Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

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Circulation. 2000;101:828-833
doi: 10.1161/01.CIR.101.7.828
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539

AHA Science Advisory

Resistance Exercise in Individuals With and Without Cardiovascular Disease

Benefits, Rationale, Safety, and Prescription

An Advisory From the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association

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Position paper endorsed by the American College of Sports Medicine

Although exercise programs have traditionally emphasized dynamic lower-extremity exercise, research increasingly suggests that complementary resistance training, when appropriately prescribed and supervised, has favorable effects on muscular strength and endurance, cardiovascular function, metabolism, coronary risk factors, and psychosocial well-being. This advisory reviews the role of resistance training in persons with and without cardiovascular disease, with specific reference to health and fitness benefits, rationale, the complementary role of stretching, relevant physiological considerations, and safety. Participation criteria and prescriptive guidelines are also provided.

Health and Fitness Benefits of Resistance Training

Although resistance training has long been accepted as a means for developing and maintaining muscular strength, endurance, power, and muscle mass (hypertrophy),[1,2] its beneficial relationship to health factors and chronic disease has been recognized only recently.[3–5] Prior to 1990, resistance training was not a part of the recommended guidelines for exercise training and rehabilitation for either the American Heart Association or the American College of Sports Medicine (ACSM). In 1990, the ACSM first recognized resistance training as a significant component of a comprehensive fitness program for healthy adults of all ages.[6]

Both aerobic endurance exercise and resistance training can promote substantial benefits in physical fitness and health-related factors.[3,5] Table 1 summarizes these benefits and attempts to weigh them according to the current literature.[3] Although both training modalities elicit benefits in most of the variables listed, the estimated weightings (ie, in terms of physiological benefits) are often substantially different. Aerobic endurance training weighs higher in the development of maximum oxygen uptake ($\dot{V}O_2$max) and associated cardiopulmonary variables, and it more effectively modifies cardiovascular risk factors associated with the development of coronary artery disease. Resistance training offers greater development of muscular strength, endurance, and mass. It also assists in the maintenance of basal metabolic rate (to complement aerobic training for weight control), promotes independence, and helps to prevent falls in the elderly.[5,7] Resistance training is particularly beneficial for improving the function of most cardiac, frail, and elderly patients, who benefit substantially from both upper- and lower-body exercise.[3,4]

Although the mechanisms for improvement may be different, both aerobic endurance exercise and resistance training appear to have similar effects on bone mineral density, glucose tolerance, and insulin sensitivity.[3] For weight control, aerobic exercise is considered a significant calorie burner, whereas resistance training assists the body in expending calories via an increase in lean body mass and basal metabolism. Thus, resistance training exercise is strongly recommended for implementation in primary and secondary cardiovascular disease–prevention programs.

Many cardiac patients and middle-aged persons develop chronic diseases that can be favorably affected by resistance training. Moreover, resistance training can be beneficial in the prevention and management of other chronic conditions, eg, low back pain, osteoporosis, obesity and weight control, sarcopenia (ie, a loss of skeletal muscle mass that may accompany aging), diabetes mellitus, susceptibility to falls, and impaired physical function in frail and elderly persons, as well as in the prevention of and rehabilitation from orthopedic injuries.[3] Consequently, most professional and govern-

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This statement was approved by the American Heart Association Science Advisory and Coordinating Committee in September 1999. A single reprint is available by calling 800-242-8721 (US only) or writing the American Heart Association, Public Information, 7272 Greenville Ave, Dallas, TX 75231-4596. Ask for reprint No. 71-0183.

(*Circulation*. 2000;101:828-833.)

***Circulation* is available at http://www.circulationaha.org**

TABLE 1. Comparison of Effects of Aerobic Endurance Training With Strength Training on Health and Fitness Variables

Variable	Aerobic Exercise	Resistance Exercise
Bone mineral density	↑↑	↑↑
Body composition		
% Fat	↓↓	↓
LBM	↔	↑↑
Strength	↔	↑↑↑
Glucose metabolism		
Insulin response to glucose challenge	↓↓	↓↓
Basal insulin levels	↓	↓
Insulin sensitivity	↑↑	↑↑
Serum lipids		
HDL	↑↔	↑↔
LDL	↓↔	↓↔
Resting heart rate	↓↓	↔
Stroke volume, resting and maximal	↑↑	↔
Blood pressure at rest		
Systolic	↓↔	↔
Diastolic	↓↔	↓↔
$\dot{V}O_2$max	↑↑↑	↑↔
Submaximal and maximal endurance time	↑↑↑	↑↑
Basal metabolism	↑	↑↑

↑ indicates values increase; ↓, values decrease; ↔, values remain unchanged; ↑ or ↓, small effect; ↑↑ or ↓↓, medium effect; ↑↑↑ or ↓↓↓, large effect; LBM, lean body mass; HDL, high-density lipoprotein cholesterol; and LDL, low-density lipoprotein cholesterol. Adapted with permission from Pollock and Vincent.[3]

ment health associations or agencies now support the inclusion of resistance training in their current recommendations and guidelines (see Table 2).[8–13]

Rationale for Resistance Training

The rationale to support resistance training as an adjunct to an adult fitness or exercise-based cardiac rehabilitation program stems from several lines of evidence. Moderate-to-high-intensity resistance training performed 2 to 3 days per week for 3 to 6 months improves muscular strength and endurance in men and women of all ages by 25% to 100%, depending on the training stimulus and initial level of strength.[14] Furthermore, many leisure and occupational tasks require static or dynamic efforts, often involving the arms rather than the legs.[15] Because the pressor response to resistance exercise is largely proportionate to the percent of maximal voluntary contraction (% MVC),[16] as well as the muscle mass involved,[17] increased muscle strength results in an attenuated heart rate and blood pressure response to any given load, because the load now represents a lower percentage of the MVC.[18]

Strength training increases muscular endurance, with modest to no improvement in $\dot{V}O_2$max.[19] In subjects in that study, although $\dot{V}O_2$max during treadmill and cycle ergometer testing remained essentially unchanged after 10 weeks of heavy resistance training, submaximal endurance time to exhaustion increased while cycling (47%) and running (12%). Similarly, Ades et al[20] reported that 12 weeks of strength training improved submaximal walking time by 38%. These findings suggest that improved endurance is not a function of aerobic exercise alone but can be significantly enhanced by increased muscular strength.

Complementary Role of Stretching

In contrast to resistance training, stretching as an isolated activity increases neither muscle strength or endurance, but it should be incorporated into an overall fitness regimen. Considerable evidence suggests that stretching exercises increase tendon flexibility, improve joint range of motion (ROM) and function, and enhance muscular performance.[9] Moreover, observational studies support the role of flexibility exercise using ballistic (movement), static (little or no movement), or modified proprioceptive neuromuscular facilitation techniques[9] in the prevention and treatment of musculoskeletal injuries.[21] These promote a transient increase in the musculotendon unit length that results from actin-myosin complex relaxation and a lasting increase through alteration in the surrounding extracellular matrix. Thus, aerobic and/or resistance training should be complemented by a stretching program that exercises the major muscle or tendon groups at least 2 to 3 days per week.[9]

Physiological Considerations

The physiological response to dynamic aerobic exercise is an increase in oxygen consumption and heart rate that parallels the intensity of the imposed activity and a curvilinear increase in stroke volume. There is a progressive increase in systolic blood pressure, with maintenance of or a slight decrease in the diastolic blood pressure, and a concomitant widening of the pulse pressure. Blood is shunted from the viscera to active skeletal muscle, where increased oxygen extraction widens the systemic arteriovenous oxygen difference. Thus, aerobic exercise imposes primarily a volume load on the myocardium.[16]

Isometric exertion involves sustained muscle contraction against an immovable load or resistance with no change in length of the involved muscle group or joint motion. The heart rate and blood pressure responses to isometric exertion are largely proportionate to the tension exerted relative to the greatest possible tension in the muscle group (% MVC) rather than the absolute tension developed.[16] Stroke volume remains largely unchanged except at high levels of tension (>50% MVC), at which it may decrease. The result is a moderate increase in cardiac output, with little or no increase in metabolism. Despite the increased cardiac output, blood flow to the noncontracting muscles does not significantly increase, probably because of reflex vasoconstriction. The combination of vasoconstriction and increased cardiac output causes a disproportionate rise in systolic, diastolic, and mean blood pressures.[16] Thus, a significant pressure load is imposed on the heart, presumably to increase perfusion to the active (contracting) skeletal muscle.

Although isometric or combined isometric and dynamic (resistance) exercise has traditionally been discouraged in patients with coronary disease, it appears that resistance

TABLE 2. Standards, Guidelines, and Position Statements Regarding Strength Training

	Sets; Reps	Stations/Devices	Frequency
Healthy/sedentary adults			
2000 ACSM Guidelines[8]	1 set; 8–15 reps	8–10 exercises*	2 days per week, minimum
1998 ACSM Position Stand	1 set; 8–12 reps for persons under 50–60 y, 10–15 reps for persons ≥50–60 y	8–10 exercises	2–3 days per week
1995 CDC/ACSM Statement[10]	Addressed, not specified		
1996 Surgeon General's Report[5]	1–2 sets; 8–12 reps	8–10 exercises	2 days per week, minimum
Elderly persons			
Pollock et al[11]	1 set; 10–15 reps	8–10 exercises	2 days per week, minimum
Cardiac patients			
1995 AHA exercise standards[12]	1 set; 10–15 reps	8–10 exercises	2–3 days per week
1999 AACVPR guidelines	1 set; 12–15 reps	8–10 exercises	2–3 days per week

ACSM indicates American College of Sports Medicine; AHA, American Heart Association; CDC, Centers for Disease Control and Prevention; AACVPR, American Association of Cardiovascular and Pulmonary Rehabilitation; and reps, repetitions.

*Minimum 1 exercise per major muscle group: eg, chest press, shoulder press, triceps extension, biceps curl, pull-down (upper back), lower-back extension, abdominal crunch/curl-up, quadriceps extension or leg press, leg curls (hamstrings), calf raise.

exercise (eg, weight lifting at 8 to 12 repetitions/set) is less hazardous than was once presumed, particularly in patients with good aerobic fitness and normal or near-normal left ventricular (LV) systolic function. Isometric exertion, regardless of the % MVC, generally fails to elicit angina pectoris, ischemic ST-segment depression, or threatening ventricular arrhythmias among selected (low-risk) cardiac patients.[22] The rate-pressure product is lower during maximal isometric and dynamic resistance exercise than during maximal aerobic exercise, primarily because of a lower peak heart rate response. Increased subendocardial perfusion secondary to elevated diastolic blood pressure and decreased venous return, LV diastolic volume, and wall tension may also contribute to the lower incidence of ischemic responses during resistance effort.[15] Furthermore, the myocardial oxygen supply/demand relationship appears to be favorably altered by the superimposition of static on dynamic effort, so that the magnitude of ST-segment depression is lessened at a given rate-pressure product.[23]

Safety of Resistance Training

The safety of resistance testing and training in moderate-to-high-risk cardiac patients requires study. However, numerous investigations in healthy adults and low-risk cardiac patients (ie, persons without resting or exercise-induced evidence of myocardial ischemia, severe LV dysfunction, or complex ventricular dysrhythmias) have reported few orthopedic complications and no cardiovascular events. Gordon et al[24] reported no significant cardiovascular events after determining the maximum weight that could be used to complete 1-repetition (ie, 1-repetition maximum, 1 RM) strength testing (bench press, leg press, and knee extension) in 6653 healthy subjects aged 20 to 69 years who had undergone a preliminary medical examination and maximal treadmill testing; all had resting blood pressures ≤160/90 mm Hg. The safety of resistance training in patients with mild hypertension has also been reported.[25] Moreover, Haslam et al[26] found intra-arterial blood pressures during weight lifting in cardiac patients to be within a clinically acceptable range at 40% and 60% of 1 RM.

Recently, the application of resistance testing or training in the rehabilitation of patients with coronary disease in 12 different studies was reviewed.[27] Resistance or circuit weight training was typically added to the physical-conditioning regimens of men with coronary disease who had already been aerobically trained, generally for 3 months or more. The latter (circuit weight training) involved the performance of upper- and lower-body resistance exercises in an alternating fashion with relatively lighter weights (40% to 60% of 1 RM), with little rest between sets (15 to 30 seconds). The duration, program length, and intensity of strength training ranged from 30 to 60 minutes, 6 to 26 weeks, and 25% to 80% of 1 RM, respectively. All studies reported improvements in muscular strength and endurance, with similar increases in overall strength for high (80% of 1 RM) and moderate (30% to 40% of 1 RM) training intensities. The absence of anginal symptoms, ischemic ST-segment depression, abnormal hemodynamics, complex ventricular dysrhythmias, and cardiovascular complications suggests that strength testing and training are safe for clinically stable men with coronary disease who are actively participating in a rehabilitative program. Unfortunately, similar data in women are lacking.

Although conventional participation guidelines have suggested that surgical and post–myocardial infarction (MI) patients should avoid resistance training for at least 4 to 6 months,[28,29] many men can safely perform static-dynamic activity equivalent to carrying up to 30 pounds by 3 weeks after an acute MI.[30] Thus, it is possible that resistance training could be initiated sooner, if low-weight programs are used.

Participation Criteria and Preliminary Instruction

Contraindications to resistance training are similar to those used for the aerobic component of adult fitness or cardiac exercise programs. Many previous strength-training studies involved small numbers of low-risk male patients with coronary disease, aged 70 years or younger, with normal or near-normal aerobic fitness and LV function. The extent to which the safety and effectiveness demonstrated by these studies can be extrapolated to other populations of coronary patients (eg, women, older patients with low aerobic fitness, and patients with severe LV dysfunction) remains unclear.[27] Accordingly, these patient subsets may require more careful evaluation and initial monitoring.

Contraindications to resistance training include unstable angina, uncontrolled hypertension (systolic blood pressure ≥160 mm Hg and/or diastolic blood pressure ≥100 mm Hg), uncontrolled dysrhythmias, a recent history of congestive heart failure that has not been evaluated and effectively treated, severe stenotic or regurgitant valvular disease, and hypertrophic cardiomyopathy.[8,12,15] Because patients with myocardial ischemia or poor LV function may develop wall-motion abnormalities or serious ventricular arrhythmias during resistance-training exertion,[31,32] moderate to good LV function and cardiorespiratory fitness (>5 or 6 metabolic equivalents) without anginal symptoms or ischemic ST-segment depression have been suggested as additional prerequisites for participation in traditional resistance-training programs, with cardiac medications maintained as clinically indicated.[15]

Low-to-moderate-risk cardiac patients who wish to initiate mild to moderate resistance training should, perhaps, first participate in a traditional aerobic exercise program for a minimum of 2 to 4 weeks. These groups include patients who have undergone percutaneous transluminal coronary angioplasty.[13] Although scientific data to support this recommendation are lacking, this time period permits sufficient surveillance of the patient in a supervised setting and allows the cardiorespiratory and musculoskeletal adaptations that may reduce the potential for complications to occur.

A preliminary orientation should establish appropriate weight loads and instruct the participant on proper lifting techniques, ROM for each exercise, and correct breathing patterns to avoid straining and the Valsalva maneuver. Because systolic blood pressure measurements taken by the standard cuff method immediately after resistance exercise may significantly underestimate true physiological responses,[33] such measurement is usually not recommended. Alternatives include the use of cuff-occlusion techniques to obtain blood pressure values in the legs of exercising patients,[15] measurement of blood pressures in an inactive arm while the patient performs resistance exercise with the other limbs, or both. The monitoring of resting and recovery blood pressures (eg, every 1 to 3 minutes) and evaluation of signs and symptoms are standard.[8,12,13]

Exercise Prescription for Resistance Training

Current research and exercise guidelines recommend the inclusion of resistance training for healthy persons of all ages and many patients with chronic diseases, including cardiovascular disease.[8,12,13] Programs that include a single set of 8 to 10 different exercises (eg, chest press, shoulder press, triceps extension, biceps curl, pull-down [upper back], lower-back extension, abdominal crunch/curl-up, quadriceps extension or leg press, leg curls [hamstrings], and calf raise) that train the major muscle groups, performed 2 to 3 days per week, will elicit favorable adaptation and improvement (or maintenance thereof). Although greater frequencies of training and more sets may be used, the additional gains among those in adult fitness programs are usually small.[9,34] Conversely, fewer exercises can be performed, although training the front and back of major muscle groups (eg, chest/back and biceps/triceps) is recommended. To achieve a balanced increase in both muscular strength and endurance, a repetition range of 8 to 12 is recommended for healthy participants younger than 50 to 60 years of age and 10 to 15 repetitions at a lower relative resistance for cardiac patients and healthy participants older than 50 to 60 years of age.[9] The increased repetition range at a lower relative effort for older or more frail patients is designed for injury prevention. The single greatest cause of musculoskeletal injury with resistance training is a previous injury. Also, higher-intensity efforts (fewer repetitions with heavier weights) can have adverse effects on the knee (leg extension) and shoulder (rotator cuff) areas.

The principles of resistance training are similar among groups, but its application will differ according to the individual's goals and age and the presence of chronic disease.[9,13,14] Usually older, more frail individuals and cardiac patients start at a lower resistance, progress more slowly, and may limit their end point to volitional fatigue, ie, submaximal versus maximal efforts to volitional fatigue.[8,12,13] Although resistance or overload of any type will provide a stimulus for improvement, the higher the intensity, the greater the result.[14] Therefore, body weight (calisthenics), rubber band devices, pulley weights, dumbbells or wrist weights, barbells, or weight machines can be adapted for most participants. The advantages of graduated weights and weight machines are their known resistance and ease of facilitating and titrating the progression of training. Also, weight machines may be safer than free weights for the middle-aged to older participant because of problems associated with poor vision, equilibrium and balance (falling), low-back pain, and dropping weights.[9] Machines that use variable-resistance cams can also provide a full range of muscle stimulation. For patients who have joint pain or discomfort and/or have limited ROM, machines can be double pinned to restrict their ROM. This allows patients to exercise through a pain-free part of their ROM and still attain a significant training effect.[9]

Prescription for Patients Without Cardiovascular Disease

Because "lack of time" is a major reason for not exercising or for dropping out of an exercise regimen, planning a time-efficient program is imperative.[35] Approximately 75% of the improvement that occurs with a 3-days-per-week resistance-training program can be attained with a 2-days-per-week regimen.[34] Furthermore, a single set of exercises to volitional fatigue, with weight loads corresponding to ≈50±10% of 1 RM, has been found to be as effective as multiple-set programs that are prescribed in the adult fitness setting.[9,34] Thus, a comprehensive resistance-training program of 8 to 10 exercises can be accomplished in 20 to 30 minutes. Participants beginning a resistance-training program may be advised to start with a minimum of 2 days per week and, if time permits, progress to 3 days per week.

The initial resistance or weight should be set at a moderate level that allows the participant to achieve the proper repetition range at a comfortably hard level (13 to 15 on the original Borg[36] perceived exertion scale, the RPE [rating of perceived exertion]). The emphasis at this early stage of training is to allow time for musculoskeletal adaptation and to practice good technique, thus reducing the potential for excessive muscle soreness and injury.[9,14] Each repetition of exercise should include the following: a slow, controlled movement (≈2 seconds up and 4 seconds down), one full inspiration and expiration, and no breath holding (Valsalva maneuver).

If maximal tests are available, eg, a 1 RM, then 30% to 40% of 1 RM for the upper body and 50% to 60% of 1 RM for the hips and legs can be used as the starting weight for the first exercise-training session. If a prior test is not available, start with an estimated easy-to-light weight. When the participant can comfortably lift the weight for up to 12 to 15 repetitions, resistance can be increased by 5% for the next training session. If the participant cannot complete the minimum number of repetitions (8 or 10) using good technique, the weight should be reduced. Most participants should be able to find their proper repetition range and adapt to volitional or near-volitional fatigue within 3 to 4 weeks. Because the level of fatigue (intensity) is an important factor for attaining optimal benefits and the performance of resistance exercise at a high level of fatigue has not been associated with an increased risk of precipitating cardiovascular events in healthy adults and low-risk cardiac patients,[24,27] resistance training to volitional or near-volitional levels of fatigue is recommended.[9,14]

Prescription for Patients With Cardiovascular Disease

Cardiac patients require a minimum amount of resistance exercise to perform activities associated with daily living. Unfortunately, many patients lack the physical strength or confidence to perform these tasks. Only ROM exercises of both the upper and lower extremities are recommended for most cardiac inpatients. Coronary artery bypass graft (CABG) surgery patients who experience sternal movement or have postsurgical sternal wound complications would not perform these exercises. Nevertheless, significant soft tissue and bone damage of the chest wall can occur during surgery. If this area does not receive ROM exercise, adhesions may develop, and the musculature can become weaker and foreshorten. Patients will also favor the arm, shoulder, and chest areas, which may accentuate later problems of poor posture and difficulties in attaining their previous strength and full ROM. Thus, a delay in performing upper-extremity ROM exercises may result in more discomfort for the CABG surgery patient during the recovery period, and the time required to achieve full recovery may be longer.

Stretching or flexibility activities can begin as early as 24 hours after CABG or 2 days after MI. Patients are seen once a day (generally by a physical therapist, exercise physiologist, or nurse clinician) and can perform 10 to 15 repetitions to an RPE of 11 to 13 (light to somewhat hard). The ROM exercises used in the inpatient program for the surgery patient typically include shoulder flexion, abduction, and internal and external rotation; elbow flexion; hip flexion, abduction, and internal and external rotation; plantar flexion and dorsiflexion; and ankle inversion and eversion. Low-level resistance training (eg, use of elastic bands, very light hand weights, and wall pulleys) should not begin until 2 to 3 weeks after MI.[13] The recommended beginning resistance exercise is with 1- to 2-lb dumbbells or wrist weights. The program consists of 8 to 10 exercises, 2 to 3 days per week, with 1 set of 10 to 15 repetitions to moderate fatigue (RPE 12 to 13, somewhat hard). Patients will progress by 1- to 2-lb increments every 1 to 3 weeks depending on signs or symptoms and adaptation to training. Once the patient completes the convalescence stage of recovery, usually 4 to 6 weeks after the event, regular barbells and/or weight machines may be included. Surgical patients should probably avoid resistance-training exercises (other than ROM) that may cause pulling on the sternum within 3 months of CABG surgery and sternotomy. Moreover, the sternum should be checked for stability by an experienced healthcare professional before resistance training is initiated for any CABG patient or at any time that symptoms of chest discomfort or clicking develop. With appropriate clearance, selected patients may proceed in their program as described for healthy older adults. The patient should start at a low weight and perform 1 set of 10 to 15 repetitions to moderate fatigue (RPE ≈13). Weight is increased slowly as a patient adapts to the program (≈2 to 5 lb/week for arms and 5 to 10 lb/week for legs). Although 10 to 15 repetitions are recommended for all patients, moderate-risk patients should exercise to an RPE of 15 (hard) or less, whereas the low-risk patient can progress to volitional fatigue after an ≈4- to 6-week adaptation period.[8,13] It should be emphasized, however, that the resistance-training prescription for patients with cardiovascular disease may differ slightly depending on the degree of LV dysfunction, concomitant comorbid conditions (eg, hypertension or diabetes), and associated neurological, vascular, and orthopedic limitations. As opposed to resistance training, which combines isometric and dynamic exercise, pure isometric exercise is not recommended for patients with cardiovascular disease. The safety and efficacy of pure isometric exercise among such patients have not been established.

Summary of Key Points

Many cardiac patients lack the physical strength and/or self-confidence to perform common activities of daily living. Mild-to-moderate resistance training can provide an effective method for improving muscular strength and endurance, preventing and managing a variety of chronic medical conditions, modifying coronary risk factors, and enhancing psychosocial well-being. Weight training has also been shown to attenuate the rate-pressure product when any given load is lifted.[18] Thus, resistance training can decrease myocardial demands during daily activities such as carrying groceries or lifting moderate-to-heavy objects. Although the safety of resistance exercise in healthy persons and men with low-risk cardiovascular disease is well established, proper preliminary screening, appropriate prescriptive guidelines, and careful supervision are important. The extent to which the safety and effectiveness of resistance training can be extrapolated to other populations of cardiac patients (eg, women, older patients with low aerobic fitness, and patients with severe LV dysfunction) remains unclear. Resistance training in these latter groups may be considered if the perceived potential benefits of such training appear to be particularly advantageous for a given patient. However, patients should proceed with such training with caution, and close monitoring of adverse cardiovascular signs and symptoms, heart rate, and blood pressure should be performed, as well as surveillance for musculoskeletal injury. Owing to the lack of available data, the routine application of resistance training in moderate-to-high-risk cardiac patients cannot be recommended at this time and requires additional study. Because long-term compliance remains a challenge for adult fitness and exercise-based cardiac rehabilitation programs, resistance training can provide a means for maintaining interest and increasing diversity. Nevertheless, it should serve as a complement to, rather than a replacement for, the patient's aerobic exercise prescription.

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