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 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 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 manually (1) 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 report (7) of 1358 individuals undergoing exercise testing (only 152 with catheterization data) and the report by Okin et al (8) regarding heart rate reserve (238 controls and 337 patients with
coronary disease). 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 study (7) 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 colleagues (15) 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:

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

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

<table>
<thead>
<tr>
<th>Feature</th>
<th>High Risk</th>
<th>Intermediate Risk</th>
<th>Low Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>History</td>
<td>At least 1 of the following features must be present:</td>
<td>No high-risk feature but must have 1 of the following:</td>
<td>No high- or intermediate-risk feature but may have any of the following features:</td>
</tr>
<tr>
<td>Character of pain</td>
<td>Prolonged ongoing (greater than 20 minutes) rest pain</td>
<td>Prolonged (greater than 20 minutes) rest angina, now resolved, with moderate or high likelihood of CAD</td>
<td>New-onset or progressive CCS III or IV angina in the past 2 weeks with moderate or high likelihood of CAD</td>
</tr>
<tr>
<td>Clinical findings</td>
<td>Pulmonary edema, most likely related to ischemia</td>
<td>Age older than 70 years</td>
<td></td>
</tr>
<tr>
<td>ECG findings</td>
<td>Angina at rest with transient ST changes greater than 0.05 mV</td>
<td>T-wave inversions greater than 0.2 mV</td>
<td>Normal or unchanged ECG during an episode of chest discomfort</td>
</tr>
<tr>
<td>Biochemical cardiac markers</td>
<td>Elevated (eg, troponin T or I greater than 0.1 mg/mL)</td>
<td>Slightly elevated (eg, troponin T greater than 0.01 but less than 0.1 mg/mL)</td>
<td>Normal</td>
</tr>
</tbody>
</table>

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.

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 colleagues (26) compared a symptom-limited predischarge (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 group (27) examined the use of predischarge...
symptom-limited bicycle exercise testing in 740 men admitted 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 1 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 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 testing in asymptomatic diabetic patients. These recommen-
dations 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 prognostic 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 defined (36): 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 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).

*Multiple risk factors are defined 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).

Modification VIII

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Class I</strong></td>
<td><strong>Class I</strong></td>
</tr>
<tr>
<td><strong>Class IIa</strong></td>
<td><strong>Class IIa</strong></td>
</tr>
<tr>
<td>1. Evaluation of asymptomatic persons with diabetes mellitus who plan to start vigorous exercise. <em>(Level of Evidence: C)</em></td>
<td>1. Evaluation of asymptomatic persons with diabetes mellitus who plan to start vigorous exercise. <em>(Level of Evidence: C)</em></td>
</tr>
<tr>
<td><strong>Class IIb</strong></td>
<td><strong>Class IIb</strong></td>
</tr>
<tr>
<td>1. Evaluation of asymptomatic men older than 45 years and women older than 55 years:</td>
<td>1. Evaluation of asymptomatic men older than 45 years and women older than 55 years:</td>
</tr>
<tr>
<td>- Who plan to start vigorous exercise (especially if sedentary) or</td>
<td>- Who plan to start vigorous exercise (especially if sedentary) or</td>
</tr>
<tr>
<td>- Who are involved in occupations in which impairment might impact public safety or</td>
<td>- Who are involved in occupations in which impairment might impact public safety or</td>
</tr>
<tr>
<td>- Who are at high risk for CAD due to other diseases (eg, chronic renal failure)</td>
<td>- Who are at high risk for CAD due to other diseases (eg, peripheral vascular disease and chronic renal failure)</td>
</tr>
<tr>
<td><strong>Class III</strong></td>
<td><strong>Class III</strong></td>
</tr>
<tr>
<td>1. Routine screening of asymptomatic men or women.</td>
<td>1. Routine screening of asymptomatic men or women.</td>
</tr>
</tbody>
</table>

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

### 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

Disorders incorporate additional recommendations that appeared 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).

### Replacement and New References

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


