, 40, 60, and 80% of 1-RM.

Higher heart rates are typically observed with higher volume (sets x repetitions), low-resistance circuit weight training with short rest periods between sets and exercises (11). Higher heart rates will also typically be seen in individuals who are in poor cardiovascular fitness (with the exception of persons taking medication that lowers heart rate, such as beta blockers) (1).

### Training Effects of Resistance Exercise

#### Muscular Strength

Increases in muscular strength have been reported following low to moderate isotonic, isokinetic, and circuit weight training exercise in high-risk and cardiac patients (17, 27, 28, 45, 46, 48, 54). Average increases in upper and lower body strength generally range from 20 to 30% in cardiac populations, but as much as 63% greater overall improvements in strength have been reported following higher intensity programs using workloads up to 80% of 1-RM (14).

Improvements in upper and lower body strength are important because they may allow the cardiac patient to perform everyday lifting activities at a lower energy cost and with greater efficiency of movement, since efficiency during weightlifting has been shown to be directly related to the relative intensity of the lifting task (20, 21).

Improved work tolerance from peripheral adaptations in trained skeletal muscle may enhance the ability to resume routine daily activities after a cardiac event. A recent study with older women has shown significant improvement in the ability to arise from a chair and carry groceries following a 16-week weight training program.

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Arterial pressure and rate pressure product increased with the relative load, but values were clinically acceptable up to and including 60% of 1-RM when compared to values observed during maximal symptom-limited cycle ergometer testing. Only single and double leg presses at 80% of 1-RM elicited a greater rate pressure product than that observed at peak ergometer exercise. No ischemic ECG changes, anginal symptoms, or significant ventricular dysrhythmias occurred during weight training, and left ventricular function was not compromised at any of the workloads.

### Heart Rate and Oxygen Consumption Responses

In general, heart rate is lower during resistance exercise (even circuit weight training) than during graded aerobic exercise in cardiac patients (17, 27, 50).

Vander et al. (50), using circuit weight training at 40 to 60% of 1-RM, reported peak heart rates of 56 to 64% of the values observed during maximal graded exercise. These were considered well below the target heart rate range for aerobic exercise prescription. Haennel et al. (17) found similar heart rate responses (56% of HR reserve) during three consecutive bouts of circuit weight training in patients who had undergone recent coronary artery bypass graft surgery. Kelemen et al. (27) observed peak heart rates that were 12% below the prescribed aerobic target HR zone during circuit weight training, compared to peak heart rates during walk/jog exercise that were 4% above target zone.

Haslam et al. (19) found that mean peak heart rate in cardiac patients increased progressively with the amount of weight lifted, from 20 to 80% of 1-RM.

In general, heart rate and oxygen consumption (VO₂) responses during resistance exercise are dependent on the following factors (51):

- Type of resistance exercise
- Amount of resistance
- Duration of rest intervals between sets and exercises
- Cardiovascular fitness of the individual
- Prescribed medications.
These improvements may also give the person more confidence in occupational and leisure-time activities and may improve self-image (7).

For strength improvements in cardiac patients, the American College of Sports Medicine recommends that patients perform resistance exercise at least 2 days a week for adequate improvements in strength, but not more than 3 days a week to allow for adequate recovery.

Maximal Oxygen Consumption
Similar to studies on healthy individuals, most studies on cardiac patients indicate that resistance training only shows low to moderate increases (4 to 15%) in maximal oxygen consumption (VO_{2max}) (17, 27, 31). The small increase in cardiovascular fitness levels observed with resistance exercise may be due to several factors (51):

- The relatively low level of oxygen consumption required during many studies of resistance exercise
- Differences in training protocols
- Duration of rest intervals between sets and exercises
- Characteristics and weight training experience of the population examined
- Total volume of work performed
- Specificity of muscle training and testing procedures
- Initial exercise capacity of the subjects examined.

Given that there are only modest increases in oxygen consumption with resistance exercise, it should not be substituted for aerobic exercise in cardiopulmonary rehabilitation programs (12, 44) but instead should be used to enhance anticipated changes in cardiovascular function following regular aerobic training. Combined resistance training and aerobic training may facilitate central and/or peripheral cardiovascular changes, which in turn may improve aerobic endurance better than aerobic training alone (31).

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Body Composition
It has been well established that, in healthy subjects, resistance training may increase lean body mass due to muscle hypertrophy (18, 24, 34, 35). However, because cardiac rehabilitation programs have traditionally emphasized aerobic exercise, it has been difficult to assess body composition parameters following exclusive resistance exercise in patients with cardiovascular disease.

Kelemen et al. (27) reported a small but significant decrease in mean body fat (20.8 ± 4.4% to 19.4 ± 3.3%) in cardiac patients who followed a circuit weight training program for 10 weeks, although there were no changes in body weight.

In longitudinal studies of selected cardiac patients, no significant changes in body fat/weight were reported following (a) 24 weeks of circuit weight training at 30 to 40% of 1-RM (45), (b) 10 weeks of high intensity isotonic training at 80% of 1-RM (14), or (c) 8 weeks of high volume hydraulic circuit weight training (17).

Since it has been well documented that aerobic exercise helps maintain lean body mass and decreases body fat in patients who participate regularly in cardiac rehabilitation (51), and since it has been documented that even frail elderly persons (up to 90 years of age) on a resistance training program have the ability to increase muscle mass (10), resistance exercise may be considered a good way to improve body composition. In healthy populations, Westcott (52) reported that subjects who performed 15 min of aerobic training combined with 15 min of resistance exercise lost more body weight and body fat, and gained more lean body mass, than subjects who performed solely 30 min of aerobic activity. However, it will take more research to assess the effect of resistance exercise on body composition in cardiac patients.

Heart Rate and Heart Function
Maximal-exercise stroke volume and cardiac output have been shown to increase up to 8% following high-intensity resistance circuit weight training in healthy subjects (16, 39). Other researchers have found no change in submaximal-exercise cardiac output following 16 weeks of high intensity circuit weight training in healthy adults (24).

In selected cardiac patients, lower resting heart rate and lower submaximal-exercise heart rate, increased resting stroke volume, and increased resting and maximal exercise cardiac output have been observed following 8 weeks of high-volume hydraulic circuit weight training (17).

Heart rate and oxygen consumption training effects of resistance exercise, like physiological responses during resistance exer-
exercise, are dependent on the following factors as noted earlier (51):

- Type of resistance exercise
- Amount of resistance
- Duration of rest intervals between sets and exercises
- Cardiovascular fitness of the individual
- Prescribed medications.

Lower resting heart rate and improved oxygen consumption training effects will typically be achieved with higher volume (sets x repetitions), low resistance, circuit weight training with short rest periods between sets and exercises (11).

**Blood Pressure**

Regular resistance training has been shown to lower resting blood pressure in middle-aged (23) and borderline hypertensive adults (18). Hurley et al. (23) observed a significant decrease in resting diastolic blood pressure in middle-aged adults after 16 weeks of circuit weight training, while resting systolic blood pressure remained unchanged. Stone et al. (49) found a significant reduction in resting systolic BP, but no change in diastolic blood pressure, after 8 weeks of Olympic-style weight-lifting in healthy young men.

Other reports showed no change in resting pressure following resistance exercise in (a) college athletes (29), (b) men and women 70 to 79 years of age (6), (c) borderline hypertensive adults (4), or (d) following high-intensity circuit weight training in middle-aged, untrained men (24).

Reduced heart rate and blood pressure during everyday tasks have been shown in older women following 16 weeks of resistance exercise (43). Further research is needed to provide more conclusive evidence on the long-term effects of resistance training on blood pressure in cardiac and high risk populations.

**Self-Efficacy—The Psychological Benefits of Resistance Training**

Self-efficacy is defined as one's level of confidence or certainty of being able to perform a given task. If a person demonstrates he or she can perform a task, then practices the task and sees performance improve, the person's self-efficacy or confidence for performing that task will increase. After a cardiac event, one's self-efficacy for many physical activities, even those of routine daily living, decreases significantly. It is during the cardiac rehabilitation program that the patient's confidence must be renewed so that he or she can return to work and recreational activities (7).

Changes in self-efficacy may partly explain improvements in mood and psychological well-being. A number of studies suggest that after uncomplicated myocardial infarction, patients frequently are more limited by the fear of exertion than by their actual medical status (7).

Aerobic exercise is only one portion of this important physical and psychological readjustment period. A walking program will generally improve self-efficacy for general locomotion activities, but it may not necessarily transfer self-efficacy to other tasks. Thus the observation that there is a level of specificity involved in self-efficacy.

Since many everyday tasks involve activities that resemble resistance exercise, it may be beneficial to incorporate resistance exercise into the program to increase the individual's self-efficacy in these areas. Examples of such everyday activities include shoveling snow, lifting groceries, picking up a child, carrying luggage, and cleaning house. Additionally, persons whose work involves manual labor or other physical work may especially benefit from a resistance exercise program, for example construction workers, carpenters, delivery persons, nurses, stock persons, factory workers, and automobile mechanics.

From this perspective, resistance exercise is uniquely valuable in its ability to provide direct, varied, and highly reliable information about a patient's physical capabilities (7).

**Limiting Isometric Exercise**

Sustained or high-intensity isometric exercise, due to the excessive level of myocardial pressure work, has been regarded as unsafe for patients with poor left ventricle function and has traditionally been contraindicated for cardiac patients (38, 42). Isometric exercise and activities with isometric components may cause unexpected increases in the rate pressure product because of higher systolic responses, which could cause ischemia and may be detrimental to the patient (42). Isometric work may result in left ventricular problems in patients with poor ventricular function. Therefore it is important to minimize pure isometric work (1).

**ACSM's Resistance Exercise Guidelines**

**Patient Screening**

Resistance exercise may pose a risk to persons who are predisposed to cardiovascular complications or to those with specific medical conditions. Therefore it is important to properly screen indi-
individuals for participation in a resistance exercise program.

Reasons to exclude a person from resistance exercise include the following:

- Abnormal hemodynamic responses to ischemic changes on the electrocardiogram during graded exercise
- Poor left ventricular function
- Peak exercise capacity <6 METs
- Uncontrolled hypertension or dysrhythmias.

**Patient Monitoring**

Persons who qualify for a resistance exercise program should begin exercise in a supervised setting. The information from the symptom-limited exercise test may be used to determine the limits for the resistance exercise program.

The intensity during resistance exercise can be monitored by the same target heart rate as prescribed for aerobic exercise, but the rate pressure product may be a better indicator. Resistance exercise will result in an increased rate pressure product, primarily due to a higher systolic pressure, with a lesser contribution of heart rate. Periodic monitoring of the rate pressure product (RPP) may be important for ensuring that patients do not exceed the RPP at which symptoms or electrocardiographic changes indicate that ischemia occurred during exercise testing. This can be done by monitoring heart rate and arm blood pressure during leg training. During arm training, blood pressure measurements can be taken at the ankle or by having the patient continue the exercise with a blood pressure cuff ready to be inflated.

It is also possible to perform the exercise in one arm and take the blood pressure quickly in the other arm (1). However, blood pressure drops dramatically the first few seconds after a resistance exercise effort. Therefore, cuff pressures taken immediately after resistance exercise will often underestimate the exact pressure during the effort (53).

The ACSM's criteria for termination of an in-patient exercise session are as follows:

- Fatigue
- Failure of monitoring equipment
- Light-headedness, confusion, ataxia, pallor, cyanosis, dyspnea, nausea, or any peripheral circulatory insufficiency
- Onset of angina with exercise
- Symptomatic supraventricular tachycardia
- ST displacement (3 mm) horizontal or downsloping from rest
- Ventricular tachycardia (3 or more consecutive PVCs)
- Exercise-induced left bundle branch block
- Onset of 2nd and/or 3rd degree A-V block
- R or T-wave PVCs
- Frequent multifocal PVCs (30% of the complexes)
- Exercise hypotension (≥20 mm Hg drop in SBP during exercise)
- Excessive blood pressure rise (systolic ≥220 or diastolic ≥110 mm Hg)
- Inappropriate bradycardia (drop in heart rate greater than 10 bpm) with increase or no change in workload.

**Exercise Prescription**

Once the patient has been properly screened, resistance exercise should be planned and started, taking into account the patient's cardiovascular status and functional capacity. Initial weights can be obtained in the following ways:

1. Test for the patient's 1-RM, use 40% of the 1-RM for the initial exercise program;
2. Test for the patient's 3-RM (90% of 1-RM), calculate the 1-RM, use 40% of the 1-RM for the initial exercise program;
3. Use the acclimatization method: start with very light weights and monitor patient responses for 12 to 15 reps or until the rate of perceived exertion is no greater than 13 (somewhat hard). If the patient is well below the target heart rate and rate pressure product, is asymptomatic, and tolerates the weight well, gradually increase the resistance to the next level until a rate of perceived exertion no greater than 13 is reached for the prescribed number of repetitions (12 to 15) for the initial exercise program.

Patients should work up to 3 sets of each exercise, with sets consisting of 12 to 15 reps in 30 sec with 30 sec rest between each exercise. All patients should be carefully instructed in the resistance exercise program. Instruct should include (a) correct body position, (b) correct exercise technique, (c) proper speed and range of movement of each exercise, and (d) correct breathing patterns and avoidance of breath holding.

For maximum benefits, exercises should be performed through a full range of motion and should not impede normal breathing. Patients who have had chest surgery should avoid exercises that put undue pressure on the sternum.

**Summary**

Since 1960, cardiac rehabilitation programs have progressed toward more aggressive treatments, in
light of the observation that inactive patients are under no greater risk for complications or death than active patients (13). Patients who are engaged in physical activity and exercise experience less cardiovascular and muscular atrophy than inactive patients and are more likely to return to vocational and recreational activities. Cardiac rehabilitation programs have typically prescribed aerobic activities, but resistance exercise is gaining wider acceptance because of the added benefits of increased muscular strength and muscular endurance.

Patients should be clinically screened and should perform a symptom-limited maximal graded exercise test before being allowed to take part in a resistance exercise program. Isotonic/isokinetic machines, free weights, cuff and hand weights, elastic bands, or body weight and other resistive modalities may be used to exercise the major muscle groups.

Resistance exercise workloads may be determined by gradual acclimatization or by 1-RM or 3-RM testing methods. Heart rate, blood pressure, rate pressure product, and rating of perceived exertion should be determined and monitored during lifting movements. Cardiac rehabilitation resistance training programs should perhaps limit isometric exercise, but isotonic circuit weight training seems to be particularly beneficial. ▲

References


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**Hank Drought** is President of Personal Trainers, a strength & conditioning consulting firm in Boston. He has been a personal trainer for some 20 years in the U.S. and Europe. He was educated at West Point and Rutgers University, earning a BS in physical education. Hank holds various professional certifications and is currently doing graduate work in exercise physiology at Northeastern University.

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