

ACC/AHA 2002 Guideline Update for Exercise Testing: Summary Article

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines)

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The American College of Cardiology (ACC)/American Heart Association (AHA) Task Force on Practice Guidelines regularly reviews existing guidelines to determine when an update or full revision is needed. This process gives priority to areas where major changes in text, and particularly recommendations, are mentioned on the basis of new understanding or evidence. Minor changes in verbiage and references are discouraged.

The ACC/AHA guidelines for exercise testing that were published in 1997 have now been updated. The full-text guidelines incorporating the updated material are available on the Internet (www.acc.org or www.americanheart.org) in

both a version that shows the changes in the 1997 guidelines in strike-over (deleted text) and highlighting (new text) and a "clean" version that fully incorporates the changes.

This article describes the 10 major areas of change reflected in the update in a format that we hope can be read and understood as a stand-alone document. The table of contents from the full-length guideline (see next page) indicates the location of these changes. Interested readers are referred to the full-length Internet version to completely understand the context of these changes. All new references appear in boldface type; all original references appear in normal type.

The ACC/AHA Task Force on Practice Guidelines makes every effort to avoid any actual or potential conflicts of interest that might arise as a result of an outside relationship or personal interest of a member of the writing panel. Specifically, all members of the writing panel are asked to provide disclosure statements of all such relationships that might be perceived as real or potential conflicts of interest. These statements are reviewed by the parent task force, reported orally to all members of the writing panel at the first meeting, and updated as changes occur.

This document was approved by the American College of Cardiology Foundation Board of Trustees in July 2002 and by the American Heart Association Science Advisory and Coordinating Committee in June 2002. When citing this document, the American College of Cardiology Foundation and the American Heart Association would appreciate the following citation format: Gibbons RJ, Balady GJ, Bricker JT, Chaitman BR, Fletcher GF, Froelicher VF, Mark DB, McCallister BD, Mooss AN, O'Reilly MG, Winters WL Jr. ACC/AHA 2002 guideline update for exercise testing: summary article: a report of the ACC/AHA Task Force on Practice Guidelines (Committee to Update the 1997 Exercise Testing Guidelines). *Circulation*. 2002;106:1883-1892.

Copies: This document is available on the World Wide Web sites of the ACC (www.acc.org) and the AHA (www.americanheart.org). A single copy of the complete guidelines is available by calling 800-253-4636 (US only) or writing the American College of Cardiology, Resource Center, 9111 Old Georgetown Road, Bethesda, MD 20814-1699. Ask for reprint No. 71-0231. To obtain a copy of the Executive Summary published in the October 1, 2002 issue of *Circulation*, ask for reprint No. 71-0232. To purchase additional reprints (specify version and reprint number): up to 999 copies, call 800-611-6083 (US only) or fax 413-665-2671; 1000 or more copies, call 410-528-4426, fax 410-528-4264, or e-mail kbradle@lww.com.

*Former Task Force member during writing effort.

(*Circulation*. 2002;106:1883-1892.)

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Circulation is available at <http://www.circulationaha.org>

DOI: 10.1161/01.CIR.0000034670.06526.15

The ACC/AHA classifications, I, II, and III are used to summarize indications as follows:

- 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.

In the original guideline, the committee did not rank the available scientific evidence in an A, B, or C fashion. The level of evidence is provided for the new recommendations appearing in the update. The weight of the evidence was ranked highest (A) if the data were derived from multiple randomized clinical trials that involved large numbers of patients and intermediate (B) if the data were derived from a limited number of randomized trials that involved small numbers of patients or from careful analyses of nonrandomized studies or observational registries. A lower rank (C) was given when expert consensus was the primary basis for the recommendation.

The ACC/AHA Task Force on Practice Guidelines welcomes feedback on this update process and the format of this article. Please direct your comments to the Task Force c/o Dawn Phoubandith, American College of Cardiology or via e-mail (dphouban@acc.org).

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Modification I

The text in the 1997 guidelines that appeared under the major heading "Diagnosis" and the subheading "Influence of Other Factors on Test Performance" has been extensively reorganized. This began on page 272 (second column) of the original guidelines. New material regarding ST-heart rate and adjustment changes during and after exercise is reproduced below. New material on atrial repolarization and right chest leads appears in the full-text guidelines on the Internet.

ST-Heart Rate Adjustment

Several methods of heart rate adjustment have been proposed to increase the diagnostic accuracy of the exercise ECG. The maximal slope of the ST segment relative to heart rate is derived either manually¹ or by computer.² A second technique, termed the ST/HR index, divides the difference between ST depression at peak exercise by the exercise-induced increase in heart rate.^{3,4} ST/HR adjustment has been the subject of several reviews since the last publication of these guidelines.^{5,6} The major studies that used this approach for diagnostic testing include Morise's report⁷ of 1358 individuals undergoing exercise testing (only 152 with catheterization data) and the report by Okin et al⁸ considering heart rate reserve (238 controls and 337 patients with coronary disease).

Modification II

1997 Exercise Testing Guideline Recommendation

2002 Exercise Testing Guideline Recommendation

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 IIa**Class IIb**

1. Patients with the following ECG abnormalities
 - Pre-excitation (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.

Class I

1. Patients undergoing initial evaluation with suspected or known CAD, including those with complete right bundle-branch block or less than 1 mm of resting ST depression. Specific exceptions are noted below in Class IIb.
2. Patients with suspected or known CAD, previously evaluated, now presenting with significant change in clinical status.
3. Low-risk unstable angina patients (see Table 17) 8 to 12 hours after presentation who have been free of active ischemic or heart failure symptoms. (*Level of Evidence: B*)
4. Intermediate-risk unstable angina patients (see Table 17) 2 to 3 days after presentation who have been free of active ischemic or heart failure symptoms. (*Level of Evidence: B*)

Class IIa

1. Intermediate-risk unstable angina patients (see Table 17) who have initial cardiac markers that are normal, a repeat ECG without significant change, and cardiac markers 6 to 12 hours after the onset of symptoms that are normal and no other evidence of ischemia during observation. (*Level of Evidence: B*)

Class IIb

1. Patients with the following resting ECG abnormalities
 - Pre-excitation (Wolff-Parkinson-White) syndrome
 - Electronically paced ventricular rhythm
 - 1 mm or more of resting ST depression
 - Complete left bundle-branch block or any interventricular conduction defect with a QRS duration greater than 120 ms
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.
2. High-risk unstable angina patients (see Table 17). (*Level of Evidence: C*)

Viik et al considered the maximum value of the ST-segment depression/heart rate (ST/HR) hysteresis over a different number of leads for the detection of coronary artery disease (CAD).⁹ The study population consisted of 127 patients with coronary disease and 220 patients with a low likelihood of the disease referred for an exercise test. Neither the study by Okin et al or that by Viik et al considered consecutive patients with chest pain, and both had limited challenge. Because healthy patients have relatively high heart rates and sick patients have low heart rates, which leads to a lower ST/HR index in normals and a higher index in sicker patients, the enrollment of relatively healthy patients in these studies presents a limited challenge to the ST/HR index. Likewise, the Morise study⁷ had a small number of patients who underwent angiography. The only study with neither of these limitations was QUEXTA.¹⁰ This large multicenter study followed a protocol to reduce workup bias and was analyzed by independent statisticians. The ST/HR slope or index was not found to be more accurate than simple measurement of the ST segment. Although some studies in asymptomatic (and therefore very low likelihood) individuals have demonstrated additional prognostic value with ST/HR adjustment, these data are not directly applicable to the issue of diagnosis in

symptomatic patients.^{11,12} Nevertheless, one could take the perspective that the ST/HR approach in symptomatic patients has at least equivalent accuracy to the standard approach. Although not yet validated, there are situations in which the ST/HR approach could prove useful, such as in rendering a judgment concerning certain borderline or equivocal ST responses, eg, ST-segment depression associated with a very high exercise heart rate.

In asymptomatic patients, in MRFIT, significant concentration of cardiac risk was associated with an abnormal ST/HR index but not with abnormal standard exercise test criteria as judged by computer interpretation.¹² Compared with patients in the usual care group, cardiac events were reduced in the risk factor modification group when the exercise test was positive according to the ST/HR index.¹³

Modification II

These revised recommendations (see top of page) incorporate new recommendations for risk stratification in patients with unstable angina. The table of recommendations originally appeared at the beginning of the heading on "Risk Assessment" on page 274 (first column).

Modification III

This revised text incorporates new published evidence on elderly patients, heart-rate responses during and after exercise, and systolic blood pressure responses during and after exercise. It replaces material in the original text that appeared under the major heading "Risk Stratification" and the subheading "Nonacute Coronary Artery Disease" beginning on page 278 (second column).

The value of exercise treadmill testing for prognostic assessment in elderly subjects has been described in the Olmstead County, Minnesota, cohort followed by the Mayo Clinic.¹⁴ As expected, the elderly patients (aged greater than or equal to 65 years) had more comorbidity and achieved a lower workload than their younger counterparts. They also had a significantly worse unadjusted survival. Workload expressed as metabolic equivalents (METs) was the only treadmill variable associated with all-cause mortality in both groups (adjusting for clinical prognostic variables), whereas both workload and exercise angina were associated with cardiac events (death plus myocardial infarction) in both groups. A positive ST response was not prognostic in the older patients when tested as a binary variable. Quantitative ST-segment deviation with exercise was apparently not available in this cohort, and the Duke Treadmill Score was not computed in this study.

Morrow and colleagues¹⁵ developed a prognostic score using data from 2546 patients from Long Beach Veterans Administration Hospital. This score includes 2 variables in common with the Duke treadmill score (exercise duration or the MET equivalent and millimeters of ST changes) and 2 different variables (drop in exercise systolic blood pressure below resting value and history of congestive heart failure [CHF] or use of digoxin [Dig]). The score is calculated as follows:

$5 \times (\text{CHF/Dig} [\text{yes}=1; \text{no}=0]) + \text{exercise-induced ST depression in millimeters} + \text{change in systolic blood pressure score} - \text{METs}$,

where systolic blood pressure=0 for an increase greater than 40 mm Hg, 1 for an increase of 31 to 40 mm Hg, 2 for an increase of 21 to 30 mm Hg, 4 for an increase of 0 to 11 mm Hg, and 5 for a reduction below standing systolic preexercise blood pressure. With this score, 77% of the Long Beach Veterans Administration Hospital population were at low risk (with less than 2% average annual mortality), 18% were at moderate risk (average annual mortality, 7%), and 6% were at high risk (average annual mortality, 15%).

Several studies have highlighted the prognostic importance of other parameters from the exercise test. Chronotropic incompetence, defined as either failure to achieve 80% to 85% of the age-predicted maximum exercise heart rate or a low chronotropic index (heart rate adjusted to MET level), was associated with an 84% increase in the risk of all-cause mortality over a 2-year follow-up in 1877 men and 1076 women who were referred to the Cleveland Clinic for symptom-limited thallium treadmill testing.^{16,17} The Cleveland Clinic investigators have also demonstrated the prognostic importance of an abnormal heart rate recovery pattern after exercise testing. Defined as a change from peak exercise heart rate to heart rate measured 2 minutes later of less than or

equal to 12 beats per minute, an abnormal heart rate recovery was strongly predictive of all-cause mortality at 6 years in 2428 patients referred for thallium exercise testing.¹⁸ Similar trends have been suggested for a delayed systolic blood pressure response after exercise, defined as a value greater than 1 for systolic blood pressure at 3 minutes of recovery divided by systolic blood pressure at 1 minute of recovery. This finding was associated with severe CAD in a study of 493 patients at the Cleveland Clinic who had both symptom-limited exercise testing and coronary angiography (within 90 days).¹⁹ In a study of 9454 consecutive patients, most of whom were asymptomatic, the Cleveland Clinic investigators reported that abnormal heart rate recovery and the Duke treadmill score were independent predictors of mortality.²⁰ Further work is needed to define the role of chronotropic incompetence, abnormal heart rate recovery, and delayed blood pressure response in the risk stratification of symptomatic patients relative to other well-validated treadmill test parameters.

In patients who are classified as low risk on the basis of clinical and exercise testing information, there is no compelling evidence that an imaging modality adds significant new prognostic information to a standard exercise test. In this regard, a distinction should be made between studies that show a statistical advantage of imaging studies over exercise ECG alone and studies that demonstrate that the imaging data would change practice (eg, by shifting patients from moderate- to low- or high-risk categories). Because of its simplicity, lower cost, and widespread familiarity in its performance and interpretation, the standard treadmill ECG is the most reasonable exercise test to select in men with a normal resting ECG who are able to exercise. In patients with an intermediate-risk treadmill score, myocardial perfusion imaging appears to be of value for further risk stratification.²¹ Patients with an intermediate-risk treadmill score and normal or near-normal exercise myocardial perfusion images and normal cardiac size are at low risk for future cardiac death and can be managed medically.²²

Modification IV

This revised text, revised Table 17, and new Table 17a incorporate new published evidence regarding patients with unstable angina and the use of treadmill testing in chest pain centers. They replace text and Table 17 that originally appeared under the major heading "Risk Stratification" and the subheading "Unstable Angina," beginning on page 280 (first column).

Patients With Acute Coronary Syndrome

Acute coronary syndrome (unstable angina or acute myocardial infarction) represents an acute phase in the life cycle of the patient with chronic coronary disease. It may be a presenting feature or may interrupt a quiescent phase of clinically manifested disease. The natural history of ACS involves progression to either death or myocardial infarction on the one hand or return to the chronic stable phase of CAD on the other. These events typically play out over a period of 4 to 6 weeks. Thus, the role and timing of exercise testing in ACS relates to this acute and convalescent period.

REVISED TABLE 17. Short-Term Risk of Death or Nonfatal Myocardial Infarction in Patients With Unstable Angina

	High Risk	Intermediate Risk	Low Risk
Feature	At least 1 of the following features must be present:	No high-risk feature but must have 1 of the following:	No high- or intermediate-risk feature but may have any of the following features:
History		Prior MI, peripheral or cerebrovascular disease, or CABG or prior aspirin use	
Character of pain	Prolonged ongoing (greater than 20 minutes) rest pain	Prolonged (greater than 20 minutes) rest angina, now resolved, with moderate or high likelihood of CAD Rest angina (less than 20 minutes) or relieved with rest or sublingual NTG)	New-onset or progressive CCSC III or IV angina in the past 2 weeks with moderate or high likelihood of CAD
Clinical findings	Pulmonary edema, most likely related to ischemia New or worsening MR murmur S ₃ or new/worsening rales Hypotension, bradycardia, tachycardia Age older than 75 years	Age older than 70 years	
ECG findings	Angina at rest with transient ST changes greater than 0.05 mV BBB, new or presumed new Sustained ventricular tachycardia	T-wave inversions greater than 0.2 mV Pathological Q waves	Normal or unchanged ECG during an episode of chest discomfort
Biochemical cardiac markers	Elevated (eg, troponin T or I greater than 0.1 mg/mL)	Slightly elevated (eg, troponin T greater than 0.01 but less than 0.1 mg/mL)	Normal

MI indicates myocardial infarction; CABG, coronary artery bypass graft; CAD, coronary artery disease; NTG, nitroglycerin; CCSC, Canadian Cardiovascular Society Classification; MR, mitral regurgitation; ECG, electrocardiography; and BBB, bundle-branch block.

Estimation of the short-term risks of death and nonfatal cardiac ischemic events in unstable angina is a complex multivariable problem that cannot be fully specified in a table such as this. Therefore, the table is meant to offer general guidance and illustration rather than rigid algorithms. Adapted from Agency for Health Care Policy and Research Clinical Practice Guideline No. 10, Unstable Angina: Diagnosis and Management, May 1994.

The ACC/AHA 2002 Guideline Update for the Management of Patients With Unstable Angina and Non-ST-Segment Elevation Myocardial Infarction has been published.²³ A clinical risk stratification algorithm useful for selecting the initial management strategy is seen in the revised Table 17. Patients are separated into low-, intermediate-, or high-risk groups based on history, physical examination, initial 12-lead ECG, and cardiac markers. (Note that this table is meant to be illustrative rather than comprehensive or definitive.) Low-risk patients, who include patients with new-onset or progressive angina with symptoms provoked by walking 1 block or 1 flight of stairs, in this scheme can typically be treated on an outpatient basis. Most intermediate-risk patients can be cared for in a monitored hospital bed, whereas high-risk patients are typically admitted to an intensive care unit.

Exercise or pharmacological stress testing should generally be an integral part of the evaluation of low-risk patients with unstable angina who are evaluated on an outpatient basis. In most cases, testing should be performed within 72 hours of presentation. In low- or intermediate-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. In low-risk patients, testing can be performed when patients have been free of active ischemic or heart failure symptoms for a minimum of 8 to 12 hours.²³ Intermediate-risk patients can be tested after 2 to 3 days, but selected patients can be evaluated earlier as part of a carefully constructed chest pain

management protocol (see section on chest pain centers below). In general, as with patients with stable angina, the exercise treadmill test should be the standard mode of stress testing in patients with a normal resting ECG who are not taking digoxin.

A majority of patients with unstable angina have an underlying ruptured plaque and significant CAD. Some have a ruptured plaque without angiographically significant lesions in any coronary segment. Still others have no evidence of a ruptured plaque or atherosclerotic coronary lesions. Little evidence exists with which to define the safety of early exercise testing in unstable angina.^{24,25} One review of this area found 3 studies covering 632 patients with stabilized unstable angina who had a 0.5% death or myocardial infarction rate within 24 hours of their exercise test.²⁵

The limited evidence available supports the use of exercise testing in acute coronary syndrome patients with appropriate indications as soon as the patient has stabilized clinically. Larsson and colleagues²⁶ compared a symptom-limited pre-discharge (3 to 7 days) exercise test with a test performed at 1 month in 189 patients with unstable angina or non-Q-wave infarction. The prognostic value of the 2 tests was similar, but the earlier test identified additional patients who would experience events during the period before the 1-month exercise test. In this population, these earlier events represented one half of all events occurring during the first year.

The Research on Instability in Coronary Artery Disease (RISC) study group²⁷ examined the use of pre-discharge symptom-limited bicycle exercise testing in 740 men admit-

TABLE 17A. Summary of Studies Using Exercise ECG Testing in Chest Pain Centers

Group (year)	Reference	No. of Subjects	Follow-Up Period	Exercise ECG	Adverse Events*	% Disease Prevalence	Clinical Outcome
Tsakonis et al (1991)	31	28	6.1 mo	Modified Bruce (SLM)	0	0	Exercise testing was safe
Kerns et al (1993)	32	32	6 mo	Bruce (APMHR)	0	0	Exercise testing was safe
Gibler et al (1995)	29	1010	30 d	Bruce (SLM)	0	5	Reduced cost vs admission Sensitivity=29% Specificity=99.4% Positive predictive value=44%† Negative predictive value=98.7%†
Gomez et al (1996)	33	50, plus 50 controls	None	Cornell (SLM)	0	6	No difference in clinical outcome Reduced cost vs admitted control
Zalenski et al (1998)	34	317	None; patients admitted for reference diagnosis	Modified Bruce	0	9.5	Sensitivity=90% Specificity=50%‡ Negative predictive value=98%‡
Polanczyk et al (1998)	35	276§	6 mo	Modified Bruce	0	25	Sensitivity=73% Specificity 74% Negative predictive value=98%
Farkouh et al (1998)	30	424	6 mo	Not specified	0		Intermediate-risk patients were studied No difference in clinical outcomes¶ Reduced cost vs admitted control

SLM indicates symptom-limited maximum end point; APMHR, age-predicted maximum heart rate end point.

*Death or myocardial infarction.

†With respect to diagnosis if admitted, and 30-day follow-up on all patients.

‡With respect to reference diagnosis from admission of all patients.

§Included 70 patients (25%) with a history of coronary heart disease.

¶Comparison of those admitted to hospital vs chest pain center.

Reprinted with permission from Stein et al, *Circulation*. 2000;102:1463–1467.²⁵

ted with unstable angina (51%) or non-Q-wave myocardial infarction (49%). The major independent predictors of 1-year infarction-free survival in multivariable regression analysis were the number of leads with ischemic ST-segment depression and peak exercise workload achieved.

In 766 unstable angina patients enrolled in the FRISC study between 1992 and 1994 who had both a troponin T level and a predischARGE exercise test, the combination of a positive troponin T and exercise-induced ST depression stratified patients into groups with a risk of death or MI ranging from 1% to 20%.²⁸ In 395 women enrolled in FRISC I with stabilized unstable angina who underwent a symptom-limited stress test at days 5 to 8, risk for cardiac events in the next 6 months could be stratified from 1% to 19%. Important exercise variables included not only ischemic parameters such as ST depression and chest pain but also parameters that reflected cardiac workload.

Chest Pain Centers

Over the last decade, an increasing experience has been gained with the use of exercise testing in emergency department chest pain centers (see new Table 17a).²⁵ The goal of a chest pain center is to provide rapid and efficient risk stratification and management for chest pain patients believed to possibly have acute coronary disease. A variety of physical and administrative setups have been used for chest pain centers in medical centers across the country; review of these

details is beyond the scope of these guidelines. In most of the published series, exercise testing has been reserved for the investigation of patients who are low risk on the basis of history and physical examination, 12-lead ECG, and serum markers. In the study by Gibler et al,²⁹ 1010 patients were evaluated by clinical examination, 9 hours of continuous ST monitoring, serial 12-lead ECGs, serial measurement of creatine kinase-MB, and resting echocardiograms. Patients without high-risk markers on the basis of this evaluation (78%) underwent a symptom-limited Bruce exercise ECG test. There were no adverse events from the testing, and the authors estimated a 5% prevalence of CAD in the tested population. These results are generally representative of the results in the approximately 2100 chest pain patients who have undergone exercise testing as part of a chest pain center protocol report (see new Table 17a).²⁵ The prevalence of CAD is extremely low in such chest pain patients, and the risk of adverse events with testing is correspondingly low.

Farkouh and colleagues from the Mayo Clinic examined the use of exercise testing in 424 intermediate-risk unstable angina patients (as defined by the ACC/AHA Committee to Develop Guidelines for the Management of Patients With Unstable Angina) as part of a randomized trial of admission to a chest pain unit versus standard hospital admission.³⁰ There was no significant difference in event rates (death, myocardial infarction, or congestive heart failure) between the 212 patients in the hospital admission group and the 212

Modification V

1997 Exercise Testing Guideline Recommendation

2002 Exercise Testing Guideline Recommendation

Class I

1. Before discharge for prognostic assessment, activity prescription, 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
 - Pre-excitation 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.

Class I

1. Before discharge for prognostic assessment, activity prescription, evaluation of medical therapy (submaximal at about 4 to 6 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. Patients with the following ECG abnormalities:
 - Complete left bundle-branch block
 - Pre-excitation syndrome
 - Left ventricular hypertrophy
 - Digoxin therapy
 - Greater than 1 mm of resting ST-segment depression
 - Electronically paced ventricular rhythm
2. 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.
2. At any time to evaluate patients with acute myocardial infarction who have uncompensated congestive heart failure, cardiac arrhythmia, or noncardiac conditions that severely limit their ability to exercise. (*Level of Evidence: C*)
3. Before discharge to evaluate patients who have already been selected for, or have undergone, cardiac catheterization. Although a stress test may be useful before or after catheterization to evaluate or identify ischemia in the distribution of a coronary lesion of borderline severity, stress imaging tests are recommended. (*Level of Evidence: C*)

*Exceptions are noted under Classes IIb and III.

patients in the chest pain unit group. Of the total chest pain unit group, 60 patients met the criteria for hospitalization before stress testing, 55 had an indeterminate or high-risk test result, and 97 had a negative stress test. There were no complications directly attributable to the performance of a stress test in these patients.

These results demonstrate that exercise testing is safe in low-risk chest pain patients who present to the emergency department. In addition, testing appears safe in carefully selected intermediate-risk patients. Use of early exercise testing in emergency department chest pain centers improves the efficiency of management of these patients (and may lower costs) without compromising safety. However, exercise testing in this setting should only be done as part of a carefully constructed management protocol and only after the

patients have been screened for high-risk features or other indicators for hospital admission.

Modification V

These revised recommendations (see top of page) incorporate additional details that were published in the ACC/AHA Guidelines for Management of Patients With Acute Myocardial Infarction. They are incorporated here to ensure consistency between guidelines. In the original text, these recommendations appeared under the major heading "Myocardial Infarction" beginning on page 280 (second paragraph).

Modification VI

These new recommendations (see next page) incorporate an additional recommendation regarding the use of exercise

Modification VI

1997 Exercise Testing Guideline Recommendation

2002 Exercise Testing Guideline Recommendation

Class IIa**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.

*Multiple risk factors are defined³⁶ as hypercholesterolemia (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.³⁸

testing in asymptomatic diabetic patients. These recommendations originally appeared under the major heading "Special Groups" and the subheading "Asymptomatic Persons," beginning on page 290 (first column).

Modification VII

This revised text clarifies the new recommendation on asymptomatic diabetic persons. It replaces text that originally appeared under the major headings of "Special Groups" and the subheading "Asymptomatic Persons," beginning on page 291 (second column).

On the basis of prognostic considerations, asymptomatic male patients older than 45 years with 1 or more risk factors (hypercholesterolemia, hypertension, smoking, diabetes, or family history of premature CAD) may obtain useful prog-

Class IIa

1. Evaluation of asymptomatic persons with diabetes mellitus who plan to start vigorous exercise. (Level of Evidence: C)

Class IIb

1. Evaluation of persons with multiple risk factors as a guide to risk-reduction therapy.*
2. Evaluation of asymptomatic men older than 45 years and women older than 55 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, peripheral vascular disease and chronic renal failure)

Class III

1. Routine screening of asymptomatic men or women.

nostic information from exercise testing. The greater the number of risk factors (ie, pretest probability), the more likely the patient will profit from screening. For these purposes, risk factors should be strictly defined³⁶: hypercholesterolemia as total cholesterol greater than 240 mg per dL, hypertension as systolic blood pressure greater than 140 mm Hg or diastolic blood pressure greater than 90 mm Hg, smoking, diabetes, and history of heart attack or sudden cardiac death in a first-degree relative less than 60 years old. The importance of more intensive risk factor management in diabetic persons has been increasingly recognized, as reflected in the most recent national guidelines for cholesterol management (ATP III), hypertension (JNC VI), and diabetes control (see <http://www.diabetes.org/main/info/link.jsp>). In asymptomatic diabetic persons, the likelihood of cardiovascular disease is

Modification VIII

1997 Exercise Testing Guideline Recommendation

2002 Exercise Testing Guideline Recommendation

Class I**Class IIa****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.

Class I

1. In chronic aortic regurgitation, assessment of functional capacity and symptomatic responses in patients with a history of equivocal symptoms.

Class IIa

1. In chronic aortic regurgitation, evaluation of symptoms and functional capacity before participation in athletic activities.
2. In chronic aortic regurgitation, prognostic assessment before aortic valve replacement in asymptomatic or minimally symptomatic patients with left ventricular dysfunction.

Class IIb

1. Evaluation of exercise capacity in patients with valvular heart disease. Comprehensive discussion is found in the ACC/AHA valvular heart disease guidelines.

Class III

1. Diagnosis of CAD in patients with moderate to severe valvular disease or with the following baseline ECG abnormalities:
 - Pre-excitation
 - Electronically paced ventricular rhythm
 - Greater than 1 mm of ST depression
 - Complete left bundle-branch block

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

Modification IX

1997 Exercise Testing Guideline Recommendation

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.

2002 Exercise Testing Guideline Recommendation

Class I

1. Identification of appropriate settings in patients with rate-adaptive pacemakers.
2. Evaluation of congenital complete heart block in patients considering increased physical activity or participation in competitive sports. (*Level of Evidence: C*)

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.
2. Investigation of prolonged first-degree atrioventricular block or type I second degree Wenckebach, left bundle-branch block, right bundle-branch block, or isolated ectopic beats in young patients considering participation in competitive sports. (*Level of Evidence: C*)

Class III

1. Routine investigation of isolated ectopic beats in young patients.

increased if at least 1 of the following is present: age older than 35 years, type 2 diabetes greater than 10 years' duration, type 1 diabetes greater than 15 years' duration, any additional atherosclerotic risk factor for CAD, presence of microvascular disease (proliferative retinopathy or nephropathy, including microalbuminuria), peripheral vascular disease, or autonomic neuropathy. Exercise testing is recommended if an individual meeting the criteria is about to embark on moderate- to high-intensity exercise.³⁷ An alternative approach would be to study patients with a certain level of cardiovascular risk expressed as a continuous variable and therefore accounting for not only the presence but also the severity of risk factors. Such data have been derived in asymptomatic persons from the Framingham study.³⁸ Attempts to extend screening to persons with lower degrees of risk are not recommended because screening is unlikely to improve patient outcome.

Modification VIII

These revised recommendations (see bottom of previous page) include many more detailed recommendations that appeared in the ACC/AHA guidelines for management of patients with valvular heart disease. They are incorporated here to ensure consistency across the guidelines. These recommendations originally appeared under the major heading "Special Groups" and the subheading "Valvular Heart Disease," beginning on page 293 (second column). Additional text on this subject appears in the revised full-text guidelines on the Internet.

Modification IX

These revised recommendations (see top of page) for the use of exercise testing in the investigation of heart rhythm disorders incorporate additional recommendations that ap-

peared in an earlier Bethesda conference on the subject of screening competitive athletes. They are incorporated here to ensure consistency among ACC statements. These recommendations originally appeared under the major heading "Special Groups" and the subheading "Investigation of Heart Rhythm Disorders," beginning on page 296 (first column).

Modification X

This new text describes the additional special group of patients with hypertension. It represents a new subheading, "Special Groups," under the original heading "Evaluation of Hypertension," beginning on page 297 (first column).

Evaluation of Hypertension

Exercise testing has been used to identify patients with abnormal blood pressure response destined to develop hypertension. Identification of such patients may allow preventive measures that would delay or prevent the onset of this disease. In asymptomatic normotensive subjects, an exaggerated exercise systolic and diastolic blood pressure response during exercise, exaggerated peak systolic blood pressure greater than 214 mm Hg, or elevated systolic or diastolic blood pressure at 3 minutes into recovery is associated with significant increased long-term risk of hypertension.^{39,40} Exercise tolerance is decreased in patients with poor blood pressure control,⁴¹ and severe systemic hypertension may cause exercise-induced ST depression in the absence of atherosclerosis.⁴²

Replacement and New References

(References from the 1997 guidelines appear in normal type; new references appear in boldface type.)

1. Elamin MS, Boyle R, Kardash MM, et al. Accurate detection of coronary heart disease by new exercise test. *Br Heart J.* 1982;48:311-320.

2. Okin PM, Kligfield P. Computer-based implementation of the ST-segment/heart rate slope. *Am J Cardiol.* 1989;64:926–930.
3. Detrano R, Salcedo E, Passalacqua M, et al. Exercise electrocardiographic variables: a critical appraisal. *J Am Coll Cardiol.* 1986;8:836–847.
4. Lachterman B, Lehmann KG, Detrano R, et al. Comparison of ST segment/heart rate index to standard ST criteria for analysis of exercise electrocardiogram. *Circulation.* 1990;82:44–50.
5. Fletcher GF, Flipse TR, Kligfield P, et al. Current status of ECG stress testing. *Curr Probl Cardiol.* 1998;23:353–423.
6. Okin PM, Kligfield P. Heart rate adjustment of ST segment depression and performance of the exercise electrocardiogram: a critical evaluation. *J Am Coll Cardiol.* 1995;25:1726–1735.
7. Morise AP. Accuracy of heart rate-adjusted ST segments in populations with and without posttest referral bias. *Am Heart J.* 1997;134:647–655.
8. Okin PM, Roman MJ, Schwartz JE, et al. Relation of exercise-induced myocardial ischemia to cardiac and carotid structure. *Hypertension.* 1997;30:1382–1388.
9. Viik J, Lehtinen R, Malmivuo J. Detection of coronary artery disease using maximum value of ST/HR hysteresis over different number of leads. *J Electrocardiol.* 1999;32(suppl):70–75.
10. Froelicher VF, Lehmann KG, Thomas R, et al, for the Veterans Affairs Cooperative Study in Health Services #016 (QUENTA) Study Group: Quantitative Exercise Testing and Angiography. The electrocardiographic exercise test in a population with reduced workup bias: diagnostic performance, computerized interpretation, and multivariable prediction. *Ann Intern Med.* 1998;128:965–974.
11. Okin PM, Anderson KM, Levy D, et al. Heart rate adjustment of exercise-induced ST segment depression: improved risk stratification in the Framingham Offspring Study. *Circulation.* 1991;83:866–874.
12. Okin PM, Grandits G, Rautaharju PM, et al. Prognostic value of heart rate adjustment of exercise-induced ST segment depression in the Multiple Risk Factor Intervention Trial. *J Am Coll Cardiol.* 1996;27:1437–1443.
13. Okin PM, Prineas RJ, Grandits G, et al. Heart rate adjustment of exercise-induced ST-segment depression identifies men who benefit from a risk factor reduction program. *Circulation.* 1997;96:2899–904.
14. Goraya TY, Jacobsen SJ, Pellikka PA, et al. Prognostic value of treadmill exercise testing in elderly persons. *Ann Intern Med.* 2000;132:862–870.
15. Morrow K, Morris CK, Froelicher VF, et al. Prediction of cardiovascular death in men undergoing noninvasive evaluation for coronary artery disease. *Ann Intern Med.* 1993;118:689–695.
16. Lauer MS, Okin PM, Larson MG, et al. Impaired heart rate response to graded exercise: prognostic implications of chronotropic incompetence in the Framingham Heart Study. *Circulation.* 1996;93:1520–1526.
17. Lauer MS, Francis GS, Okin PM, et al. Impaired chronotropic response to exercise stress testing as a predictor of mortality. *JAMA.* 1999;281:524–529.
18. Cole CR, Blackstone EH, Pashkow FJ, et al. Heart-rate recovery immediately after exercise as a predictor of mortality. *N Engl J Med.* 1999;341:1351–1357.
19. McHam SA, Marwick TH, Pashkow FJ, et al. Delayed systolic blood pressure recovery after graded exercise: an independent correlate of angiographic coronary disease. *J Am Coll Cardiol.* 1999;34:754–759.
20. Nishime EO, Cole CR, Blackstone EH, et al. Heart rate recovery and treadmill exercise score as predictors of mortality in patients referred for exercise ECG. *JAMA.* 2000;284:1392–1398.
21. Hachamovitch R, Berman DS, Kiat H, et al. Exercise myocardial perfusion SPECT in patients without known coronary artery disease: incremental prognostic value and use in risk stratification. *Circulation.* 1996;93:905–914.
22. Gibbons RJ, Hodge DO, Berman DS, et al. Long-term outcome of patients with intermediate-risk exercise electrocardiograms who do not have myocardial perfusion defects on radionuclide imaging. *Circulation.* 1999;100:2140–2145.
23. Braunwald E, Antman EM, Beasley JW, et al. ACC/AHA 2002 guideline update for the management of patients with unstable angina and non-ST-segment elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on the Management of Patients With Unstable Angina). 2002. Available at: <http://www.acc.org/clinical/guidelines/unstable/unstable.pdf>.
24. Butman SM, Olson HG, Gardin JM, et al. Submaximal exercise testing after stabilization of unstable angina pectoris. *J Am Coll Cardiol.* 1984;4:667–673.
25. Stein RA, Chaitman BR, Balady GJ, et al. 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.
26. Larsson H, Areskog M, Areskog NH, et al. Should the exercise test (ET) be performed at discharge or one month later after an episode of unstable angina or non-Q-wave myocardial infarction? *Int J Card Imaging.* 1991;7:7–14.
27. Nyman I, Larsson H, Areskog M, et al, for the RISC Study Group. The predictive value of silent ischemia at an exercise test before discharge after an episode of unstable coronary artery disease. *Am Heart J.* 1992;123:324–331.
28. Lindahl B, Andren B, Ohlsson J, et al, for the FRISC Study Group. Risk stratification in unstable coronary artery disease. Additive value of troponin T determinations and pre-discharge exercise tests. *Eur Heart J.* 1997;18:762–770.
29. Gibler WB, Runyon JP, Levy RC, et al. A rapid diagnostic and treatment center for patients with chest pain in the emergency department. *Ann Emerg Med.* 1995;25:1–8.
30. Farkouh ME, Smars PA, Reeder GS, et al, for the Chest Pain Evaluation in the Emergency Room (CHEER) Investigators. A clinical trial of a chest-pain observation unit for patients with unstable angina. *N Engl J Med.* 1998;339:1882–1888.
31. Tsakonis JS, Shesser R, Rosenthal R, et al. Safety of immediate treadmill testing in selected emergency department patients with chest pain: a preliminary report. *Am J Emerg Med.* 1991;9:557–559.
32. Kerns JR, Shaub TF, Fontanarosa PB. Emergency cardiac stress testing in the evaluation of emergency department patients with atypical chest pain. *Ann Emerg Med.* 1993;22:794–798.
33. Gomez MA, Anderson JL, Karagounis LA, et al. An emergency department-based protocol for rapidly ruling out myocardial ischemia reduces hospital time and expense: results of a randomized study (ROMIO). *J Am Coll Cardiol.* 1996;28:25–33.
34. Zalenski RJ, Rydman RJ, Ting S, et al. A national survey of emergency department chest pain centers in the United States. *Am J Cardiol.* 1998;81:1305–1309.
35. Polanczyk CA, Lee TH, Cook EF, et al. Cardiac troponin I as a predictor of major cardiac events in emergency department patients with acute chest pain. *J Am Coll Cardiol.* 1998;32:8–14.
36. Bruce RA, DeRouen TA, Hossack KF. Pilot study examining the motivational effects of maximal exercise testing to modify risk factors and health habits. *Cardiology.* 1980;66:111–119.
37. Diabetes mellitus and exercise: a position statement by the American Diabetes Association. *Diabetes Care.* 2000;23(Suppl 1).
38. Anderson KM, Wilson PW, Odell PM, et al. An updated coronary risk profile: a statement for health professionals. *Circulation.* 1991;83:356–362.
39. Singh JP, Larson MG, Manolio TA, et al. Blood pressure response during treadmill testing as a risk factor for new-onset hypertension: the Framingham heart study. *Circulation.* 1999;99:1831–1836.
40. Allison TG, Cordeiro MA, Miller TD, et al. Prognostic significance of exercise-induced systemic hypertension in healthy subjects. *Am J Cardiol.* 1999;83:371–375.
41. Lim PO, MacFadyen RJ, Clarkson PB, et al. Impaired exercise tolerance in hypertensive patients. *Ann Intern Med.* 1996;124:41–55.
42. Otterstad JE, Davies M, Ball SG, et al. Left ventricular hypertrophy and myocardial ischaemia in hypertension: the THAMES Study. *Eur Heart J.* 1993;14:1622–1628.

KEY WORDS: ACC/AHA Scientific Statements ■ coronary disease ■ electrocardiography ■ exercise ■ tests