USING AND INTERPRETING EXERCISE STRESS TESTING IN CLINICAL PRACTICE

Exercise stress testing may be useful to elicit the presence of cardiovascular disease and in later evaluation of such disease.

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Tony Dalby is a cardiologist in private practice as Milpark Hospital in Johannesburg. He received his MB ChB from Pretoria University in 1970 and undertook his postgraduate studies at Groote Schuur Hospital and the University of Cape Town first as a research fellow in the Ischaemic Heart Disease Research Laboratory directed by Professor Lionel Opie and later as a Registrar in Medicine and at the Cardiac Clinic at Groote Schuur. In 1977 he received his FCP (SA). He entered private practice in 1984. His professional interests range from prophylaxis of coronary artery disease to interventional cardiology. He is currently a member of the Ethics and Guidelines Sub-Committee of SA Heart. He serves on the Steering Committees and is the National Co-ordinator for South Africa of several international phase III drug trials in unstable coronary syndrome, acute myocardial infarction, heart failure and secondary prevention of atherothrombotic disease.

Exercise, by increasing heart rate, blood pressure and cardiac output, is used in clinical practice to elicit abnormalities of cardiac function that are not present in the resting state. As such, it may be used to discover the presence of cardiovascular disease and aid in the assessment of the patient's prognosis, functional capacity and the evaluation of therapeutic effects.

Exercise stress testing refers to the performance of a preselected exercise protocol which may employ an exercise apparatus such as a motorised treadmill or bicycle ergometer, before, during and after which assessments of symptoms, haemodynamic parameters and the electrocardiogram (ECG) are carried out. Although bicycle ergometry has certain advantages, treadmill testing is the more widely used technique, especially as the implications of treadmill test results are better understood.

A wide range of exercise protocols has been developed, each with particular advantages and disadvantages. An exercise test protocol should be tailored to the patient's physical capabilities, to ensure that the exercise stress will last long enough to bring out any abnormality of cardiac function and yet not long enough to test endurance rather than functional capacity. Among them, the Bruce protocol (Fig. 1) has the largest database and has been the most widely used. The Bruce protocol has been modified for elderly patients and those with limited physical capacity by adding two warm-up phases that precede the protocol.

NYHA functional class	3 minute stages		
Normal	MPH	% Grade	
and	5.0	18	
I	4.6	17	
	4.2	16	The usual Bruce protocol
	3.4	14	
	2.5	12	
II	1.7	10	
III	1.7	5	Modified Bruce protocol for the elderly and those with physical incapacity
	1.7	0	

Fig. 1. The Bruce treadmill protocol and its modification for those with lesser physical capacity.

An exception to the use of an exercise apparatus occurs with the 6-minute hall walk test which is used to test the functional capacity of patients with heart failure. It consists of measuring the distance the patient is able to walk at his/her own pace in 6 minutes in a 30-metre corridor.

USES OF EXERCISE STRESS TESTING

The American College of Cardiology – American Heart Association guidelines recommend that exercise testing be used to diagnose obstructive coronary artery disease, to

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perform risk assessment and establish prognosis in patients with established coronary artery disease, to risk-stratify patients after myocardial infarction, to demonstrate ischaemia in patients before and at certain times after revascularisation, to assist in activity counselling and the planning of rehabilitation after revascularisation, to evaluate functional capacity in patients with aortic valve regurgitation and to evaluate certain aspects of heart rhythm disorders. Among these recommendations the authors discourage exercise testing in individuals with a low pre-test probability of disease as a positive test would be unlikely to alter management. Although the same authors do not recommend routine exercise testing after revascularisation procedures, the early (up to 1 year) risk of re-stenosis after coronary angioplasty – stenting and the late risk of vein graft degeneration 5 or more years after coronary bypass surgery suggest that judiciously applied exercise testing should assist in detecting the re-emergence of ischaemia in such patients.

DETECTION AND MONITORING OF CORONARY ARTERY DISEASE

The most frequent use of exercise stress testing by far is the detection and monitoring of coronary artery disease. For this purpose, observations are directed at finding evidence of myocardial ischaemia during and after exercise – this includes effort-induced ischaemic chest pain or anginal-equivalent symptoms, abnormal heart rate and blood pressure responses and the detection of ischaemic changes in the 12-lead ECG. It is vitally important to recognise that even advanced coronary atherosclerosis may not be accompanied by coronary stenosis. Acute coronary events most often arise from the disruption of unstable coronary plaque, the majority of which are not associated with a prior flow-limiting coronary stenosis. In consequence, although the stress testing provides a useful guide to prognosis, it cannot provide the assurance that there is no risk of an acute myocardial ischaemic event in any given patient.

Exercise stress testing should be undertaken after the patient has not eaten, smoked or drunk caffeinated beverages for at least 3 hours. Whether regular medication is taken before the test will be governed by the indication for the test. The patient should wear comfortable walking shoes and light clothing. A 12-lead ECG should be recorded with the limb leads initially placed distally, after which the limb leads are moved to the trunk and the ECG recorded again both in the supine and standing positions. The use of adhesive gel electrodes facilitates recording during and immediately after exercise. It is helpful to strap the electrodes and redundant leads to the chest and upper abdomen to minimise movement during exercise. The patient should be familiarised with the use of the treadmill and requested where possible not to hold on to the side or front bars of the apparatus. Optimally, 3 leads of the ECG should be displayed on the monitor during exercise. The heart rate, blood pressure and ECG should be recorded at the end of each stage of the exercise and for at least 5 - 10 minutes thereafter. The ECG should be recorded at the end of exercise, and at 1, 2, 5 and if necessary 10 minutes after the end of exercise as well as at any time the patient develops symptoms or manifests an arrhythmia. Exercise testing should be carried out where facilities exist for immediate electrical defibrillation and/or other resuscitation should the need arise.

INTERPRETING THE STRESS TEST

The interpretation of the stress ECG is beset by certain difficulties that include patient selection and the pre-test probability of disease as well as the nature of the electrocardiographic changes observed with exercise.

The issues surrounding patient selection include, firstly, whether one is testing an asymptomatic individual or one with symptoms suggestive of cardiac ischaemia. So-called false-positive results are always more likely in those without symptoms and in women. To compensate for this, it is useful to consider the likelihood of coronary artery disease before undertaking stress testing and factor this into the overall evaluation. Thus, the meaning of identical exercise-induced ST depression in a 24-year-old asymptomatic woman without risk factors is very different from that in a 57-year-old man who smokes and gets tightness in his chest on effort. These considerations are governed by Bayes' theorem which states that the pre-test likelihood of disease influences the post-test likelihood. In the case of a positive test that shows ST-segment depression, the test will be most useful when the pre-test likelihood of disease was around 50%. Whether positive or negative, stress testing does not add much value to the assessment when the pre-test likelihood of disease is very high or very low. It is therefore important to take into consideration such factors as the patient's age, sex, smoking history, the presence or absence of hypertension, diabetes mellitus and/or dyslipidaemia, the family history and the nature of the patient's symptoms when estimating the pre-test probability of coronary disease and deciding upon the significance of the ST-segment changes that are seen as a result of exercise.

Secondly, it is important to know whether there are pre-existing conditions that predispose to non-coronary causes of ST-segment shift in the ECG (Table I). These conditions generally make the stress ECG uninterpretable, as ST-segment shifts frequently appear or worsen with exercise in the absence of flow-limiting coronary stenosis.

Table I. **Non-coronary causes of ST-segment change with exercise**

- **Organic cardiac disease**
  Severe aortic stenosis
  Severe hypertension
  LV hypertrophy
  Mitral valve prolapse
  Cardiomyopathy
  Severe aortic or mitral regurgitation
- **Abnormal conduction**
  Left bundle branch block
  Intraventricular conduction delay
  Pre-excitation (Wolf-Parkinson-White)
- **Arrhythmia**
  Supraventricular tachycardia
- **Metabolic aberrations**
  Anaemia
  Hypokalaemia
  Severe hypoxia
  Hyperventilation
  Glucose load
  Sudden excessive exercise
- **Drugs**
  Digitalis

INTERPRETING THE STRESS ECG

The stress ECG should be carefully evaluated for the presence of ST-segment depression during and after exercise. Typical ischaemic ST-segment depression may start during exercise and persist into the post-exercise period. It is most often slightly upsloping initially with a clear angle between the ST-segment and T wave, first becoming planar and then downsloping in the later (2 - 5 minute) post-exercise tracings (Fig. 2). Several variations of these changes are encountered in coronary artery disease, with either later appearance or earlier resolution of the ST-segment shift. ST-segment elevation after exercise is a very unusual but highly specific finding, the affected leads correlating closely with the site of the underlying ischaemia.

In contrast, ST-segment depression occurs in around 80% of cases in leads V4 - V6 and correlates poorly with the site of ischaemia. These facts notwithstanding, the amount of exercise required to precipitate the changes, the maximum amplitude of the changes and the duration of the changes post exercise are important prognostic indicators of the severity of the underlying coronary disease.

Junctional ST-segment depression is frequently confused with ischaemic change. Junctional ST-segment depression is recognised by identifying the continuous parabolic curve formed by the PR segment and ST segment and the absence of an angle between the ST segment and T wave (Fig. 3). Other nonspecific changes not indicative of ischaemia are T-wave inversion and the appearance of supraventricular arrhythmias.

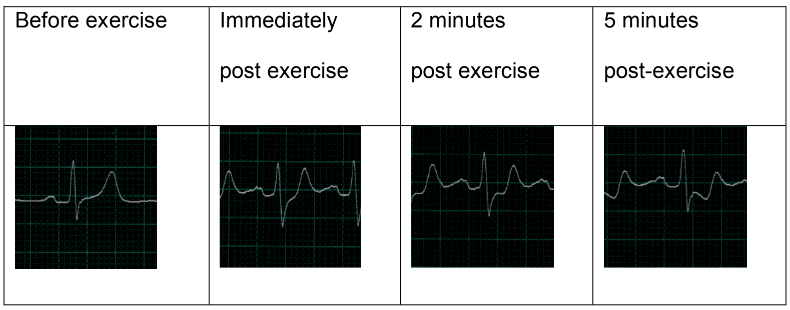

Fig. 2. Typical ST-segment depression in lead V5 after exercise in a 49-year-old male diabetic with known coronary artery disease, showing upsloping change immediately post exercise evolving to planar depression 2 minutes after exercise and then becoming downsloping at 5 minutes.

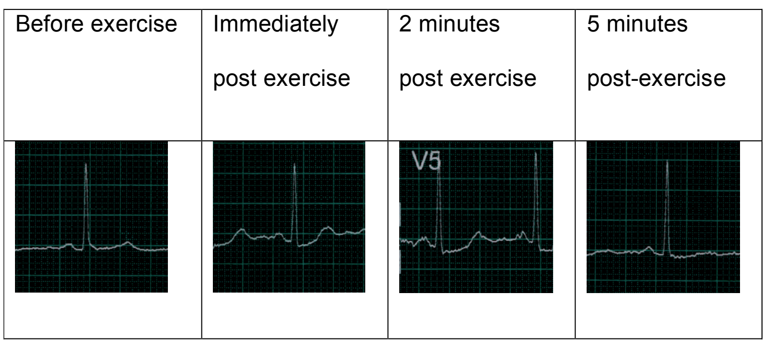

Fig. 3. Junctional ST-segment depression in lead V5 after exercise in an asymptomatic 60-year-old male diabetic hypertensive, showing a continuous parabola between the PR and ST segments without angulation between the ST segment and T wave immediately post exercise, resolving by 5 minutes after exercise.

ST-segment depression ≥ 0.1 mV (1 mm) 0.08 sec after the J-point has been defined as the threshold for the diagnosis of cardiac ischaemia. ST-segment depression is, however, a continuous variable and the division between normal and ischaemic is arbitrary. The diagnostic threshold simply reflects the amplitude at which ST-segment depression is associated with fairly satisfactory specificities and sensitivities.

GENERAL POINTS

It is a normal response for the systolic blood pressure to rise during exercise. A sustained fall of > 10 mmHg during exercise, particularly when coupled with symptoms or signs of myocardial ischaemia, suggests the induction of left ventricular dysfunction. It has serious prognostic implications and is often associated with severe left mainstem or triple vessel disease.

ST-segment depression should be interpreted in conjunction with the amount of exercise performed, any symptoms suggesting angina occurring as a result of the exercise, the maximum heart rate achieved and the blood pressure response in order to arrive at a conclusion about the presence or absence of ischaemia. This approach is best illustrated by the Duke treadmill score which uses most of these parameters and has been proved to be a useful guide to prognosis.

DUKE TREADMILL SCORE

Duke treadmill score = exercise time – (ST deviation × 5) – (angina index × 4); where 0 = no angina, 1 = angina during exercise, and 2 = angina that was the reason for stopping exercise.

Exercise testing has an excellent safety record. This record can be maintained by not exposing patients with absolute contraindications to exercise testing (Table II), by only performing correctly monitored exercise testing in appropriately selected patients, and by knowing when to terminate exercise in those patients (Table III).

Given the many reservations and caveats applied to exercise testing and the many new tests that have appeared in the past 25 years to evaluate patients with ischaemic coronary artery disease, why do we continue to employ the test? Firstly, it can be provided widely, at low cost and with a high degree of safety. Secondly, it is backed up by an extensive literature that allows for confident interpretation of the patient's prognosis and/or the need for altering management. In contrast, many of the newer test modalities such as radionuclide myocardial perfusion imaging, stress echocardiography and high-resolution computed tomography are available only in certain centres, often at considerably greater cost. These tests are based on novel and different paradigms, some structural, some functional, the clinical and prognostic implications of which have still to be fully understood. At present it is best to reserve these forms of testing for the further investigation of those patients whose clinical problem has not been resolved by exercise testing alone.

Table II. **Absolute contra-indications to exercise testing**

- **Acute myocardial ischaemia / infarction**
  Acute myocardial infarction < 2 days
  High-risk acute coronary syndrome
- **Myocardial insufficiency**
  Decompensated heart failure
  Acute myocarditis/pericarditis
- **Outflow tract obstruction**
  Severe aortic stenosis
  Hypertrophic cardiomyopathy
- **Severe hypertension (systolic BP > 220/120 before exercise)**
- **Heart rhythm disorders**
  Advanced atrioventricular block
  Uncontrolled symptomatic arrhythmia
- **Acute systemic illness**
  Pulmonary embolism
  Aortic dissection

Table III. **Indications for stopping the exercise test**

- Drop in systolic blood pressure > 10 mmHg from baseline despite an increase in workload and accompanied by other evidence of ischaemia
- Moderate to severe angina
- Increasing nervous system symptoms such as ataxia, dizziness or near syncope
- Poor peripheral perfusion such as pallor or cyanosis
- Sustained ventricular tachycardia
- ST-segment elevation > 1 mV in non-infarct leads
- Patient's desire to stop
- Technical difficulties monitoring the patient's ECG or systolic BP

Further reading

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IN A NUTSHELL

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Even advanced coronary atherosclerosis may not be accompanied by coronary stenosis.

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SINGLE SUTURE

STROKE AND FAMILY HISTORY

We know that a family history of stroke raises the risk of suffering an ischaemic stroke. However, it appears that even a family history of stroke is not predictive for the risk of stroke following a transient ischaemic attack (TIA). Enrico Flosmann and Peter Rothwell from the Stroke Prevention Research Unit in Oxford, UK, related a detailed family history of stroke to the subsequent risk of stroke in three studies of patients who had suffered a recent TIA. In none of the studies did a family history of stroke or a previous myocardial infarction predict the risk of stroke subsequent to TIA, even when hypertension was added into the analysis.

Flosmann E, Rothwell P. *Stroke* 2006; **37:** 544.