

The Role of the Exercise Stress Test in the Adult

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The use, limitations, and value of the exercise stress test have been under debate in the recent cardiology literature.¹⁻⁵ The purpose of this discussion is to examine the current role of the stress test.

Procedure

Common reasons for obtaining a stress test are:

1. Chest pain evaluation;
2. Screening for coronary heart disease in asymptomatic persons;
3. Post-myocardial infarction, including rehabilitation;
4. Angina pectoris evaluation;
5. Arrhythmia evaluation—complementary to Holter monitoring; this is less sensitive than the 24-hour Holter monitor but will detect arrhythmias not present on the Holter recording;
6. Functional capacity evaluation (also used in valvular heart disease and other types of heart disease);
7. Evaluation of therapy (coronary bypass surgery, antiarrhythmic agents, propranolol, rehabilitation programs).

Patients with the following problems are usually not exercised:

1. Recent myocardial infarction (although the test can be done at three weeks to a heart rate of 130 or symptoms, or at two to three months to 85% of predicted maximal heart rate):

2. Acute myocarditis or pericarditis;
3. Acute coronary insufficiency or unstable angina pectoris (since an exercise test can precipitate a myocardial infarction, it is preferable to wait two to three weeks until the patients's condition is stable);
4. Rapid ventricular or atrial arrhythmias;
5. Second- or third-degree heart block;
6. Congestive heart failure;
7. Acutely ill patients (infections, hyperthyroidism);
8. Severe symptomatic aortic stenosis.

For practical purposes, ST-segment changes cannot be interpreted in the presence of digitalis, left bundle-branch block, left ventricular hypertrophy with the ST-T wave changes of the left ventricular strain pattern on the resting ECG, or the Wolff-Parkinson-White syndrome. The stress test is more difficult to interpret in patients with resting ST-T wave changes, particularly in women. If possible, cardiac medications should be discontinued prior to the test.

There are many different protocols for exercise tests. I prefer the submaximal graded treadmill exercise test, using the Bruce protocol.⁶ This is a continuous test with incremental increases in the elevation and speed of the treadmill every three minutes (Table 1). Patients are exercised to a target heart rate which is 90% of their age-predicted maximum heart rate (Table 2). The predicted maximum heart rate for untrained individuals is $205 - .41$ (age, years) beats/minute and for athletically trained persons is $198 - .41$ (age, years).⁷ Post-myocardial infarction patients are exercised to 85%

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TABLE 1
Bruce Protocol

STAGE	SPEED (mph)	GRADE (%)
1	1.7	10
2	2.5	12
3	3.4	14
4	4.2	16
5	5.0	18
6	5.5	20
7	6.0	22

of their age-predicted maximum heart rate. Thus, the stress test requires a considerable amount of effort on the part of the patient.

The major reasons for stopping an exercise test are as follows:

1. Target heart rate achieved;
2. Chest pain typical of angina pectoris;
3. Arrhythmias such as
 - a. premature ventricular contractions—pairs, bigeminy, R on T, or increasing frequency,
 - b. ventricular tachycardia (≥ 3 PVCs),
 - c. atrial fibrillation, flutter, tachycardia,
 - d. heart block—second- or third-degree;
4. Marked hypertension (>250 mm Hg systolic);
5. Hypotension with continuing exercise (>10 mm Hg fall in systolic pressure);
6. Fatigue, weakness, dyspnea;
7. Cerebral symptoms such as dizziness;
8. Intermittent claudication;
9. Decrease in heart rate with continuing exercise;
10. Marked ST-segment depression;
11. General appearance—pale, vasoconstricted appearance.

Interpretation

The interpretation of the exercise test is based on ST-segment changes, although there are other factors to be considered. The exercise test is considered positive when there is 1 mm of additional ST-segment depression which is horizontal or down-sloping for at least .08 seconds (Fig 1) or 1 mm of ST-segment elevation in an ECG lead without Q waves. When ST-segment elevation occurs with exercise in a lead without Q waves, there is usually a very critical narrowing of at least one of the coronary arteries. The following are other findings which should be considered in the interpretation of the exercise test:

1. Chest pain typical of angina pectoris during the test should be recorded in the interpretation.
2. An increase in R wave height with exercise in the left precordial leads is abnormal.⁸ Patients without coronary heart disease decrease their systolic and diastolic volume progressively with exercise which results in a decrease in R wave height; the ischemic ventricle is unable to decrease its volume and R wave height increases.
3. Inverted U waves in the absence of antiarrhythmic drugs or left ventricular hypertrophy; incidence is probably small.
4. Hypotensive response to exercise: A fall in systolic blood pressure of 10 mm Hg or more is abnormal; other etiologies of severe heart disease and vasovagal responses must be excluded.
5. Ventricular arrhythmias: Premature ventricular contractions at low heart rates (below 130) with exercise in patients who do not have PVCs at rest;

TABLE 2
Maximal Heart Rates (MHR)

	AGE (years)												
	20	25	30	35	40	45	50	55	60	65	70	75	80
	PHYSICALLY TRAINED												
MHR	197	195	193	191	189	187	184	182	180	178	176	174	172
90% MHR	177	175	173	172	170	168	166	164	162	160	158	157	155
85% MHR	167	166	164	162	161	160	156	155	153	151	150	148	146
	PHYSICALLY UNTRAINED												
MHR	190	188	186	184	182	180	177	175	173	171	169	167	165
90% MHR	171	169	167	166	164	162	159	158	156	154	152	150	149
85% MHR	161	160	158	156	155	153	150	149	147	145	144	142	140

these are probably not specific for coronary heart disease.

6. Development of a pansystolic murmur of mitral regurgitation.

The interpretation of the exercise test must be assessed in the clinical setting in which it occurs. The largest amount of information is available in patients with chest pain. A few years ago we evaluated the sensitivity and specificity of the exercise test in 124 patients with chest pain undergoing coronary arteriography.⁹ The criterion for a positive exercise test was 1 mm of additional ST-segment depression (or elevation) which was horizontal or down-sloping for .08 second. Sixty-five patients had greater than a 50% narrowing of one coronary artery; 49 (75%) of these had a positive exercise test; thus there were 25% false-negatives. Fifty-nine patients had less than a 50% narrowing in any coronary artery; 4 (7%) had a positive exercise test and were considered to be false-positives. This sensitivity of 75% and

specificity of 93% is comparable to eight other studies¹⁰⁻¹⁷ where sensitivity ranged from 54% to 80% and specificity from 88% to 97%. The sensitivity of the exercise test will be higher in patients with three-vessel disease than in patients with single-vessel disease. The use of slowly up-sloping ST segments with ST-segment depression greater than or equal to 1.5 mm at 80 msec after the J point increased the sensitivity in one study from 64% to 76% but decreased specificity from 93% to 82%.¹⁷ It is important to realize that most false-negative calculations include only those patients who reach their target heart rate.

In general, patients with more severe coronary artery disease will have an exercise test which is positive at lower heart rates and during the early stages of the test. We compared the maximum heart rate achieved during an exercise test with the severity of coronary artery disease on angiography¹⁸ in 40 patients with a positive exercise test.⁸ There was a significant

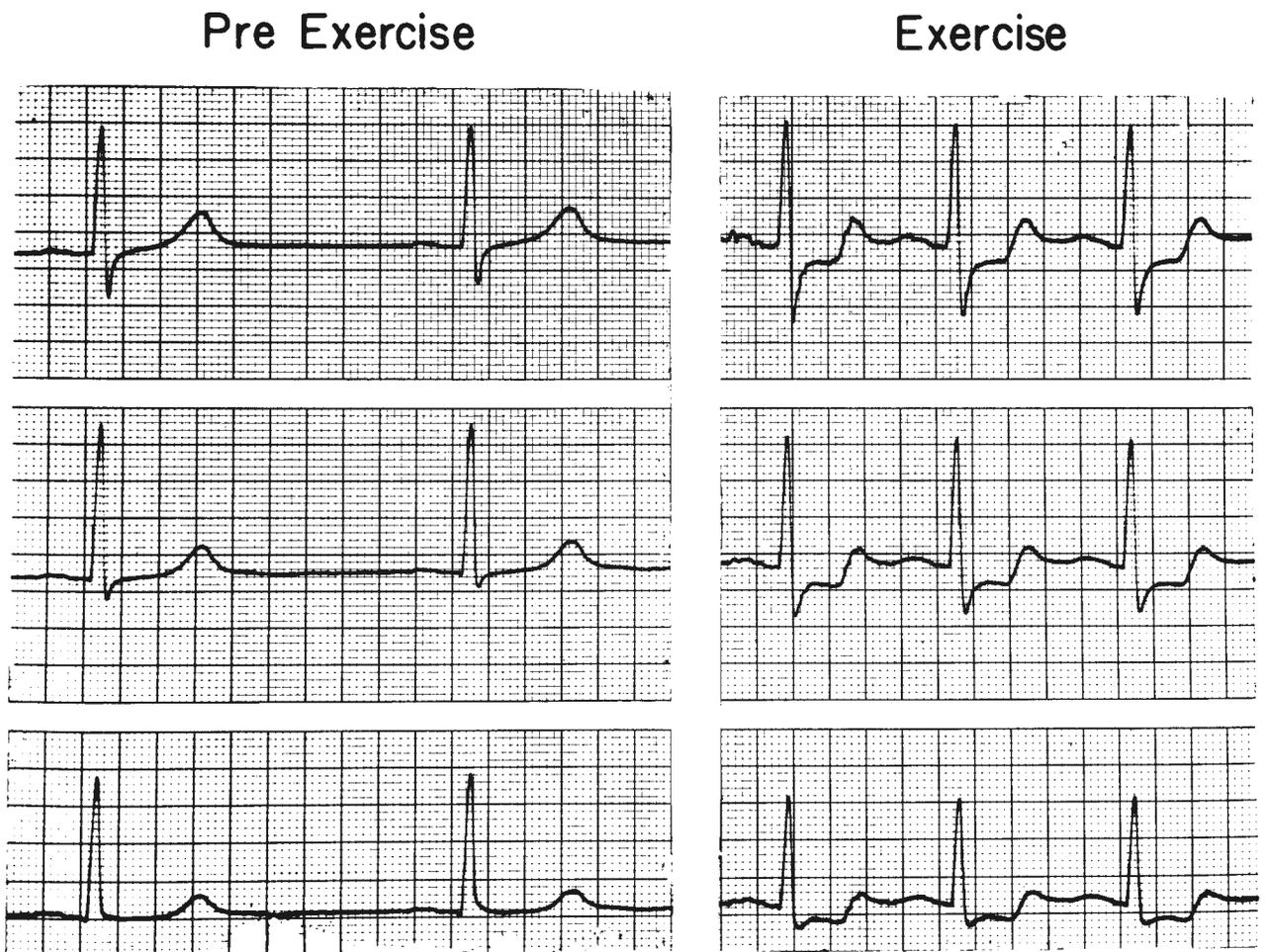


Fig 1—Example of positive exercise test. In the exercise tracing there is more than 1 mm of ST-segment depression which is horizontal and persists for more than .08 seconds.

inverse correlation ($p > .001$, $r = -0.62$) between the severity of coronary artery disease and the maximum heart rate achieved (Fig 2). In a recent study patients who had a positive exercise test in stage I or II had: (1) greater than a 60% chance of having three-vessel disease, (2) greater than a 25% chance of having main left coronary artery disease, (3) greater than a 97% chance of having coronary heart disease, and (4) nonsurgical patients had a survival rate of 85% at one year and 63% at four years.¹⁹

In post-myocardial infarction patients the diagnosis of coronary artery disease is established, but the exercise test may provide useful information. A recent study has shown that an exercise test to symptoms, or a heart rate of 130, is safe at three weeks post-infarction.²⁰ Patients with a positive test based on ST-segment depression have a significantly higher incidence of cardiac events during the next eighteen months. At two or three months post-infarction patients who have additional ST-segment elevation in leads with a Q wave have a high incidence of either a ventricular aneurysm

or a large infarction.^{21,22} Post-infarction patients²² with a positive exercise test based on ST-segment depression are likely to have multiple-vessel disease (87%) compared to patients with a negative test who are likely to have single-vessel disease (62%).

The assessment of the meaning of a positive exercise test is most difficult in the asymptomatic patient. It is difficult to determine the sensitivity and specificity in this population because coronary arteriograms are not routinely done. In selected populations where they have been done the incidence of false-positives has ranged from 36% to 69%²³⁻²⁵ and were lowest in the least selected population. The persistence of ST-segment depression for two minutes after termination of exercise may improve the specificity in asymptomatic patients.²⁶ Despite the large percentage of false-positives, there is a significant increase in cardiac event rate (myocardial infarction and sudden death) in asymptomatic subjects with a positive test compared to those with a negative test.²⁷ Also, it should be recognized that the significance of a positive exercise test is entirely different in an asymptomatic young woman who has 1 mm of horizontal ST-segment depression at the end of the tenth minute of exercise which lasts for 20 or 30 seconds compared to a middle-aged man with 2 or 3 mm of horizontal ST-segment depression in the fourth minute of exercise which persists for several minutes.

In summary, the exercise stress test can provide useful information in the diagnosis and prognosis of patients with heart disease or suspected heart disease when it is interpreted with the knowledge of the clinical findings.

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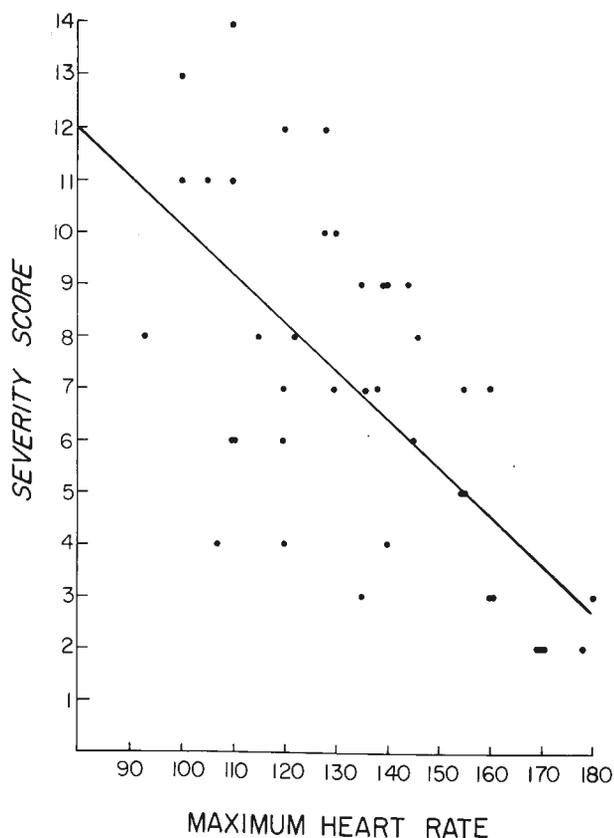


Fig 2—Regression analysis of inverse linear relationship between maximum heart rate at the conclusion of exercise and severity of coronary artery disease. The severity score is based on the findings of Friesinger and co-workers.¹⁸

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