Articles

Table of Contents
Circulation. 1997;96:345-354

(*Circulation.* 1997;96:345-354.)

Articles

ACC/AHA Guidelines for Exercise Testing: Executive Summary

A Report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing)

Committee Members
Raymond J. Gibbons, MD, FACC, Chair; Gary J. Balady, MD, FACC; John W. Beasley, MD; FAAFP; J. Timothy Bricker, MD, FACC; Wolf F. C. Duvernoy, MD, FACC; Victor F. Froelicher, MD, FACC; Daniel B. Mark, MD, MPH, FACC; Thomas H. Marwick, MD, FACC; Ben D. McCallister, MD, FACC; Paul Davis Thompson, MD, FACC; FACSM; William L. Winters, Jr, MD, FACC; ; Frank G. Yanowitz, MD, FACP
Task Force Members

Key Words: AHA Medical/Scientific Statements • coronary disease • tests • exercise

I. Introduction

The American College of Cardiology/American Heart Association Task Force on Practice Guidelines was formed to make recommendations regarding the appropriate use of testing in the diagnosis and treatment of patients with known or suspected cardiovascular disease. Exercise testing is widely available and relatively low in cost. For the purposes of these guidelines, exercise testing is a cardiovascular stress test using treadmill or bicycle exercise and electrocardiographic and blood pressure monitoring. Pharmacological stress testing and imaging modalities (radionuclide imaging, echocardiography) are beyond the scope of these guidelines.

These guidelines have been endorsed by the American College of Sports Medicine, the American Society of Echocardiography, and the American Society of Nuclear Cardiology.

This executive summary appears in the July 1, 1997, issue of *Circulation.* The guidelines in their entirety are published in the July 1997 issue of the *Journal of the American College of Cardiology.* Reprints of both the executive summary and the full text are available from both organizations.

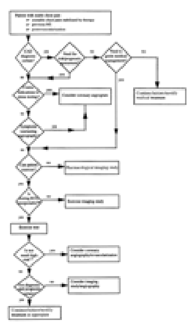
Exercise testing is a well-established procedure that has been in widespread clinical use for many decades. It is described in detail in previous publications of the AHA, to which interested readers are referred.

Although exercise testing is generally a safe procedure, both myocardial infarction and death have been reported and can be expected to occur at a rate of up to 1 per 2500 tests. Good clinical judgment should therefore be used in deciding which patients should undergo exercise testing. Absolute and relative contraindications to exercise testing are summarized in Table 1.

Table 1. Contraindications to Exercise Testing

View this table:
In this window
In a new window

The vast majority of treadmill exercise testing is performed in adults with symptoms of known or suspected ischemic heart disease. Special groups who are exceptions to this norm are discussed in detail in sections VI and VII. Sections II through IV illustrate the variety of patients and clinical decisions for which exercise testing is used. Although this document is not intended to be a guideline for the management of stable chest pain, the committee thought that it was important to provide an overall context for the use of exercise testing to facilitate use of these guidelines (Fig 1).



View larger version (23K):
In this window
In a new window

Figure 1. Clinical context for exercise testing for patients with suspected ischemic heart disease. *Electrocardiogram interpretable unless preexcitation, electronically paced rhythm, left bundle branch block, or resting ST-segment depression >1 mm. See text for discussion of digoxin use, left ventricular hypertrophy, and ST depression <1 mm. †For example, high-risk *if* Duke treadmill score predicts average annual cardiovascular mortality >3% (see Fig 2 for nomogram). MI indicates myocardial infarction; CAD, coronary artery disease; and ECG, electrocardiogram.

Patients who are candidates for exercise testing may have stable symptoms of chest pain, may be stabilized by medical therapy following symptoms of unstable chest pain, or may be post-myocardial infarction or postrevascularization patients. The clinician should first address whether the diagnosis of coronary artery disease (CAD) is certain, based on the patient's history, electrocardiogram (ECG), and symptoms of chest pain. If not, treadmill exercise testing may be useful.

When the diagnosis of CAD is certain, based on age, gender, description of chest pain, and history of prior myocardial infarction, there may be a clinical need for risk or prognostic assessment to reach a decision about possible coronary angiography or revascularization or to guide further medical management.

Post-myocardial infarction patients represent a common first presentation of ischemic heart disease. These patients are a subset of patients who may need risk or prognostic assessment.

The ACC/AHA classifications I, II, and III are used to summarize indications for exercise testing:

Class I: Conditions for which there is evidence and/or general agreement that a given procedure or treatment is useful and effective.

Class II: Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment.

IIa: Weight of evidence/opinion is in favor of usefulness/efficacy.

IIb: Usefulness/efficacy is less well established by evidence/opinion.

Class III: Conditions for which there is evidence and/or general agreement that the procedure/treatment is not useful/effective and in some cases may be harmful.

II. Exercise Testing in Diagnosis of Obstructive Coronary Artery Disease

Class I
1. Adult patients (including those with complete right bundle branch block or less than 1 mm of resting ST depression) with an intermediate pretest probability of CAD (see Table 2), based on gender, age, and symptoms (specific exceptions are noted under Classes II and III below).

Table 2. Pretest Probability of Coronary Artery Disease by Age, Gender, and Symptoms[1]

View this table:
In this window
In a new window

Class IIa
1. Patients with vasospastic angina.

Class IIb
1. Patients with a high pretest probability of CAD by age, symptoms, and gender.

2. Patients with a low pretest probability of CAD by age, symptoms, and gender.

3. Patients with less than 1 mm of baseline ST depression and taking digoxin.

4. Patients with electrocardiographic criteria for left ventricular hypertrophy (LVH) and less than 1 mm of baseline ST depression.

Class III
1. Patients with the following baseline ECG abnormalities: ▪ Preexcitation (Wolff-Parkinson-White) syndrome ▪ Electronically paced ventricular rhythm ▪ Greater than 1 mm of resting ST depression ▪ Complete left bundle branch block

2. Patients with a documented myocardial infarction or prior coronary angiography demonstrating significant disease have an established diagnosis of CAD; however, ischemia and risk can be determined by testing (see sections III and IV).

The exercise test may be used for diagnosis of significant obstructive CAD if the diagnosis is uncertain. Although other clinical findings, such as dyspnea on exertion, resting ECG abnormalities, or multiple risk factors for atherosclerosis may suggest the possibility of CAD, the most important clinical finding is a history of chest discomfort or pain. Myocardial ischemia is the most important cause of chest discomfort or pain and is most commonly a consequence of underlying CAD. The clinician's estimation of the pretest probability of CAD is based primarily on the patient's history. The most predictive parameters are description of chest pain, gender, and age. Table 2 summarizes the pretest probability of CAD based on these parameters.

Diagnostic testing is most valuable in patients with an intermediate pretest probability. Exercise testing for the diagnosis of CAD is most commonly expressed by sensitivity and specificity. Results of correlative studies have been divided over the use of 50% or 70% luminal diameter occlusion.

Meta-analysis of the studies has not demonstrated that the criteria affect the test characteristics. Meta-analysis of 58 consecutively published reports involving 11

691 patients without prior myocardial infarction who underwent coronary angiography and exercise testing revealed a wide variability in sensitivity and specificity. Mean sensitivity was 67%; mean specificity was 72%. In the three studies where work-up bias was avoided by having the patients agree to undergo both procedures, the approximate sensitivity and specificity of 1 mm of horizontal or downsloping ST depression for diagnosis of CAD were 50% and 90%, respectively. It is apparent that the true diagnostic value of the exercise ECG lies in its relatively high specificity.

The wide variability in test performance apparent from this meta-analysis shows the importance of using proper methods for testing and analysis. Upsloping ST depression should be considered borderline or negative. Hyperventilation is no longer routinely recommended before testing. Although specificity is lowered somewhat by resting ST depression of less than 1 mm, the standard exercise test is still the first option in evaluation of possible CAD in such patients with an intermediate pretest probability. Specificity is also lowered by LVH with less than 1 mm of ST depression and use of digoxin with less than 1 mm of ST depression, but the standard exercise test is still a reasonable option in such patients.

In contrast, other baseline ECG abnormalities such as preexcitation, ventricular pacing, greater than 1 mm of ST depression at rest, and complete left bundle branch block greatly affect the diagnostic performance of the exercise test. Imaging modalities are preferred in these subsets of patients.

While computer processing of the exercise ECG can be helpful, it can result in a false-positive indication of ST depression. To avoid this problem, the physician should always be provided with ECG recordings of the raw unprocessed ECG data for comparison with any averages the exercise test monitor generates. It is preferable that the averages always be contiguously preceded by the raw ECG data. The degree of filtering and preprocessing should always be presented along with the ECG recordings and compared with the AHA recommendations (0 to 100 Hz using notched power line frequency filters). It is preferable that the default setting be the AHA standards. All averages should be carefully labeled and explained, particularly those that simulate raw data. Simulation of raw data with averaged data should be avoided. Obvious breaks should be inserted between averaged ECG complexes. Averages should be marked with checks indicating the PR isoelectric line as well as the ST measurement points. None of the computerized scores or measurements have been sufficiently validated to recommend their widespread use.

III. Risk Assessment and Prognosis in Patients With Symptoms or a Prior History of Coronary Artery Disease

Class I
1. Patients undergoing initial evaluation with suspected or known CAD. Specific exceptions are noted below in Class IIb.

2. Patients with suspected or known CAD previously evaluated with significant change in clinical status.

Class IIb
1. Patients with the following ECG abnormalities: ▪ Preexcitation (Wolff-Parkinson-White) syndrome ▪ Electronically paced ventricular rhythm ▪ Greater than 1 mm of resting ST depression ▪ Complete left bundle branch block

2. Patients with a stable clinical course who undergo periodic monitoring to guide treatment.

Class III
1. Patients with severe comorbidity likely to limit life expectancy and/or candidacy for revascularization.

Unless cardiac catheterization is indicated, patients with suspected or known CAD and new or changing symptoms that suggest ischemia should generally undergo exercise testing to assess risk of future cardiac events. As described in the ACC/AHA guidelines for percutaneous transluminal coronary angioplasty and coronary artery bypass grafting, documentation of exercise or stress-induced ischemia is desirable for most patients undergoing evaluation for revascularization.

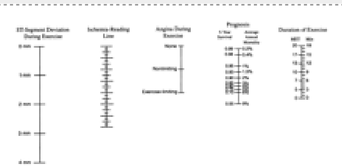
The choice of initial stress-test modality should be based on an evaluation of the patient's resting ECG, physical ability to exercise, and local expertise and technologies. For risk assessment, the exercise test should be the standard initial mode of stress testing used in patients with a normal ECG who are not taking digoxin. Patients unable to exercise because of physical limitations (eg, arthritis, amputations, severe peripheral vascular disease, severe chronic obstructive pulmonary disease, general debility) should undergo pharmacological stress testing in combination with imaging.

Exercise testing may be useful for prognostic assessment of patients on digoxin or with abnormal resting ECGs, but its usefulness is less well established in this setting. Patients with preexcitation, ventricular paced rhythm, widespread ST depression (greater than or equal to 1 mm), and left bundle branch block should usually be tested with an imaging modality. Exercise testing may still provide prognostic information (particularly exercise capacity) in patients with these ECG changes but cannot be used to identify ischemia.

One of the strongest and most consistent prognostic markers identified in exercise testing is maximum exercise capacity, which is at least partly influenced by the extent of resting left ventricular dysfunction and the amount of further left ventricular dysfunction induced by exercise. When interpreting the exercise test, it is very important to take exercise capacity into account. This may be done with one of several markers of exercise capacity, including maximal exercise duration, maximal metabolic equivalent (MET) level achieved, maximum workload achieved, or maximum heart rate and heart rate–blood pressure product.

A second group of prognostic markers identified from the exercise test relates to exercise-induced ischemia and includes exercise-induced ST deviation (elevation and depression) and exercise-induced angina.

The Duke treadmill score incorporates both groups of prognostic markers (exercise capacity and exercise-induced ischemia). This score was originally developed using data from 2842 inpatients with known or suspected CAD who underwent exercise testing before diagnostic angiography. None of the patients had prior revascularization or recent myocardial infarction. The Duke treadmill score has subsequently been validated in 613 outpatients at Duke as well as in populations at other centers. The score works equally well in males and females but has not been extensively evaluated in elderly patients. A nomogram for practical application of this score is shown in Fig 2.



View larger version (12K):
In this window
In a new window

Figure 2. Nomogram of the prognostic relations embodied in the treadmill score. Prognosis is determined in five steps: (1) The observed amount of exercise-induced ST-segment deviation (the largest elevation or depression after resting changes have been subtracted) is marked on the line for ST-segment deviation during exercise. (2) The observed degree of angina during exercise is marked on the line for angina. (3) The marks for ST-segment deviation and degree of angina are connected with a straight edge. The point where this line intersects the ischemia-reading line is noted. (4) The total number of minutes of exercise in treadmill testing according to the Bruce protocol (or the equivalent in multiples of resting oxygen consumption [METs] from an alternative protocol) is marked on the exercise-duration line. (5) The mark for ischemia is connected with that for exercise duration. The point at which this line intersects the line for prognosis indicates the 5-year cardiovascular survival rate and average annual cardiovascular mortality for patients with these characteristics. Patients with <1 mm of exercise-induced ST-segment depression should be counted as

having 0 mm. Angina during exercise refers to typical effort angina or an equivalent exercise-induced symptom that represents the patient's presenting complaint. This nomogram applies to patients with known or suspected coronary artery disease, without prior revascularization or recent myocardial infarction, who undergo exercise testing before coronary angiography. Modified from Mark DB, Shaw L, Harrell FE Jr, et al. Prognostic value of a treadmill exercise score in outpatients with suspected coronary artery disease. *N Engl J Med.* 1991; 325(12):849-853.

Risk assessment may also be appropriate in certain patients with unstable angina. Guidelines for the diagnosis and treatment of unstable angina were recently published by the Agency for Health Care Policy and Research and endorsed by the ACC and the AHA. Patients were classified as being at low, moderate, or high risk on the basis of their history, physical examination, and initial resting ECG.

In low-risk patients with unstable angina who are evaluated on an outpatient basis, exercise or pharmacological stress testing should generally be performed within 72 hours of presentation. In low- or moderate-risk patients with unstable angina who have been hospitalized for evaluation, exercise or pharmacological stress testing should generally be performed unless cardiac catheterization is indicated. Testing can be performed when patients have been free of active ischemic or heart failure symptoms for a minimum of 48 hours. In general, as with patients with stable angina, the treadmill test should be the standard stress test for patients with a normal resting ECG who are not taking digoxin.

IV. After Myocardial Infarction

Class I
1. Before discharge for prognostic assessment, activity prescription, or evaluation of medical therapy (submaximal at about 4 to 7 days).*

2. Early after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the predischarge exercise test was not done (symptom-limited/about 14 to 21 days).*

3. Late after discharge for prognostic assessment, activity prescription, evaluation of medical therapy, and cardiac rehabilitation if the early exercise test was submaximal (symptom-limited/about 3 to 6 weeks).*

Class IIa
1. After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization.

Class IIb
1. Before discharge in patients who have undergone cardiac catheterization to identify ischemia in the distribution of a coronary lesion of borderline severity.

2. Patients with the following ECG abnormalities: ▪ Complete left bundle branch block ▪ Preexcitation syndrome ▪ Left ventricular hypertrophy ▪ Digoxin therapy ▪ Greater than 1 mm of resting ST-segment depression ▪ Electronically paced ventricular rhythm

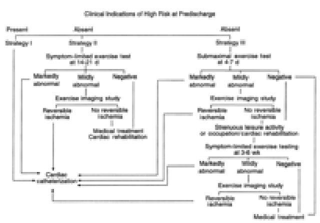
3. Periodic monitoring in patients who continue to participate in exercise training or cardiac rehabilitation.

Class III
1. Severe comorbidity likely to limit life expectancy and/or candidacy for revascularization.

Contemporary treatment of the patient with acute myocardial infarction includes one or more of the following: medical therapy, thrombolytic agents, and coronary revascularization. These interventions have led to a marked improvement in prognosis for postinfarction patients, particularly those who have been treated with reperfusion. Subsequent mortality rates are low among patients who have received thrombolytic agents or direct angioplasty. Patients who are unable to perform an exercise test have a much higher adverse event rate than those who are able. Symptomatic ischemic ST depression on exercise testing after thrombolytic therapy increases the risk of cardiac mortality twofold, but absolute risk remains low (1.7% at 6 months).

There is limited evidence regarding the ability of exercise testing to risk-stratify patients who have not received reperfusion therapy. A meta-analysis of 28 studies involving 15 613 patients found that markers of ventricular dysfunction were more sensitive predictors of adverse cardiac events after myocardial infarction than measures of exercise-induced ischemia. However, the vast majority of the studies included in this analysis were performed before the reperfusion era.

Exercise testing after myocardial infarction is safe. Submaximal testing can be performed at 4 to 7 days, and a symptom-limited test can be performed 3 to 6 weeks later. Alternatively, symptom-limited tests can be conducted early after discharge, at about 14 to 21 days. Strategies for exercise test evaluation after myocardial infarction are outlined in Fig 3.



View larger version (34K):
In this window
In a new window

Figure 3. Strategies for exercise test evaluation soon after myocardial infarction. Clinical indications of high risk include hypotension, congestive heart failure, sinus tachycardia, recurrent chest pain, and inability to exercise. Modified from Ryan TJ, Anderson JL, Antman EM, Braniff BA, Brooks NH, Califf RM, Hillis LD, Hiratzka LF, Rapaport E, Riegel BJ, Russell RO, Smith EE Jr, Weaver WD. ACC/AHA guidelines for the management of patients with acute myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Acute Myocardial Infarction). *J Am Coll Cardiol.* 1996;28:1328-1428.

Exercise testing is useful in activity counseling after discharge from the hospital. It is also an important tool in exercise training as part of comprehensive cardiac rehabilitation, where it can be used to develop and modify the exercise prescription, assist in providing activity counseling, and assess the patient's response to and progress in the exercise training program.

V. Exercise Testing Using Ventilatory Gas Analysis

Class I
1. Evaluation of exercise capacity and response to therapy in patients with heart failure who are being considered for heart transplantation.

2. Assistance in differentiating cardiac versus pulmonary limitations as a cause of exercise-induced dyspnea or impaired exercise capacity when the cause is uncertain.

Class IIa
1. Evaluation of exercise capacity when indicated for medical reasons in patients in whom subjective assessment of maximal exercise is unreliable.

Class IIb
1. Evaluation of the patient's response to specific therapeutic interventions in which improvement of exercise tolerance is an important goal or end point.

2. Determination of the intensity for exercise training as part of comprehensive cardiac rehabilitation.

Class III
1. Routine use to evaluate exercise capacity.

Ventilatory gas exchange analysis during exercise testing is a useful adjunctive tool in assessment of patients with cardiovascular and pulmonary disease. Measures of gas exchange primarily include oxygen uptake (VO_2), carbon dioxide output (VCO_2), minute ventilation, and ventilatory/anaerobic threshold. VO_2 at maximal exercise is considered the best index of aerobic capacity and cardiorespiratory function. Estimation of maximal aerobic capacity using published formulas without direct measurement is limited by physiological and methodological inaccuracies.

Data derived from exercise testing with ventilatory gas analysis have proved to be reliable and important in evaluation of patients with heart failure. Such data are only partly influenced by resting left ventricular dysfunction. Maximal exercise capacity does not necessarily reflect the daily activities of patients with heart failure. Use of this technique in stratification of ambulatory heart failure patients has improved ability to identify those with the poorest prognosis, who should be considered for heart transplantation.

VI. Special Groups: Women, Asymptomatic Individuals, and Postrevascularization Patients

The accuracy of the exercise ECG for diagnosis of coronary disease in women is problematic. Exercise-induced ST depression is less sensitive in women than men, reflecting a lower prevalence of severe coronary disease and the inability of many women to exercise to maximum aerobic capacity. The exercise ECG is commonly viewed as less specific in women than in men, although careful review of the published data shows that this finding has certainly not been uniform. Studies that demonstrated lower specificity in women have cited lower disease prevalence, non-Bayesian factors, and possible hormonal differences. Physicians need to be cognizant of the decrease in sensitivity that occurs when women do not exercise to maximum aerobic capacity. Patients likely to exercise submaximally should undergo pharmacological stress testing. Concern about false-positive ST-segment responses may be addressed by careful assessment of post-test probability and selective use of stress imaging tests before proceeding to angiography. The difficulties posed by clinical evaluation of women for possible CAD have led to speculation that stress imaging approaches may be an efficient initial alternative to the exercise ECG in women. Although the optimal strategy for circumventing false-positive test results for diagnosis of CAD in women remains to be defined, the data are insufficient to justify routine stress imaging tests as the initial test for diagnosis of CAD in women.

Diagnosis of Coronary Artery Disease in the Elderly
Patients older than 65 years are usually defined as "elderly." One possible subdivision of this group is the "young old" (65 to 75 years) and the "old old" (older than 75 years); CAD is highly prevalent in symptomatic patients in both groups. Pharmacological stress testing is more often required in the elderly because of their inability to exercise adequately.

Interpretation of exercise tests in the elderly differs somewhat from that in younger patients. Resting ECG abnormalities may compromise the accuracy of diagnostic data from the ECG. Nonetheless, the application of standard ST-segment response criteria to elderly subjects is not associated with a significantly different accuracy from younger patients. Due to the greater prevalence of both CAD and severe CAD, it is not surprising that exercise testing in this group is reported to have a slightly higher sensitivity than in younger patients. A slightly lower specificity has also been reported, which may reflect the coexistence of LVH due to valvular disease and hypertension. Although the risk of coronary angiography may be greater in the elderly and the justification for coronary intervention less, the results of exercise testing in the elderly remain important, because medical therapy may itself carry substantial risks for this group.

Exercise Testing in Asymptomatic Persons Without Known Coronary Artery Disease

Class I

1. None.

Class IIb
1. Evaluation of persons with multiple risk factors.*

2. Evaluation of asymptomatic men older than 40 years and women older than 50 years: ▪ Who plan to start vigorous exercise (especially if sedentary) or ▪ Who are involved in occupations in which impairment might impact public safety or ▪ Who are at high risk for CAD due to other diseases (eg, chronic renal failure)

Class III
1. Routine screening of asymptomatic men or women.

The purpose of screening for possible CAD in persons without known CAD is to either prolong life or improve its quality because of early detection of disease. In asymptomatic patients with severe CAD, data from the Coronary Artery Surgery Study (CASS) and the Asymptomatic Cardiac Ischemia Pilot (ACIP) study suggest that revascularization may prolong life. Detection of ischemia may identify patients for risk factor modification. Although this may seem inconsistent with the current position that simple reduction of risk factors should be attempted in all patients, identification of functional impairment may motivate patients to be more compliant with a program of risk factor modification.

Prediction of myocardial infarction and death are considered the most important end points of screening in asymptomatic patients. In general, the relative risk of a subsequent event is increased in patients with a positive exercise test result, although the absolute risk of a cardiac event in an asymptomatic patient remains low. The annual rate of myocardial infarction and death in such patients is only approximately 1%, even if ST-segment changes are associated with risk factors. A positive exercise test result is more predictive of later development of angina than occurrence of a major event. Even when subsequent angina is considered an event, a minority of patients with a positive test result experience cardiac events. Unfortunately, those with positive test results may suffer from being labeled as being at risk.

For example, general population screening programs attempting to identify young patients with early disease are limited in that severe CAD that requires intervention in asymptomatic patients is exceedingly rare. Although the physical risks of exercise testing are negligible, false-positive test results may engender inappropriate anxiety and may have serious adverse consequences related to work and insurance coverage. For these reasons, exercise testing in healthy, asymptomatic persons is not recommended.

Selected patients with multiple risk factors for CAD are at greater absolute risk for subsequent myocardial infarction and death. Screening may be potentially helpful in patients who are at least at moderate risk. Such patients may be identified from the available prognostic data in asymptomatic persons from the Framingham study. For these purposes, risk factors should be very strictly defined, as indicated in the footnote to recommendations for exercise testing in asymptomatic persons without CAD. Attempts to extend screening to persons with lower degrees of risk are not recommended, as screening is extremely unlikely to improve patient outcome.

Valvular Heart Disease

Class I
1. None.

Class IIb
1. Evaluation of exercise capacity of patients with valvular heart disease.*

Class III
1. Diagnosis of CAD in patients with valvular heart disease.

In symptomatic patients with documented valvular disease, the course of treatment is usually clear and exercise testing is not required. However, the expanding use of Doppler echocardiography has greatly increased the number of asymptomatic patients with well-defined valvular abnormalities. The primary value of exercise testing in valvular heart disease is to objectively assess atypical symptoms, exercise capacity, and extent of disability, all of which may have implications for clinical decision making. This is particularly important in the elderly, who may not have symptoms because of their limited activity. Use of the exercise ECG for diagnosis of CAD in these situations is limited by false-positive responses due to LVH and baseline ECG changes.

In patients with aortic stenosis, the test should be directly supervised by a physician familiar with the patient's condition, and exercise should be terminated for inappropriate blood pressure augmentation, slowing of the heart rate with increasing exercise, or premature beats.

Because the major indication for surgery in mitral stenosis is symptom status, exercise testing is of most value when a patient is thought to be asymptomatic due to inactivity or when a discrepancy exists between the patient's symptoms and the valve area. Because ejection fraction is a reliable index of left ventricular function in aortic regurgitation, decisions regarding surgery are likely based on resting ejection fraction, and exercise testing is not commonly required, unless symptoms are ambiguous. Resting ejection fraction is a poor guide to ventricular function in patients with mitral regurgitation; thus, combinations of exercise and assessment of left ventricular function may be of value in documenting occult dysfunction.

Exercise Testing Before and After Revascularization

Class I
1. Demonstration of proof of ischemia before revascularization.

2. Evaluation of patients with recurrent symptoms suggesting ischemia after revascularization.

Class IIa
1. After discharge for activity counseling and/or exercise training as part of cardiac rehabilitation in patients who have undergone coronary revascularization.

Class IIb
1. Detection of restenosis in selected, high-risk asymptomatic patients within the first months after angioplasty.

2. Periodic monitoring of selected, high-risk asymptomatic patients for restenosis, graft occlusion, or disease progression.

Class III
1. Localization of ischemia for determining the site of intervention.

2. Routine, periodic monitoring of asymptomatic patients after percutaneous transluminal coronary angioplasty (PTCA) or coronary artery bypass grafting without specific indications.

Exercise Testing Before Revascularization
Patients who undergo myocardial revascularization should have documented ischemic or viable myocardium, especially if they are asymptomatic. The exercise ECG is useful in these circumstances, particularly if the patient has multivessel disease and the culprit vessel does not need to be defined. However, in the setting of one-vessel disease, sensitivity of the exercise ECG is frequently suboptimal, especially if the revascularized vessel supplies the posterior wall. Moreover, use of the exercise ECG is inappropriate when the culprit vessel must be defined.

Exercise Testing After Revascularization
There are two postrevascularization phases. In the early phase, the goal of exercise testing is to determine the immediate result of revascularization. In the second or late phase, the goal of exercise testing is to assist in evaluation and treatment of patients 6 months or more after revascularization, ie, with long-term established CAD (as outlined in section III).

After coronary artery bypass surgery, exercise testing may be used in symptomatic patients to distinguish between cardiac and noncardiac causes of recurrent chest pain, which is often atypical after surgery. If a management decision is to be based on the presence of ischemia, the exercise ECG may suffice. However, if a management decision is to be based on the site and extent of ischemia, the exercise ECG is less desirable than a stress imaging test.

In asymptomatic patients after coronary artery bypass surgery, the development of silent graft disease, especially with venous conduits, is clearly a major concern. The value of the exercise ECG for detecting silent graft disease is not well established. Stress imaging tests are more favored in this patient group because of their capability to document the site of ischemia and their increased sensitivity.

In symptomatic patients after PTCA, a positive exercise test is predictive of restenosis. However, the value of a negative exercise test is reduced by the limited sensitivity of exercise testing, particularly for one-vessel disease.

Silent restenosis is a common clinical manifestation in asymptomatic patients after PTCA. Some authorities have advocated routine exercise testing, because restenosis is frequent. The alternative approach favored by the committee is to perform exercise testing in selected patients considered to be at particularly high risk, including those with decreased left ventricular function, multivessel CAD, proximal left anterior descending disease, previous sudden death, diabetes mellitus, hazardous occupations, and suboptimal PTCA results. Regardless of the strategy used, the exercise ECG is an insensitive predictor of restenosis, the sensitivities ranging from 40% to 55%, reflecting the high prevalence of one-vessel disease in this population.

Investigation of Heart Rhythm Disorders

Class I
1. Identification of appropriate settings in patients with rate-adaptive pacemakers.

Class IIa
1. Evaluation of patients with known or suspected exercise-induced arrhythmias.

2. Evaluation of medical, surgical, or ablative therapy in patients with exercise-induced arrhythmias (including atrial fibrillation).

Class IIb
1. Investigation of isolated ventricular ectopic beats in middle-aged patients without other evidence of CAD.

Class III
1. Investigation of isolated ectopic beats in young patients.

Exercise testing has a well-established role in identifying appropriate settings for adaptive-rate pacemakers using various physiological sensors. A number of studies have compared different pacing modes with respect to their influence on exercise capacity. A formal exercise test may not always be necessary, as the required data can be supplied from a 6-minute walk.

Exercise testing may be used to evaluate patients with symptoms that suggest exercise-induced arrhythmias, such as syncope. The usefulness of exercise testing in such patients varies, depending on the arrhythmia in question, which may include ventricular arrhythmias, supraventricular arrhythmias, atrioventricular block, and sinus node dysfunction. Exercise testing may also be used to evaluate medical therapy in patients with exercise-induced arrhythmias. A common, specific example of this indication is the use of exercise testing to assess control of the ventricular response to exercise in patients with atrial fibrillation.

Exercise testing has been used to investigate isolated ventricular ectopic beats in middle-aged patients without clinical evidence of CAD. This is a special case of the problem of screening asymptomatic individuals, which was covered above.

VII. Pediatric Testing: Exercise Testing in Children and Adolescents

Class I
1. Evaluation of exercise capacity in children or adolescents with congenital heart disease, those who have had surgery for congenital heart disease, and children who have acquired valvular or myocardial disease.

2. Evaluation of the rare child with a description of anginal chest pain.

3. Assessment of the response of an artificial pacing system to exertion.

4. Evaluation of exercise-related symptoms in young athletes.

Class IIa
1. Evaluation of the adequacy of the response to medical, surgical, or radiofrequency ablation treatment for children with a tachyarrhythmia that was found during exercise testing before therapy.

2. As an adjunct in assessment of the severity of congenital or acquired valvular lesions, especially aortic valve stenosis.

3. Evaluation of the rhythm during exercise in patients with known or suspected exercise-induced arrhythmia.

Class IIb
1. As a component of the evaluation of children or adolescents who have a family history of unexplained sudden death related to exercise in young persons.

2. Follow-up of cardiac abnormalities with possible late coronary involvement such as Kawasaki disease and systemic lupus erythematosus.

3. Assessment of ventricular rate response and development of ventricular arrhythmia in children and adolescents with congenital complete atrioventricular block.

4. Quantitation of the heart-rate response to exercise in children and adolescents treated with ß-blocker therapy to estimate the adequacy of ß-blockade.

5. Measurement of response of shortening or prolongation of the corrected QT interval to exercise as an adjunct in the diagnosis of hereditary syndromes of prolongation of the QT interval.

6. Evaluation of blood pressure response and/or arm-to-leg gradient after repair of coarctation of the aorta.

7. Assessment of degree of desaturation with exercise in patients with relatively well-balanced or palliated cyanotic congenital cardiac defects.

Class III
1. Screening before athletic participation by healthy children and adolescents.

2. Routine use of exercise testing for evaluating the usual nonanginal chest pain common in children and adolescents.

3. Evaluation of premature atrial and ventricular contractions in otherwise healthy children and adolescents.

Ischemic heart disease is extremely uncommon in a young population. This results in a much lower risk of routine testing as well as differences in the indications, usefulness, and interpretation of exercise laboratory data in the pediatric population. Applications of exercise testing in the young are most often related to measurement of exercise capacity, evaluation of known or possible abnormalities of cardiac rhythm, and evaluation of symptoms elicited by exertion. Exercise capacity may be diminished in children or adolescents with congenital heart disease, those who have had surgical treatment of congenital heart disease, and those who have acquired valvular or myocardial disease. Measurement of exercise capacity is often useful in evaluating subjective limitations in this age group.

Exercise testing in younger populations provides a number of technical challenges. Developmental factors may influence the conduct of the test as well as interpretation of data. Younger patients may be less cooperative than older patients, possibly making it difficult to differentiate limitations of exercise capacity from lack of cooperation. Ventilatory measurements are used in many pediatric exercise testing laboratories to measure respiratory exchange ratio and ventilatory anaerobic threshold for this reason.

Some indications for exercise testing in children, adolescents, and young adults are very similar to indications for exercise testing in older patients (see sections VI and VII). An example is evaluation of patients with known or suspected exercise-induced arrhythmias.

Other recommendations for exercise testing in younger patients are unique and reflect the impact of congenital heart disease. An example is assessment of degree of desaturation with exercise in patients with well-balanced or palliated cyanotic congenital heart defects.

Footnotes

"ACC/AHA Guidelines for Exercise Testing" was approved by the American College of Cardiology Board of Trustees in March 1997 and the American Heart Association Science Advisory and Coordinating Committee in April 1997.

A single reprint of this document (Executive Summary) is available by calling 800-242-8721 (US only) or writing the American Heart Association, Public Information, 7272 Greenville Avenue, Dallas, TX 75231-4596. Ask for reprint No. 71-0111. To obtain a reprint of the complete Guidelines published in the July 1997 issue of the *Journal of the American College of Cardiology,* ask for reprint No. 71-0112. To purchase additional reprints, specify version reprint number: up to 999 copies, call 800-611-6083 (US only) or fax 413-665-2671; 1000 or more copies, call 214-706-1466, fax 214-691-6342, or

[1] Exceptions are noted under Classes IIb and III.

[2] Exceptions are noted under Classes IIb and III.

[3] Multiple risk factors are defined as hypercholesterolemia (cholesterol greater than 240 mg/dL), hypertension (systolic blood pressure greater than 140 mm Hg or diastolic blood pressure greater than 90 mm Hg), smoking, diabetes, and family history of heart attack or sudden cardiac death in a first-degree relative younger than 60 years. An alternative approach might be to select patients with a Framingham risk score consistent with at least a moderate risk of serious cardiac events within 5 years.

[4] As noted earlier, the presence of symptomatic, severe aortic stenosis is a contraindication to exercise testing.

Articles citing this article

Computed Tomography Myocardial Perfusion Imaging With 320-Row Detector Computed Tomography Accurately Detects Myocardial Ischemia in Patients With Obstructive Coronary Artery Disease
Circ Cardiovasc Imaging. 2012;5:333-340,
Abstract | Full Text | PDF

Meaning of zero coronary calcium score in symptomatic patients referred for coronary computed tomographic angiography

Eur Heart J Cardiovasc Imaging. 2012;0:jes060v1-jes060,
Abstract | Full Text | PDF

Using Stress Testing to Guide Primary Prevention of Coronary Heart Disease Among Intermediate-Risk Patients: A Cost-Effectiveness Analysis
Circulation. 2012;125:260-270,
Abstract | Full Text | PDF

Anomalous Origin of the Right Coronary Artery from the Left Coronary Sinus with an Interarterial Course: Subtypes and Clinical Importance
Radiology. 2012;262:101-108,
Abstract | Full Text | PDF

Long-Term Effects of Changes in Cardiorespiratory Fitness and Body Mass Index on All-Cause and Cardiovascular Disease Mortality in Men: The Aerobics Center Longitudinal Study
Circulation. 2011;124:2483-2490,
Abstract | Full Text | PDF

Pharmacist-Led Shared Medical Appointments for Multiple Cardiovascular Risk Reduction in Patients With Type 2 Diabetes
The Diabetes Educator. 2011;37:801-812,
Abstract | Full Text | PDF

Stable Angina Pectoris: Head-to-Head Comparison of Prognostic Value of Cardiac CT and Exercise Testing
Radiology. 2011;261:428-436,
Abstract | Full Text | PDF

Is Computed Tomography Coronary Angiography the Most Accurate and Effective Noninvasive Imaging Tool to Evaluate Patients With Acute Chest Pain in the Emergency Department?: CT Coronary Angiography Is the Most Accurate and Effective Noninvasive Imaging Tool for Evaluating Patients Presenting With Chest Pain to the Emergency Department: Antagonist Viewpoint
Circ Cardiovasc Imaging. 2009;2:264-275,
Full Text | PDF

A Review of the Six-Minute Walk Test: Its Implication as a Self-Administered Assessment Tool
Eur J Cardiovasc Nurs. 2009;8:2-8,
Abstract | Full Text | PDF

CHAPTER 17 Chronic Ischaemic Heart Disease
ESC Textbook of Cardiovascular Medicine. 2009;2:med-9780199566990-chapter,
Abstract | Full Text | PDF

The Exercise Assessment and Screening for You (EASY) Tool: Application in the Oldest Old Population
AMERICAN JOURNAL OF LIFESTYLE MEDICINE. 2008;2:432-440,
Abstract | PDF

Cardiorespiratory fitness and brain atrophy in early Alzheimer disease
Neurology. 2008;71:210-216,
Abstract | Full Text | PDF

Decreased maximal heart rate with aging is related to reduced {beta}-adrenergic responsiveness but is largely explained by a reduction in intrinsic heart rate
J. Appl. Physiol.. 2008;105:24-29,
Abstract | Full Text | PDF

Head-to-head comparison of multislice computed tomography and

exercise electrocardiography for diagnosis of coronary artery disease
Eur Heart J. 2007;28:2485-2490,
Abstract | Full Text | PDF

Exercise Stress Testing in Patients With Type 2 Diabetes: When Are Asymptomatic Patients Screened?
Clin. Diabetes. 2007;25:126-130,
Abstract | Full Text | PDF

Stress echocardiography safely classified more patients as low risk of serious CAD than exercise electrocardiography
Evid. Based Med.. 2007;12:119,
Full Text | PDF

Impact of multivessel disease on reperfusion success and clinical outcomes in patients undergoing primary percutaneous coronary intervention for acute myocardial infarction
Eur Heart J. 2007;28:1709-1716,
Abstract | Full Text | PDF

A 52-Year-Old Woman With Hypertension and Diabetes Who Presents With Chest Pain
Clin. Diabetes. 2007;25:115-118,
Full Text | PDF

Subclinical Coronary and Aortic Atherosclerosis Detected by Magnetic Resonance Imaging in Type 1 Diabetes With and Without Diabetic Nephropathy
Circulation. 2007;115:228-235,
Abstract | Full Text | PDF

Coronary Multidetector Computed Tomography in the Assessment of Patients With Acute Chest Pain
Circulation. 2006;114:2251-2260,
Abstract | Full Text | PDF

Determination of exercise training heart rate in patients on {beta}-blockers after myocardial infarction
European Journal of Preventive Cardiology. 2006;13:538-543,
Abstract | Full Text | PDF

Implications of exercise test modality on modern prognostic markers in patients with known or suspected coronary artery disease: Treadmill versus bicycle
European Journal of Preventive Cardiology. 2006;13:45-50,
Abstract | Full Text | PDF

Cardiovascular Endurance and Heart Rate Variability in Adolescents With Type 1 or Type 2 Diabetes
Biol Res Nurs. 2005;7:16-29,
Abstract | PDF

Physical Activity/Exercise and Type 2 Diabetes
Diabetes Care. 2004;27:2518-2539,
Full Text | PDF

Studies on intragastric PCO2 at rest and during exercise as a marker of intestinal perfusion in patients with chronic heart failure
Eur J Heart Fail. 2004;6:403-407,
Abstract | Full Text | PDF

Clinical Correlates and Prognostic Significance of Exercise-Induced Ventricular Premature Beats in the Community: The Framingham Heart Study
Circulation. 2004;109:2417-2422,

Abstract | Full Text | PDF

Exercise Capacity: The Prognostic Variable That Doesn't Get Enough Respect
Circulation. 2003;108:1534-1536,
Full Text | PDF

Interpreting exercise treadmill tests needs scoring system
BMJ. 2002;325:443,
Full Text

Prevention Conference VI: Diabetes and Cardiovascular Disease: Writing Group III: Risk Assessment in Persons With Diabetes
Circulation. 2002;105:e144-e152,
Full Text | PDF

Guidelines for the Management of Patients with Chronic Stable Angina: Diagnosis and Risk Stratification
ANN INTERN MED. 2001;135:530-547,
Abstract | Full Text | PDF

Prognostic value of stress echocardiography in women with high ({>=}80%) probability of coronary artery disease
Postgrad. Med. J.. 2001;77:573-577,
Abstract | Full Text | PDF

Estrogen Replacement Therapy Improves Baroreflex Regulation of Vascular Sympathetic Outflow in Postmenopausal Women
Circulation. 2001;103:2909-2914,
Abstract | Full Text | PDF

Recommendations for exercise testing in chronic heart faliure patients
Eur Heart J. 2001;22:37-45,
PDF

The Effect of Race on the Referral Process for Invasive Cardiac Procedures
Med Care Res Rev. 2000;57:162-180,
Abstract | PDF

Safety and Utility of Exercise Testing in Emergency Room Chest Pain Centers : An Advisory From the Committee on Exercise, Rehabilitation, and Prevention, Council on Clinical Cardiology, American Heart Association
Circulation. 2000;102:1463-1467,
Full Text | PDF

Exercise testing, still the method of choice when evaluating patients with chronic stable angina pectoris
Eur Heart J. 2000;21:875-877,
PDF

Emergency cardiac care: introduction
J Am Coll Cardiol. 2000;35:825-880,
Full Text | PDF

Non-contrast second harmonic imaging improves interobserver agreement and accuracy of dobutamine stress echocardiography in patients with impaired image quality
Heart. 2000;83:133-140,
Abstract | Full Text

Long-Term Additive Prognostic Value of Thallium-201 Myocardial Perfusion Imaging Over Clinical and Exercise Stress Test in Low to

Intermediate Risk Patients : Study in 1137 Patients With 6-Year Follow-Up
Circulation. 1999;100:1521-1527,
Abstract | Full Text | PDF

Diabetes and Cardiovascular Disease : A Statement for Healthcare Professionals From the American Heart Association
Circulation. 1999;100:1134-1146,
Full Text | PDF

ACC/AHA/ACP-ASIM guidelines for the management of patients with chronic stable angina: A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Management of Patients With Chronic Stable Angina)
J Am Coll Cardiol. 1999;33:2092-2197,
Full Text | PDF

Technetium Tc 99m Sestamibi Myocardial Perfusion Imaging: Current Role for Evaluation of Prognosis
Chest. 1999;115:1684-1694,
Abstract | Full Text | PDF

Guide to Preventive Cardiology for Women
Circulation. 1999;99:2480-2484,
Full Text | PDF

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