Exercise and the Heart: Risks, Benefits, and Recommendations for Providing Exercise Prescriptions

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Considerable research from the Ochsner Heart and Vascular Institute has focused on the effects of exercise training in patients with coronary heart disease. In this review, the authors discuss the risks and benefits of exercise training in general patients, as well as those with known vascular disease, and provide suggestions for exercise prescriptions for these patients, including modes of exercise and intensity, duration, and frequency of exercise sessions.

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In 1975, Bassler said that marathon runners are immune to coronary heart disease (CHD) as long as they maintain fitness, train at distances over 6 miles, and do not smoke (1). Considerable attention during the past 2 decades has been focused on the risks and benefits of exercise training in people with and without established heart disease. Much discussion on exercise and the heart has focused on whether this relationship is good, benign, or evil (2). Even now, considerable controversy exists about the risks and benefits of vigorous exercise training. Dramatic examples of the sudden deaths of well-known, competitive, and highly trained athletes (e.g., Jim Fixx) clearly contradict Bassler's statement and often dominate the lay press, prompting questions from physicians and patients.

Types of Exercise

Exercise can be broadly categorized in four ways: dynamic (isotonic) or static (isometric), and, within each of these categories, dependent on either aerobic or anaerobic metabolism. Dynamic exercise involves repetition of low-resistance motion and performance of external work; frequent performance increases endurance. Examples include running, walking, swimming, cycling, cross-country skiing, aerobic dancing, and elliptical training. Static exercise involves sustained contraction of skeletal muscles against fixed resistance and does not involve movement of the joints or axial skeleton; no external work is performed, and regular performance of static exercise does not generally increase endurance. Classic examples include hand grip, leg extension, and weight lifting, and the movements in many competitive sports and daily activities involve isometric exercise.

Although dynamic exercise typically relies on aerobic metabolism and isometric exercise on anaerobic metabolism, either form of exercise can be predominantly aerobic or anaerobic, depending on the rate of energy expenditure required for the activity. For example, a slow run is predominantly aerobic for most people in terms of energy expenditure, whereas a very fast sprint (a dynamic form of exercise) is a highly anaerobic activity from a metabolic standpoint. In general, if exercise can be sustained for more than 1-2 minutes, the primary energy source is aerobic metabolism.

With dynamic exercise, systolic blood pressure rises markedly, but diastolic pressure usually declines, producing only a modest increase in mean arterial pressure. For this reason, dynamic exercise can be described as "volume work." In contrast, both systolic and diastolic pressure markedly rise with isometric exercise in order to maintain blood flow to actively contracting skeletal muscles, thus producing a marked increase in both heart rate and mean arterial pressure. These increases are proportional to the amount of skeletal muscle that is contracting (for example, hand grip requires less increase than leg extension, which requires less than heavy weight lifting).

Therefore, at any given level of oxygen uptake, vigorous isometric exercise raises heart rate, raises systemic vascular resistance, and lowers stroke volume and cardiac output more than dynamic exercise does. For this reason, vigorous isometric activity is considered contraindicated for cardiac patients who may have an even more greatly altered response (e.g., exaggerated increase in systemic vascular resistance and left ventricular end-diastolic pressure, with a marked decrease in stroke volume, cardiac output, and ejection fraction). Despite these factors, some isometric activity and strengthening exercises are regularly used in most cardiac rehabilitation and exercise training programs as we discuss below. This is because many daily activities involve isometrics and because regular performance of light isometric exercise may decrease heart rate, systolic pressure, and oxygen consumption at submaximal workloads and improve quality of life in cardiac patients, particularly those with left ventricular dysfunction.

Athletic Heart Syndrome

Regular exercise training has effects on cardiac rhythm as well as cardiac structure and function. Compared with controls, long distance runners clearly have slower sinus rates, more sinus bradycardia, and often have sinus pauses (3-5). They also have a considerably higher incidence of first and second degree atrioventricular block (Type I or Wenckebach block), more premature atrial beats, and slightly more premature ventricular beats.

A number of studies have utilized serial echocardiography to measure the effects of exercise training on cardiac structure and function. Ehsani and colleagues (6) demonstrated that left ventricular mass increased by nearly 30% only 2 weeks after sedentary persons began a vigorous swimming program, and left ventricular mass declined by nearly 30% in 2 weeks when well-trained endurance runners stopped running. DeMaria and colleagues (7) demonstrated that left ventricular diastolic diameter increased by about 10% and left ventricular mass increased by about 15% in sedentary persons who began a run/walk program. Using pooled data from M-mode studies in over 2000 athletes, Maron (8) demonstrated that the average increase in left ventricular end-diastolic diameter in athletes was 10% compared with controls, which represents a 33% increase in volume. Septal thickness and posterior wall thickness increased by 15% and 20%, respectively. Right ventricular diastolic diameter increased by 25% and left ventricular mass increased by about 45%.

Cardiac structural adaptation varies with the type of exercise. Morganroth and associates (9) demonstrated that although left ventricular mass increases in swimmers, runners, and wrestlers, left ventricular diastolic diameter does not increase significantly in wrestlers (who do considerable isometric exercises). The increase in left ventricular mass in wrestlers is primarily manifested by an increase in left ventricular wall thickness. This study suggests that dynamic exercise requires "volume work," producing left ventricular hypertrophy (LVH) and chamber dilatation (eccentric LVH), whereas isometric exercise involves "pressure work," producing increased wall thickness without chamber dilatation (concentric LVH).

These types of LVH are also found in patients with heart disease (10-12). Eccentric LVH is frequently present in patients with obesity, and especially obesity-hypertension, and is also present in patients with regurgitant valvular heart disease and cardiomyopathies associated with significant systolic dysfunction. Concentric LVH is present in many patients with hypertrophic cardiomyopathy, or end-stage renal disease, most patients with long-standing essential hypertension, as well as those patients with significant aortic stenosis. Although initially LVH is considered a benign compensatory response to these disorders (remember from Laplace's equation that increased ventricular wall thickness leads to reduction in wall stress), clearly, as LVH progresses, it is not a benign process, but, rather, is associated with a number of adverse sequelae, including increased ventricular dysrhythmias, reduced coronary flow reserve, diastolic ventricular dysfunction, and an increased propensity for major cardiovascular events, cardiac mortality, and increased risk of sudden cardiac death(10-16). Although concentric LVH from static exercise (e.g., weight lifting) has been associated with diastolic ventricular dysfunction and possibly other adverse sequelae, studies have demonstrated that the mild eccentric hypertrophy from dynamic exercise (e.g., distance running) is not associated with adverse effects on myocardial function and this "physiologic hypertrophy" may in fact be associated with enhanced diastolic filling. (17)

When a significant degree of LVH is discovered in an athlete, the question of whether this is the result of training or of hypertrophic cardiomyopathy arises. Recent data demonstrate that marked LVH (wall thickness > 15 mm) is extraordinarily rare in trained athletes (18). Furthermore, LVH resulting from training quickly regresses with deconditioning. In borderline cases, careful screening of family members using echocardiography can help differentiate training-induced LVH from familial hypertrophic cardiomyopathy (8), and this differentiation is important since moderate and vigorous exertion is contraindicated in hypertrophic cardiomyopathy.

Sudden Death and Cardiac Events

In the early to mid 1970s, Bassler stated that marathon running may confer total protection against significant CHD (1,2). Although some remarkable claims have been made regarding the protective effects of exercise, numerous examples of sudden death in athletes trained for endurance (including marathon runners) continue to cause concern among lay persons and physicians regarding the safety of vigorous exercise.

In fact, the legendary Pheidippides, who collapsed and died after running from Marathon to Athens, probably represents the first known case of sudden death associated with long-distance running. Noakes (19) reviewed autopsy findings in 36 cases of sudden death among marathoners: 27 (75%) of the runners had significant CHD (two also had hypertrophic cardiomyopathy). Only one had a

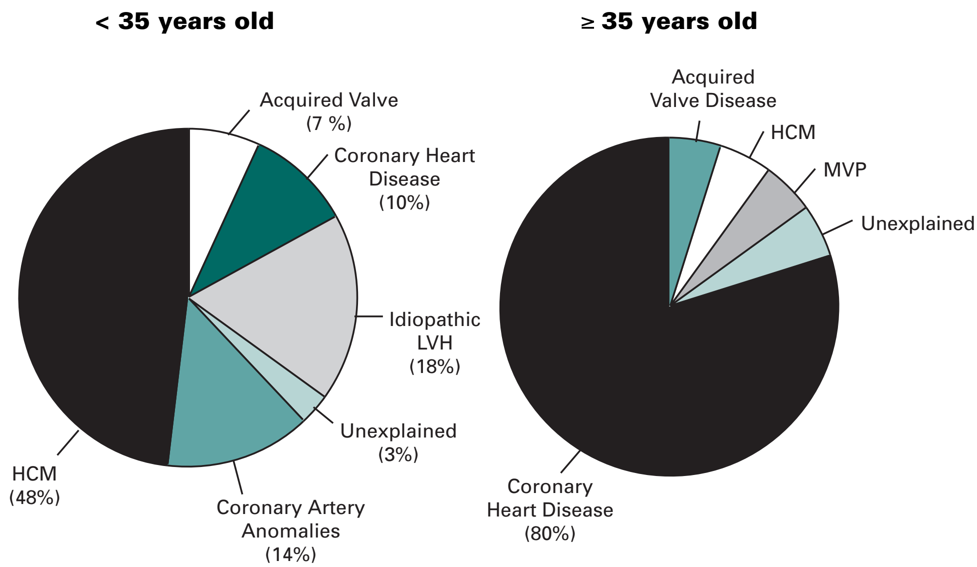

Figure. Causes of death in competitive athletes. Estimated prevalences of diseases responsible for death are compared in young (<35 years old) and older (≥ 35 years old) athletes. (Reproduced by permission of Elsevier Science from Maron et al, Journal of the American College of Cardiology 1986; 7:204-214.)

"normal" heart and brain at autopsy. Among those who had significant CHD, nearly 75% had high-risk blood lipid levels, 71% had warning symptoms, and 64% had a family history of premature CHD. Although persons with CHD are certainly at risk for morbid cardiac events during extreme exertion, the fact that only one or two cases of both sudden death and acute myocardial infarction (MI) occur among over 30,000 marathon runners annually indicates the relative safety of even extremely vigorous forms of exertion.

Maron and colleagues (20) have reviewed the causes of sudden death during exercise in relation to age (Figure 1). In persons under age 35, hypertrophic cardiomyopathies are by far the leading cause of sudden death, followed by idiopathic LVH, coronary artery anomalies, CHD, and aortic rupture. Among persons over age 35 years, however, nearly 80% of sudden deaths during exercise result from CHD.

A few major medical articles, including major reports in the New England Journal of Medicine, which received substantial media attention, demonstrate that vigorous exertion can precipitate myocardial infarction (MI) and sudden cardiac death (21, 22). In fact, 6%-17% of all sudden deaths occur in association with exertion. Although clearly there is substantial evidence that regular exercise is associated with marked reductions in cardiac events and mortality (discussed below), there is also evidence to suggest that vigorous exertion simultaneously triggers and protects against cardiac events and sudden death. Unfortunately, this triggering of events has received widespread attention and often overrides the marked protective effects of regular exercise.

Although only a minority of cardiac events is triggered by heavy physical exertion, the relative risk of these events is increased nearly 80-fold when a sedentary individual performs vigorous physical exertion defined as 6 METs or more (21, 22). Classic examples of this include a normally sedentary individual shoveling snow or performing yard work in hot temperatures. However, regular physical exertion significantly attenuates these risks, decreasing the risk of MI with vigorous exertion to only 2-fold and sudden death with vigorous exertion to only 10-fold. Likewise, another potential trigger of MI is sexual activity, with the risk being increased by about 2.5-fold, whereas regular physical exertion seems to completely abolish this slightly increased risk associated with sexual activity (23).

In patients who have survived a major cardiac event, the risks of vigorous exertion are particularly concerning, but, even in these patients, vigorous exertion seems relatively safe. Fifteen years ago, Van Camp and Peterson (24) pooled data from 167 randomly selected cardiac rehabilitation and exercise programs covering 51,000 patients and over 2 million exercise hours. Among these patients, there were 21 cardiac arrests (3 fatal), and 8 non-fatal MIs, which is equivalent to 1 cardiac arrest per 112,000 exercise hours, one acute MI per 300,000 exercise hours, and 1 fatality per 800,000 exercise hours. While these events are serious, they are also extremely rare.

Nearly 20 years ago, Hossock and Hartwig (25) demonstrated that predictors of cardiac events during exercise training in cardiac patients included above-average exercise capacity, poor compliance with target heart-rate recommendations (discussed below), marked ST-segment depression with exercise, and the presence of high-grade disease in the left anterior descending coronary artery. In 2001, patients with these latter two conditions would usually undergo mechanical revascularization procedures before cardiac rehabilitation and exercise training, which would further decrease their risk.

Various agencies have met to consider the safety of cardiac rehabilitation and exercise training and to consider which patients absolutely require electrocardiographic (ECG) monitoring with its accompanying expense. We believe that most patients benefit, at least initially, from ECG monitoring. The Task Force of the American Heart Association and the American College of Cardiology has stated that monitoring during exercise is indicated only in patients at moderate to high risk (e.g., those with significant left ventricular dysfunction, resting or exercise-induced complex ventricular dysrhythmias, decreases in systolic blood pressure with exercise, or mechanical or electrical complications after MI, as well as survivors of sudden death), and in those who are unable to accurately monitor their heart rate during exercise (26). However, all cardiac patients should have a graded assessment and receive carefully prepared prescriptions to maximize the safety of their exercise program.

Benefits of Regular Exercise

> Exercise and temperance can preserve something of our strength in old age.
> *Cicero*

> And is not bodily habitus spoiled by rest and illness, but preserved for a long time by motion and exercise?
> *Socrates*

> Those who think they have no time for bodily exercise will sooner or later have to find time for illness
> *Earl of Derby*

> Healthy exercise is valuable not only for the maintenance of good physiologic function of the body, but also mental clarity, and a feeling of good health.
> *Paul Dudley White*

As indicated in these classic quotations, the potential benefits of regular exercise training have been noted for centuries. Clearly, numerous studies have concluded that regular exercise is associated with marked reductions in the long-term risks of major cardiac events, cardiac mortality, and all-cause mortality (27-33). Unfortunately, this information does not often receive the same degree of publicity as the risks of exercise. Even in regular exercisers, a vigorous bout of exercise may increase the risk of a cardiac event by 2- or 3-fold for about 30-60 minutes following the vigorous exertion. However, major cardiac events are reduced by 30% to 50% for the remaining 23-23.5 hours, making the net effect of regular exercise markedly beneficial. The numerous potential benefits of regular exercise are listed in Table 1 (2).

In addition, numerous studies, particularly data from Blair and colleagues who have studied over 13,000 men and women at the Cooper Heart Clinic (34-36) indicate that objective measures of physical fitness correlate strongly with total mortality, as well as with deaths from cardiovascular causes and cancer (34-39). In fact, even in obese individuals or in people with several adverse CHD risk factors, high levels of physical fitness provide considerable protection against cardiovascular events. In addition, improvements in physical fitness over time have correlated with reductions in cardiovascular and total mortality (35, 37).

We have focused on the benefits of Phase II cardiopulmonary rehabilitation and exercise training programs for patients with known disease, which have demonstrated marked improvements in risk factors, improvements in quality of life, and 20%-25% reductions in major cardiac morbidity and mortality for our CHD patients (Table 2) (40). Substantial research from the Ochsner Heart and Vascular Institute has focused on subgroups proven to benefit from formal exercise training programs (Table 3). Although exercise training was initially felt to be dangerous for cardiac patients with significant left ventricular dysfunction, recent evidence has even focused on the marked benefits of exercise training in patients with severe congestive heart failure (40-42).

Exercise Prescription

A major part of our cardiac rehabilitation program involves providing an appropriate exercise prescription. In addition, questions about exercise prescription are often an important part of patients' visits to primary care physicians as well as specialists in cardiovascular diseases. Four major elements should be considered for the exercise program: mode, intensity, frequency, and duration.

Table 1. Potential beneficial effects of regular exercise.

Benefits related to risk factors for coronary artery disease
Eases smoking cessation
Improves glucose metabolism
Raises serum high-density lipoprotein cholesterol level
Reduces arterial blood pressure
Reduces body weight
Reduces serum triglyceride and possibly low-density lipoprotein cholesterol level
Reduces stress
Hematologic benefits
Decreases hematorit and blood viscosity
Expands blood plasma volume
Increases red blood cell deformability
Increases fibrinolytic activity
Other benefits
Decreases atherosclerosis (proven in animals)
Decreases morbidity and mortality
Increases coronary collateral circulation (in many species)
Increases coronary flow reserve
Increases myocardial capillary density (in most species)
Increases tolerance of ischemia
Increases ventricular fibrillation threshold
Possibly increases epicardial coronary artery size

Table 2. Benefits of Cardiopulmonary Rehabilitation and Exercise Training Programs. Adapted from Lavie et al. Cardiopulmonary Rehabilitation, Exercise Training, and Preventive Cardiology: An Overview of a Decade of Research at the Ochsner Heart and Vascular Institute. The Ochsner Journal 1999;1:159-169.

Improved Exercise Capacity and Peak VO_2
Improved Work Efficiency
Improved Lipids
a. Increased HDL Cholesterol
b. Reduced Triglycerides
c. Possibly Reduced LDL Cholesterol
Improved Obesity Indices
Improved Behavioral Characteristics (especially Depression and Hostility)
Improved Quality of Life
Decreased Hospitalization Costs
Reduced Major Cardiac Morbidity and Mortality

VO_2 = oxygen consumption; HDL = high density lipoprotein; LDL = low density lipoprotein

Table 3: Subgroups Proven to Benefit from Cardiopulmonary Programs at Ochsner Heart and Vascular Institute. Adapted from Lavie et al. Cardiopulmonary Rehabilitation, Exercise Training, and Preventive Cardiology: An Overview of a Decade of Research at the Ochsner Heart and Vascular Institute. The Ochsner Journal 1999;1:159-169.

Elderly
Women
Obese
Patients with High or Low Exercise Capacity
Diabetics
Patients with Psychological Distress
a. Depression
b. Hostility
Patients with Dyslipidemia
a. Low HDL Cholesterol
b. “Isolated” Low HDL Cholesterol
c. Hypertriglyceridemia
Patients with Other Coronary Risk Factors
a. High Homocysteine
b. High Blood Viscosity
Congestive Heart Failure
Chronic Obstructive Lung Disease

HDL = high density lipoprotein

Mode

The usual mode of exercise recommended is dynamic or aerobic exercise, including walking, running, cycling, swimming, aerobic dancing, cross-country skiing, and elliptical machines. Although isometric exercise does not improve cardiac performance, we usually recommend light isometric exercises to most people as well as to our cardiac patients. Since so much of daily activity involves isometric exercises (e.g., carrying groceries or a child, taking the garbage out, manual labor, etc.), light isometrics such as hand grips, and light weight lifting (e.g., frequent repetition of low weight loads) has proven to be safe and improves the quality of life of our patients. In addition, since muscle mass progressively declines with aging (probably more so in women), some isometric exercise has other potential advantages for our middle-aged and older patients.

Intensity

In order to increase aerobic capacity, it is best to exercise to 50%-75% of one’s maximal oxygen capacity (usually 65%-85% of maximal heart rate). This generally corresponds to 60%-70% of the heart rate reserve (maximal heart rate minus resting heart rate) plus the resting heart rate. For example, if the resting heart rate is 60 and the peak heart rate is 160, the target heart rate during exercise would be approximately 120-130 beats per minute. In our cardiac patients, we generally have this information from exercise stress tests, and in our cardiac rehabilitation patients, we usually precisely measure exercise capacity with cardiopulmonary stress tests that allow us to precisely determine anaerobic thresholds (or actually ventilatory thresholds), and we provide exercise prescriptions with target heart rates close to the anaerobic threshold. In addition, if there is any evidence of either symptomatic or silent ischemia, target heart rates 10-15 beats per minutes below the level of ischemia should be chosen. We teach our patients to monitor their heart rates, and when they prove that their heart rate corresponds to a particular level of perceived exertion (Table 4), this perceived exertion scale can be utilized to more easily monitor exercise intensity.

In the office setting, however, many primary care physicians see patients without the luxury of exercise stress test results. Although we feel that exercise stress testing is reasonable for sedentary middle-aged and older patients with several risk factors, especially prior to starting an exercise program, the American Heart Association/ American College of Cardiology state that there are no absolute indications for exercise stress testing in asymptomatic individuals (43). Without stress testing data, intensity of exercise can be prescribed using a 10-point scale: 0 represents complete rest and 10 represents complete exhaustion. Using this scale, most exercise should be in the 5 to 7 intensity range. Another way to simplify this is to explain that one should be exercising at a low enough intensity to allow one to speak while exercising, but the exercise intensity should be high enough so that one would rather not speak for most of the exercise session. Recent studies, however, have indicated that even light to moderate activity may provide substantial protection against CHD (44, 45). Regular walking or heavy gardening may be sufficient to achieve these benefits.

Frequency

Generally, we recommend 3-5 exercise sessions per week. However, since overweightness and obesity are increasing at alarming rates in our adult population, particularly in our cardiac patients, often patients may benefit from 6-7 exercise sessions per week. Recent evidence suggests that frequency may be as, or more, important than exercise intensity for achieving protection against CHD (46).

Duration

In order to improve aerobic capacity, exercise sessions of 20-30 minutes are generally required. However, as mentioned above, for our overweight and obese patients, 40-60 minutes of exercise may be ideal for achieving and maintaining a reasonable body weight. Recent evidence suggests that accumulations of short sessions of physical activity may provide as much protection as one longer, continuous session of exercise (44), thus lending support to the recent recommendations from the Centers for Disease Control and Prevention and the American College of Sports Medicine stating: "Every US adult should accumulate 30 minutes or more of moderate-intensity of physical activity on most, preferably all, days of the week" (47). This recommendation was devised to promote physical activity among those who do not enjoy or are unable to participate in vigorous activity.

Table 4. Borg scale of perceived exertion.

Perceived Level of Exertion	Rating
	6
Very, very light	7
	8
Very light	9
	10
Fairly light	11
	12
Somewhat light	13
	14
Hard	15
	16
Very hard	17
	18
Very, very hard	19
	20

Conclusion

The risks and benefits of regular exercise training have been studied extensively. In general, regular exercise has proven to be extraordinarily safe and the theoretical and proven benefits appear to greatly outweigh the risks for most people, including those with CHD, those with severe left ventricular dysfunction, and the elderly. This article provides information that may be helpful for providing exercise prescriptions to patients with and without established heart disease.

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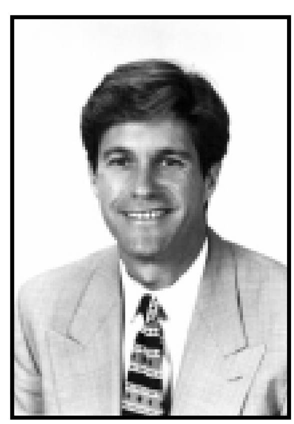

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