# Cardiac Rehabilitation and Secondary Prevention of Coronary Heart Disease

## An American Heart Association Scientific Statement From the Council on Clinical Cardiology (Subcommittee on Exercise, Cardiac Rehabilitation, and Prevention) and the Council on Nutrition, Physical Activity, and Metabolism (Subcommittee on Physical Activity), in Collaboration With the American Association of Cardiovascular and Pulmonary Rehabilitation

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***Abstract*—**This article updates the 1994 American Heart Association scientific statement on cardiac rehabilitation. It provides a review of recommended components for an effective cardiac rehabilitation/secondary prevention program, alternative ways to deliver these services, recommended future research directions, and the rationale for each component of the rehabilitation/secondary prevention program, with emphasis on the exercise training component. **(*Circulation*. 2005;111:369-376.)**

**Key Words:** AHA Scientific Statements ■ rehabilitation ■ exercise ■ coronary disease ■ prevention

This article updates the American Heart Association (AHA) 1994 scientific statement on cardiac rehabilitation.[1] It provides a review of the recommended components of optimal rehabilitation/secondary prevention programs, ways to deliver these services, recommended future research directions, and the rationale for these recommendations, with emphasis on the exercise training component. Secondary prevention is an essential part of the contemporary care of the patient with cardiovascular disease (CVD). The term *cardiac rehabilitation* refers to coordinated, multifaceted interventions designed to optimize a cardiac patient's physical, psychological, and social functioning, in addition to stabilizing, slowing, or even reversing the progression of the underlying atherosclerotic processes, thereby reducing morbidity and mortality.[2] As such, cardiac rehabilitation/secondary prevention programs provide an important and efficient venue in which to deliver effective preventive care. In 1994, the AHA declared that cardiac rehabilitation should not be limited to an exercise training program but also should include multifaceted strategies aimed at reducing modifiable risk factors for CVD.[1] Since then, detailed guidelines have been published that clearly specify each of the core components of cardiac rehabilitation/secondary prevention programs, along with information about the evaluation, intervention, and expected outcomes in each area.[3–10] Thus, cardiac rehabilitation/secondary prevention programs currently include baseline patient assessments, nutritional counseling, aggressive risk factor management (ie, lipids, hypertension, weight, diabetes, and smoking), psychosocial and vocational counseling, and physical activity counseling and exercise training, in addition to the appropriate use of cardioprotective drugs that have evidence-based efficacy for secondary prevention. Candidates for cardiac rehabilitation services historically were patients who recently had had a myocardial infarction or had undergone coronary artery bypass graft surgery, but candidacy has been broadened to include patients who have undergone percutaneous coronary interventions; are heart transplantation candidates or recipients; or have stable chronic heart failure, peripheral arterial disease with claudication, or other forms of CVD. In addition, patients

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This statement was approved by the American Heart Association Science Advisory and Coordinating Committee on September 28, 2004. 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. 71-0311. To purchase additional reprints: up to 999 copies, call 800-611-6083 (US only) or fax 413-665-2671; 1000 or more copies, call 410-528-4121, fax 410-528-4264, or e-mail kgray@lww.com. To make photocopies for personal or educational use, call the Copyright Clearance Center, 978-750-8400.

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***Circulation* is available at http://www.circulationaha.org** **DOI: 10.1161/01.CIR.0000151788.08740.5C**

who have undergone other cardiac surgical procedures, such as those with valvular heart disease, also may be eligible.

Unfortunately, cardiac rehabilitation programs remain underused in the United States, with an estimated participation rate of only 10% to 20% of the >2 million eligible patients per year who experience an acute myocardial infarction or undergo coronary revascularization.[7] Contributing to the vast underuse of these services are a low patient referral rate, particularly of women, older adults, and ethnic minority patients; poor patient motivation; inadequate third-party reimbursements for services; and geographic limitations to accessibility of program sites.[7,11] In addition, there is a lack of "visibility" and recognition by the public of the importance of cardiac rehabilitation services. To potentially rectify these concerns, alternative models to the traditional hospital- or community center–based setting for outpatient programs have been developed. These models include home-based programs for which a nurse generally serves as case manager and facilitates, supervises, and monitors patient care and progress,[12,13] and community-based group programs that use nurses or other nonphysician healthcare providers.[14] Electronic media programs are an alternative method for providing home-based comprehensive risk-factor modification education and instruction for structured exercise.[15] Additional research is required to establish the effectiveness of these non–hospital-based approaches for rehabilitation and secondary prevention and to determine how to deliver these services optimally.

## Exercise Training Intervention

Guidelines for prescribing aerobic and resistance exercise for patients with CVD are available elsewhere.[6,9,10,16,17] Specific activity recommendations also are available for women,[18] older adults,[19] patients with chronic heart failure and heart transplants,[20] stroke survivors,[21] and patients with claudication induced by peripheral arterial disease.[22]

### Safety Considerations

The relative safety of medically supervised, physician-directed, cardiac rehabilitation exercise programs that follow these guidelines is well established. The occurrence of major cardiovascular events during supervised exercise in contemporary programs ranges from 1/50 000 to 1/120 000 patient-hours of exercise, with only 2 fatalities reported per 1.5 million patient-hours of exercise.[23] Contemporary risk-stratification procedures for the management of coronary heart disease (CHD) help to identify patients who are at increased risk for exercise-related cardiovascular events and who may require more intensive cardiac monitoring in addition to the medical supervision provided for all cardiac rehabilitation program participants.[5]

### Effect on Exercise Capacity

Exercise training and regular daily physical activities (eg, working around the house and yard, climbing stairs, walking or cycling for transportation or recreation) are essential for improving a cardiac patient's physical fitness. Supervised rehabilitative exercise for 3 to 6 months generally is reported to increase a patient's peak oxygen uptake by 11% to 36%, with the greatest improvement in the most deconditioned individuals.[5,7] Improved fitness enhances a patient's quality of life and even can help older adults to live independently.[24] Improved physical fitness also is associated with reductions in submaximal heart rate, systolic blood pressure, and rate-pressure product (RPP), thereby decreasing myocardial oxygen requirements during moderate-to-vigorous activities of daily living. Improved fitness allows patients with advanced coronary artery disease (CAD) who ordinarily experience myocardial ischemia during physical exertion to perform such tasks at a higher intensity level before reaching their ischemic ECG or anginal threshold. Furthermore, improvement in muscular strength after resistance training also can decrease RPP (and associated myocardial demands) during daily activities, such as carrying groceries or lifting moderate to heavy objects.[10] In addition, improvement in cardiorespiratory endurance on exercise testing is associated with a significant reduction in subsequent cardiovascular fatal and nonfatal events independent of other risk factors.[25–28] These findings also apply to patients with chronic heart failure. In a recent meta-analysis of 81 studies involving 2587 patients with stable heart failure, Smart and Marwick[29] demonstrated a trend toward increased survival ($P=0.06$) associated with improved functional capacity, as well as a reduction in cardiorespiratory symptoms after aerobic and strength training.

### Return to Work

Although exercise training–induced improvement in functional capacity and the associated reduction in cardiorespiratory symptoms may enhance a cardiac patient's ability to perform most job-related physical tasks, factors unrelated to physical fitness appear to have a greater influence on whether a patient returns to work after a cardiac event.[30] These factors include socioeconomic and worksite-related issues and previous employment status. The educational and vocational counseling components of cardiac rehabilitation programs should further improve the ability of a patient to return to work.

### Effect on CVD Prognosis

During the past 5 decades, numerous studies have demonstrated a reduced rate of initial CHD events in physically active people.[31–33] These findings, along with those from studies that demonstrate biologically plausible cardioprotective mechanisms (discussed below), provide strong evidence that regular physical activity of at least moderate intensity reduces the risk of coronary events, thus leading to the conclusion that physical inactivity is a major CHD risk factor. An even greater impact is seen when the endurance exercise program is of sufficient intensity and volume to improve aerobic capacity. Data from the Health Professionals' Follow-up Study[34] also provide evidence that as little as 30 minutes per week of strength training may reduce the risk of an initial coronary event.

In the absence of definitive randomized controlled trials, meta-analyses of smaller studies have been used to assess the role of exercise training, alone or as part of a comprehensive cardiac rehabilitation program, on morbidity and mortality rates of CHD patients. Meta-analyses based on studies performed in the 1970s and 1980s and reviewed in the 1994 AHA scientific statement on cardiac rehabilitation programs[1] and the Agency for Health Care Policy and Research guidelines[5] revealed a statistically significant reduction in both cardiac and total mortality after completion of cardiac rehabilitation programs that included exercise training[35,36]; however, the rate of nonfatal cardiovascular events was not altered significantly by rehabilitative exercise. Subjects in these earlier trials were predominately low-risk, middle-aged, white male survivors of myocardial infarction. Women, older people, ethnic minorities, and patients who underwent revascularization procedures or who had other types of cardiac conditions were excluded or markedly underrepresented in these studies. Major advances in the management of patients with CHD during the 1990s raise further questions about the relevance of findings from these earlier meta-analyses to the independent effects of the exercise component of contemporary cardiac rehabilitation programs on morbidity, mortality, and other outcome variables. These medical advances include attenuation of residual myocardial damage from acute coronary occlusion by emergent medical interventions and pharmacological therapy to reduce myocardial oxygen demands; development and use of antiplatelet and anticoagulant drugs; prompt coronary revascularization by thrombolysis or percutaneous interventions; and more frequent use of revascularization procedures. Wider prophylactic use of adjunctive cardioprotective drugs (eg, statins), as demonstrated in definitive clinical trials, has been shown to be effective for reducing cardiovascular morbidity and mortality rates. Furthermore, biotechnical advances that have improved the survival rates of cardiac patients include conventional or drug-eluting coronary stents, implantable cardioverter defibrillators, and biventricular pacing and left ventricular assist devices for treating patients with chronic heart failure. In light of these advances, the additional effect of exercise training on morbidity and mortality rates in current cardiac rehabilitation participants is unclear.

Taylor et al[2] reported encouraging findings in a meta-analysis based on a review of 48 randomized trials of ≤6 months' duration that compared outcomes of exercise-based rehabilitation with usual medical care. This meta-analysis, which updated an earlier study by the same investigators,[37] added >4000 more-recent subjects with CHD to the database from the earlier meta-analyses,[35,36] for a total of 8940 patients. Greater numbers of women (20% of the cohort), people ≥65 years of age, and patients who had undergone coronary revascularization procedures were included than in previous meta-analyses. As shown in the Table, exercise-based cardiac rehabilitation was associated with lower total and cardiac mortality rates compared with usual medical care, which was in agreement with previous reports. Subgroup analysis showed that mortality rates did not differ between programs limited to exercise and those providing more comprehensive secondary interventions, or between pre- and post-1995 studies. Favorable trends also were noted for a lower incidence of nonfatal myocardial infarction and revascularization procedures in cardiac patients who received exercise-based rehabilitation, but these trends did not achieve statistical significance. Data from a limited number of studies included in this meta-analysis also showed more favorable changes in some modifiable cardiovascular risk factors among patients who received exercise therapy. Few data were provided in these studies on the use of acute thrombolytic therapy and adjunctive cardioprotective drugs. Furthermore, quality of life was assessed, via a variety of measures, in only 25% of the clinical trials, and similar improvement was noted in both the exercise-based rehabilitation and control groups.

**Effects of Exercise-Based Cardiac Rehabilitation on Study End Points***

| Outcome | Mean Difference, % | 95% Confidence Limit | Statistical Difference |
|---|---|---|---|
| Total mortality | −20 | −7% to −32% | $P=0.005$ |
| Cardiac mortality | −26 | −10% to −29% | $P=0.002$ |
| Nonfatal MI | −21 | −43% to 9% | $P=0.150$ |
| CABG | −13 | −35% to 16% | $P=0.400$ |
| PTCA | −19 | −51% to 34% | $P=0.400$ |

Mean difference is the percentage of difference between exercise-trained and usual-care control group. MI indicates myocardial infarction; CABG, coronary artery bypass graft; and PTCA, percutaneous coronary angioplasty.

*Data are derived from Taylor et al.[2]

## Cardioprotective Mechanisms

Exercise training, as part of a comprehensive rehabilitation program, has been shown to slow the progression or partially reduce the severity of coronary atherosclerosis.[38,39] Multiple factors directly or indirectly appear to contribute to this antiatherosclerotic effect. Increased flow-mediated shear stress on artery walls during exercise results in improved endothelial function,[40] which is associated with enhanced synthesis, release, and duration of action of nitric oxide.[41–43] Nitric oxide is responsible for endothelium-dependent vasodilatation and inhibits multiple processes involved in atherogenesis and thrombosis.[40] Hambrecht et al[44] demonstrated a significant improvement in endothelium-dependent arterial dilatation in patients with CHD and abnormal endothelial function after only 4 weeks of vigorous endurance exercise training.

Chronic inflammation plays a major role in the pathogenesis of CAD and in plaque stability.[45] Plasma level of C-reactive protein, a nonspecific biomarker of inflammation, is associated with an increased risk of CHD.[46] Aerobic exercise training and improved cardiorespiratory endurance are associated with reduced C-reactive protein levels, which suggests that exercise training has antiinflammatory effects.[47–49] These observations require confirmation, however, especially in patients with CAD.

In addition, exercise training and regular physical activity can result in moderate losses in body weight and adiposity.[50,51] Endurance exercise also can promote decreases in blood pressure[52,53] and serum triglycerides, increases in high-density lipoprotein cholesterol,[54–57] and improvements in insulin sensitivity and glucose homeostasis,[58] which along with modest weight reduction have been shown to reduce the risk of type 2 diabetes mellitus in individuals with glucose intolerance.[59,60] Thus, aerobic exercise can favorably modify all of the components of the metabolic syndrome[61] and serve as a first-line therapy to combat this complex constellation of risk factors for type 2 diabetes mellitus and CVD.[62] In addition, the value of exercise training likely goes beyond the recognized benefits on glycemic control by improving many of the cardiovascular abnormalities associated with diabetes, such as left ventricular diastolic dysfunction, endothelial dysfunction, and systemic inflammation.[63]

Endurance exercise training also has potential antiischemic effects. As previously mentioned, it can reduce myocardial ischemia in patients with advanced CHD by decreasing RPP and myocardial oxygen demands during physical exertion, thereby raising the ischemic threshold.[9,31,32] In addition, exercise training also can increase coronary flow by improving coronary artery compliance or elasticity[64,65] and endothelium-dependent vasodilatation[49] and by increasing the luminal area of conduit vessels through remodeling or arteriogenesis and myocardial capillary density by angiogenesis.[66]

Furthermore, in the presence of advanced CAD, exercise training has been shown to induce ischemic preconditioning of the myocardium, a process by which transient myocardial ischemia during exercise enhances tolerance of the myocardium to subsequent more prolonged ischemic stress, thereby reducing myocardial damage and the risk of potentially lethal ventricular tachyarrhythmias.[67,68] Aerobic exercise training also may decrease the risk of sudden cardiac death due to ventricular tachyarrhythmias by reducing sympathetic and enhancing parasympathetic (vagal) activity, as evidenced by increased heart rate variability and reduced baroreceptor sensitivity.[69–71]

Furthermore, exercise training has favorable hemostatic effects, which can reduce the risk of a thrombotic occlusion of a coronary artery after the disruption of a vulnerable plaque. These antithrombotic effects include increased plasma volume, reduced blood viscosity, decreased platelet aggregation, and enhanced thrombolytic ability.[72,73] Strenuous exercise training enhances fibrinolytic activity by increasing the endothelial synthesis of tissue plasminogen activator and reducing the levels of its inhibitor, plasminogen activator inhibitor-1.[73] Some studies also have shown that exercise training may reduce plasma levels of fibrinogen.[73]

### Risk Factor Modification and Interventions

In addition to exercise training, a comprehensive secondary prevention program for cardiac patients requires aggressive reduction of risk factors through nutritional counseling, weight management, and adherence to prescribed drug therapy.[3–7] Clinical trials during the past 2 decades have provided conclusive evidence of reduced mortality in patients with CHD via the reduction of individual risk factors by pharmacological and nonpharmacological interventions.[74]

Previously published AHA, American College of Cardiology, US Public Health Service, and American Association of Cardiovascular and Pulmonary Rehabilitation guidelines about prevention of heart attack and death in CVD patients summarize evidence-based strategies and recommendations for controlling risk factors.[3–6] Nutritional counseling plays an important role in the prevention and management of obesity, dyslipidemias, hypertension, and diabetes mellitus. Dietary recommendations for modifying these risk factors are available from the AHA.[75–77] National guidelines also have been published for the management of dyslipidemias,[78] hypertension,[79] obesity,[80] and diabetes mellitus[81] and for smoking cessation and the prevention of relapses.[82] In addition, the value of drug therapy has been well documented for secondary prevention in CVD patients with the use of aspirin or clopidogrel alone or in combination with other antiplatelet drugs,[83,84] HMG-coenzyme A reductase inhibitors (statins),[85–87] angiotensin-converting enzyme inhibitors,[88,89] and $\beta$-blockers.[90–93]

### Psychosocial Interventions

Psychosocial dysfunction is common in patients receiving cardiac rehabilitation treatment. These problems include depression, anger, anxiety disorders, and social isolation. Observational studies have demonstrated associations between psychosocial disorders and the risk of initial or recurrent cardiovascular events.[94,95] A large randomized multicenter trial, Enhanced Recovery in Coronary Heart Disease Patients (ENRICHD), assessed whether morbidity (recurrent myocardial infarction) or mortality would be reduced by psychosocial interventions in 2481 people hospitalized for acute myocardial infarction associated with depression and low social support.[96] Treatment for depression was provided through cognitive behavior therapy and selective serotonin reuptake inhibitors, when indicated. The ENRICHD intervention did not improve event-free survival; however, both depression and social isolation improved in the intervention and control groups. Nevertheless, even if psychosocial interventions ultimately are shown not to alter the prognosis of CHD patients, they remain an integral part of cardiac rehabilitation services to improve the psychological well-being and quality of life of cardiac patients.

## Future Research Recommendations

1. Evaluations are needed to determine the effectiveness and safety of a variety of approaches designed to increase patient referrals, accessibility, and delivery of cardiac rehabilitation and secondary prevention services and to promote adherence to program components. These include evaluations of community-based, home-based, and Internet-based interventions and of care management by nonphysician healthcare professionals to complement physicians' services.
2. Because of continuously escalating medical costs, third-party payers demand evidence of cost-effectiveness and the cost-related benefits of healthcare services and procedures. Only a limited number of studies have examined these issues for cardiac rehabilitation and secondary prevention services.[97,98] These studies strongly indicate the cost-effectiveness of comprehensive rehabilitation/secondary prevention programs and their individual components, including exercise training. Future studies should include comparisons of the cost-effectiveness of traditional supervised programs versus home-based exercise and educational services with regard to improving functional capacity, self-efficacy, independent living, risk factor

modification, long-term compliance, rehospitalization rates, and quality of life.

3. Additional research is required to study contributions of endurance and resistance exercise for the modification of risk factors and for their effects on pathophysiological mechanisms involved in atherogenesis, myocardial ischemia, coronary thrombosis, and ventricular tachyarrhythmias. This research should include the effects of exercise on endothelial function, vasomotor reactivity, blood-flow rheology, inflammatory and oxidative stress markers, endothelial-adhesion proteins, baroreceptor and related neurohumoral functions, and platelet aggregation and other factors involved in blood coagulation and fibrinolysis. Exercise dose–response relationships also need to be determined.
4. Randomized trials are needed to better define the role of exercise therapy for safely improving functional capacity, reducing cardiovascular symptoms, and enhancing the quality of life among specific subgroups of CVD patients, particularly older, female, and ethnic minority patients. Further research also is needed to clarify better the role of exercise in patients with chronic stable angina, peripheral arterial disease, diabetes, impaired left ventricular function, heart transplantation, or an implanted cardioverter defibrillator.
5. The feasibility of definitive randomized multicenter clinical trials should be explored to assess the independent contribution of exercise training to the morbidity and mortality of patients after myocardial infarction or coronary artery revascularization procedures and of patients with stable angina pectoris or silent myocardial ischemia. These trials should include older, female, and ethnic minority patients. A multicenter randomized trial of comprehensive cardiac rehabilitation and secondary prevention for patients with CAD in which interventions with or without an exercise component are compared during a 3- to 5-year observational period is estimated to require 4000 to 4500 patients to have the power to demonstrate a statistically significant 20% reduction in cardiac mortality in the exercise group.[99] Secondary end points should include nonfatal cardiovascular events, requirements for revascularization procedures, and the rate of progression or regression of disease as assessed by quantitative coronary arteriography, carotid artery ultrasound, or developing technologies such as coronary intravascular ultrasound, multislice computed tomography, and MRI.[100] The projected required sample size is comparable to that of several major multicenter randomized placebo-controlled trials that involve the use of statins in patients with CAD, in which a 20% to 30% reduction in many of the above-referenced primary and secondary end points was demonstrated.[99–103]
6. The proven salutary impact of comprehensive lifestyle modification often has been overlooked and underemphasized as a first-line approach to secondary prevention. Additional studies are needed to clarify the independent and additive benefits of lifestyle modification (ie, beyond coronary revascularization and effective pharmacotherapies) individually or in combination with other interventions in preventing recurrent cardiovascular events.[104]
7. Research should be geared toward evaluating the use of cardiac rehabilitation programs as centers for intensive lifestyle management for weight loss, physical activity, nutrition, and psychosocial support for people with additional chronic medical conditions, such as type 2 diabetes mellitus, the metabolic syndrome, and other insulin-resistant states. Preventing these conditions from following their natural course into acute and chronic vascular disease would be lifesaving and economically beneficial.

**Disclosures**

| Writing Group Member Name | Research Grant | Speakers Bureau/Honoraria | Stock Ownership | Consultant/Advisory Board | Other |
|---|---|---|---|---|---|
| Dr Arthur S. Leon | None | None | None | None | None |
| Dr Barry A. Franklin | None | Merck, Pfizer, Bayer | None | None | None |
| Dr Fernando Costa | None | None | None | None | None |
| Dr Gary J. Balady | None | None | None | None | None |
| Dr Kathy A. Berra | None | None | None | None | None |
| Dr Kerry J. Stewart | None | None | None | None | None |
| Dr Paul D. Thompson | Otsuka, Merck, Pfizer, AstraZeneca, Bristol-Myers Squibb, Schering-Plough | Merck, Pfizer, Schering-Plough, AstraZeneca, Bristol-Myers Squibb, Reliant | Pfizer, Schering-Plough | Merck, Pfizer, AstraZeneca, Schering-Plough | None |
| Dr Mark A. Williams | None | None | None | None | None |
| Dr Michael S. Lauer | None | None | None | None | None |

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group were required to complete and submit.

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