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Exercise considerations in coronary artery disease, peripheral vascular disease, and diabetes mellitus

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Physical inactivity is a risk factor for cardiovascular disease [1]. Regular aerobic and resistance training increase exercise capacity and play a role both in the primary and secondary prevention of cardiovascular disease [2–5].

Patients with coronary artery disease, peripheral vascular disease, and diabetes mellitus must be considered individually when prescribing exercise, because their clinical status can vary greatly. In addition, most of these patients have multiple comorbid disorders, such as renal, neurologic, or retinal disease, that may affect their ability to exercise safely.

Before beginning an exercise routine, the benefits and risks of a physical activity program need to be discussed. A preparticipation medical evaluation is required. An exercise prescription should be tailored to each person's unique set of circumstances and reflect an effort to maximize the anticipated benefits while minimizing the risks. Special precautions in select patients who suffer from secondary comorbidities must be taken. Decisions regarding the degree of supervision and monitoring during exercise need to be clearly defined. Finally, physicians need to increase their awareness of common compliance barriers, and be skilled at behavioral strategies to maintain fitness motivation in this population.

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Benefits

Risk factor modification

Dyslipidemia

Aerobic exercise training favorably alters lipid metabolism. Modest decreases in total cholesterol, low-density lipoprotein (LDL) cholesterol, and triglycerides, along with increases in high-density lipoprotein (HDL) cholesterol, have been seen with training [6]. Modifying these lipoproteins has proven to be important in the secondary prevention of cardiovascular disease [7].

Hypertension

Aerobic exercise training can contribute via weight reduction to control hypertension [8]. Effective control of elevated blood pressure in the post-myocardial infarction population reduces cardiovascular mortality by 20% [9].

Diabetes mellitus

Acute bouts of mild- to moderate-intensity exercise favorably affect blood glucose in type II diabetics, and this is sustained into the postexercise period [10]. The effect is attributed to an attenuation of hepatic glucose production, along with increases in peripheral insulin sensitivity and muscle glucose utilization [11–13].

Obesity

Obesity is associated with hypertension, glucose intolerance, and unfavorable lipid profiles [14]. Therefore, its presence is an independent risk factor for the development of coronary artery disease [15]. A well-designed, regular exercise program helps contribute to weight loss, and thus can reduce subsequent cardiovascular morbidity and mortality [16].

Smoking

Continued cigarette smoking after a myocardial infarction increases mortality rates [17]. A formal exercise rehabilitation program may promote smoking cessation and cessation maintenance in patients with cardiovascular disease [18].

Functional capacity

In patients with coronary artery disease, aerobic exercise training allows for a higher degree of physical work before reaching the level of oxygen requirement that results in myocardial ischemia [19]. As a result, the onset of symptoms at any given workload or activity is delayed, and some patients actually have a disappearance of anginal pain following training [20]. Exercise training programs can also have a clinically important impact on functional capacity in patients who suffer from peripheral vascular disease [21,22]. The physiologic mechanisms that may be responsible for the observed improvement

in walking ability are not clear; however, there are numerous proposed mechanisms. These mechanisms include adaptations in peripheral blood flow or distribution of flow, changes in muscle metabolism, and changes in gait and pain threshold [23].

Endothelial dysfunction

Endothelial injury and vessel denudation results in dysfunction (paradoxical vasoconstriction in response to known vasodilating agents) that appears to be the initiating event in the development of atherosclerosis [24]. A variety of interventions, including aerobic exercise training, have been shown to improve endothelial dysfunction [25,26]. Improving endothelial dysfunction is currently hypothesized to enhance coronary blood flow in patients with or at risk for cardiovascular disease, and thus to reduce the risk for atherosclerosis progression and recurrent events.

Cardiovascular mortality

Exercise training programs have been documented to reduce subsequent fatal cardiovascular events and total mortality in patients with known pre-existing cardiovascular disease [27,28].

Risks

The risk of a major cardiovascular event during exercise increases tenfold for those with underlying cardiovascular disease [29]. This is more evident among patients with cardiovascular disease who are habitually sedentary and who are embarking on a new exercise program. Additional potential health hazards of exercise that are more commonly related to people with diabetes also exist. Potential adverse effects of exercise in patients with diabetes are listed below [30]:

Cardiovascular
- Cardiac dysfunction and arrythmias due to ischemic heart disease (often silent)
- Exercise-induced hypertension or postexercise orthostatic hypotension

Microvascular
- Retinal hemorrhage
- Increased proteinuria or acceleration of other microvascular lesions

Metabolic
- Worsening of hyperglycemia and ketosis
- Hypoglycemia in patients on insulin or sulfonylurea therapy

Musculoskeletal and traumatic
- Foot ulcers (especially in the presence of neuropathy)
- Accelerated degenerative joint disease or other orthopedic injuries

Preparticipation medical evaluation

History, physical examination, and laboratory testing

Before beginning an exercise program, patients with coronary artery disease, peripheral vascular disease, or diabetes mellitus require a complete medical history and physical examination, along with associated laboratory testing when indicated. This evaluation is directed at identifying the patient's cardiovascular, metabolic, orthopedic, and general medical status. The presence of absolute and relative contraindications to aerobic exercise and resistance training can be determined by this evaluation [31] (Table 1). Functional status measures can be assessed with validated questionnaires that are reliable, sensitive to change, and feasible [22]. Once a baseline functional status has been established, the benefit of an intervention can then be measured.

Vascular and exercise stress testing

Noninvasive studies can be used to establish the presence of ischemia in patients suspected to have peripheral vascular disease [32]. Signs and symptoms of peripheral arterial disease are listed below:

Intermittent claudication
Cold feet
Nocturnal or rest pain (relieved with dependency)
Absent or diminished pulses
Dependent rubor
Atrophy of subcutaneous fatty tissue
Shiny appearing skin
Loss of extremity hair
Thickened nails
Gangrene

Measurements of resting ankle pressure can be noted as a ratio relative to the brachial pressure (ankle/brachial index or ABI). This ratio corrects for variations in systolic pressure between individuals and is used to identify and quantify the degree of peripheral vascular disease [33].

Table 1
Absolute and relative contraindications to exercise training

Absolute	Relative
Recent EKG change or myocardial infarction	Tachyarrhythmias
Unstable angina	Bradyarrhythmias
Serious cardiac arrhythmias	Moderate valvular disease
Acute pericarditis	Electrolyte abnormality
Endocarditis	HCM
Severe aortic stenosis	Left main coronary disease
Severe left ventricular dysfunction	Significant hypertension
Acute pulmonary embolus/infarction	Pulmonary hypertension
Acute/serious noncardiac disorder	Mild noncardiac disorder
Severe physical handicap/disability	Psychiatric disease

Abbreviations: EKG = electrocardiogram; HCM = hypertrophic cardiomyopathy.
Adapted from Fletcher G, Froelicher V, Hartley L, et al. Exercise standards: a statement for health professionals from the American Heart Association. Circulation 1990;82:2286–322.

The American College of Sports Medicine recommends exercise stress testing as a noninvasive cardiac and functional evaluation for all patients with a history of known or suspected cardiovascular disease before beginning an exercise program. Listed below are indications for cardiac stress testing[34]:

Patients with an intermediate probability of angiographically significant coronary artery disease (CAD)
Men >45 years and women >55 years who plan to exercise at >60% VO2max
Known coronary artery disease or cardiac symptoms to assess severity and prognosis
Post-myocardial infarction for prognostic assessment, activity prescription, and evaluation of medical therapy
Asymptomatic persons with two or more coronary artery disease risk factors (hypertension, smoking, hypercholesterolemia, obesity, sedentary lifestyle, family history of early coronary artery disease)
Those involved in occupations in which cardiovascular events may affect public safety
To determine functional capacity in persons with known or major signs and symptoms of pulmonary or metabolic disease

A graded exercise stress test should also be performed in any diabetic patient about to begin a moderate- to high-intensity ($\geq 60\%$ VO_2max) exercise program, or if he is determined to be at high risk for underlying cardiovascular disease according to the criteria below[35]:

Age >35 years
Type II diabetes of >10 years duration
Type I diabetes of >15 years duration
Presence of any additional risk factors for coronary artery disease
Presence of microvascular disease (retinopathy or nephropathy)

Presence of peripheral vascular disease
Presence of autonomic neuropathy

Exercise prescription

Mode

Activities that involve large muscle groups, that can be maintained for a prolonged period, and that are rhythmic and aerobic in manner are appropriate for cardiovascular endurance conditioning [36,37]. Provided that no contraindications exist, the types of aerobic exercises performed are a matter of personal preference. In patients with secondary complications of their disease such as a diabetic foot, however, preferred exercises include swimming, bicycling, and rowing as opposed to step exercises, prolonged walking, or jogging [32]. In patients with intermittent claudication associated with peripheral vascular disease, weight-bearing activities improve functional capacity [21], but non-weight bearing activities may allow for a longer duration and higher intensity of exercise. Furthermore, resistance training can also be an integral component of an activity program for select patients [38,39]. The health benefits of resistance training include improvements in muscle strength and endurance, which translate into enhanced functional capacity and ability to carry out activities of daily living. In addition, the increased weight bearing with resistance exercise is considered beneficial in improving bone density and combating the effects of osteoporosis. It should be noted that maximum strength testing in many older adults is not recommended, and that submaximal resistance testing protocols should be performed for estimating maximum strength when appropriate.

Frequency

An exercise program should be performed on at least 3 nonconsecutive days each week. Progression to 5 days per week is often needed to achieve the desired weekly energy expenditure that promotes weight loss [34,36,40]. It is important to recognize, however, that more frequent exercise sessions may result in a higher incidence of musculoskeletal injuries and problems with compliance unless various and enjoyable cross-training activities are performed. Consequently, there is no contraindication to daily exercise, especially for diabetics on insulin who experience difficulty in balancing their insulin and caloric needs.

Duration

Twenty to 60 minutes of cardiovascular exercise performed either continuously or through interval training is recommended [40]. Ten minutes of warm-up and cool-down periods should precede and follow exercise [36]. The precise duration of each exercise session is inversely related to the intensity at which the exercise is being performed. Longer exercise sessions are likely to result in a higher incidence

of musculoskeletal injuries and problems with compliance. Therefore, those who would like to exercise for longer durations should vary their exercise mode and perform less intense activities such as golf or walking.

Intensity

The degree of supervision available and the patient's level of risk directly affects the recommended intensity of exercise prescribed. Suggested exercise intensity parameters include: (1) 40% to 85%of maximal functional capacity (VO_2max), which correlates with 40% to 85% of maximal heart rate reserve (HRRmax); (2) 50% to 90% of maximal heart rate (HRmax); or (3) a moderate intensity level (12–13) on ratings of perceived exertion (RPE) [36]. Exercise at more vigorous intensities has been shown to increase the risk tenfold for a major cardiovascular event in patients with underlying cardiovascular disease [29]. It must also be kept in mind that using heart rate as the only means to monitor intensity is unsuitable for those on medications with negative chronotropic effects or for diabetics who have associated autonomic neuropathy. In these instances, the exercise intensity should always be kept below a level that provokes myocardial ischemia, significant arrhythmias, or symptoms of exercise intolerance, as judged clinically or by exercise testing.

Rate of progression

Baseline cardiorespiratory fitness, age, weight, health status, personal preferences, and individual goals are all factors that need to be considered when determining the rate of progression of an exercise program. Moreover, initial changes in progression should focus on a slow, gradual increase in the frequency and duration of physical activity, rather than intensity. The rule of tens can be applied by advancing activity no more than 10% each week until exercise and fitness goals are achieved.

Special precautions

Patients with coronary artery disease, peripheral vascular disease, and diabetes mellitus often suffer from comorbidities secondary to their cardiovascular and metabolic derangements. In these patients, additional special precautions need to be taken.

Renal disease

Light to moderate exercise ($\leq 60\%$ VO_2max) should only be performed in patients with microalbuminuria and overt renal disease. Intense and erratic exercise may have deleterious effects on vascular and renal disease, although such adverse effects have not yet been documented in clinical trials [41]. In more

advanced cases of nephropathy requiring dialysis, exercise capacity may be limited by autonomic neuropathy, anemia, and myopathy [42].

Retinopathy

Because it is often seen in diabetics, it is advisable to determine accurately the level of retinopathy before suggesting an exercise program. Low-impact, cardiovascular conditioning is the most vigorous acceptable activity for patients with proliferative diabetic retinopathy. Activities that dramatically elevate blood pressure, result in Valsalva maneuvers, or involve jarring are discouraged in moderate to very severe nonproliferative diabetic retinopathy [43].

Neuropathy

Neuropathic changes often occur in diabetics with peripheral vascular disease. The presence of somatic neuropathy increases susceptibility to ulcers, joint destruction, and limb loss; thus the preferred exercises in this population are non-weight bearing. Nevertheless, proper footwear and counseling to inspect feet daily and after exercise needs to be encouraged. In contrast, autonomic neuropathy can interfere with the ability to exercise safely for a variety of separate reasons, including: (1) impaired cutaneous blood flow and sweating; (2) gastroparesis with irregular fuel delivery; (3) failure of pupillary adaptation to darkness restricting night vision; and (4) cardiovascular instability [44]. These patients thus need to be closely monitored if involved in an exercise program, and counseled appropriately about necessary special precautions to avoid complications such as dehydration and heat-related illnesses.

Supervision and monitoring

The nature and degree of supervision and monitoring depends on the patient's risk for exercise complications, the level of control of his disease, and the intensity of exercise planned. Direct patient supervision and monitoring of heart rate, heart rhythm, and blood pressure should be performed when dealing with high-risk cardiovascular patients. Characteristics of patients at high risk requiring direct medical supervision and monitoring include [31]:

Severely depressed left ventricular function (ejection fraction $< 30\%$)
Complex ventricular arrhythmias uncontrolled at mild to moderate work intensities
Three-vessel or left-main coronary artery disease
Exercise test abnormalities not directly related to ischemia
Cardiomyopathy
Valvular heart disease

Survived ventricular fibrillation or sudden cardiac arrest
Coronary artery disease with poor clinical characteristics

In addition, all diabetics on insulin or under poor control require more intensive monitoring around exercise to prevent metabolic complications [45]. General guidelines to avoid exercise-induced metabolic derangements are listed below:

Hypoglycemia
- Measure blood glucose before, during, and after exercise
- Consume extra carbohydrates before unplanned exercise
- Consider decreasing insulin dose after unplanned exercise
- Decrease insulin dose before and after planned exercise
- Consider consuming an easily absorbable carbohydrate during exercise
- Consider an extra carbohydrate-rich snack after exercise

Hyperglycemia/ketosis
- Measure blood glucose before, during, and after exercise
- A glucose >300mg/dl is a relative contraindication to exercise
- A glucose >240mg/dl with urine ketones is a relative contraindication to exercise

Compliance Issues and behavioral strategies

A large percent of patients tend to discontinue an exercise training program within the first year. Common barriers to continued exercise participation include time constraints, facilities that are inconveniently located, lack of physician encouragement and monitoring, unrealistic expectations, and boredom with the current exercise program. Consequently, alternative activities that are moderate in intensity should be encouraged in select patients. Such activities can be just as beneficial when incorporated into one's lifestyle, and include using a push mower to cut the lawn, taking the stairs instead of an elevator, and walking from your car to the office rather than taking the shuttle. Frequent physician visits are recommended to monitor progress, provide encouragement and feedback, answer questions, and reward exercise training. Practical behavioral interventions can be taken to help establish and maintain fitness motivation in this patient population Strategies to improve compliance with an exercise program include: (1) ensuring reasonable expectations, (2) choosing enjoyable activities and exercises, (3) establishing convenient exercise time and location, (4) reinforcing behavior with the help of family members, friends, and health professionals, and (5) providing feedback with quantitative indices of progress [30].

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