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Larry W. Gibbons

Steven N. Blair

University of South Carolina - Columbia, sblair@mailbox.sc.edu

Harold W. Kohl III

Kenneth H. Cooper

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The Safety of Maximal Exercise Testing

Larry Gibbons, MD, Steven N. Blair, PED,
Harold W. Kohl, MSPH, and Kenneth Cooper, MD

Previous reports on the safety of exercise testing have been based on surveys from different testing facilities with a variety of testing protocols and patient types. From 1971 through 1987, 71,914 maximal exercise tests conducted in a population with a low prevalence of known coronary heart disease under uniform conditions at a single medical facility resulted in six major cardiac complications including one death. No complications have occurred in the past 10 years in 45,000 maximal tests. The overall cardiac complication rate in men and women is 0.8 complications per 10,000 tests with 95% confidence intervals of 0.3–1.9 complications per 10,000 tests. Maximal exercise testing appears safer than some previously published reports have suggested and seems to be getting safer with time. (*Circulation* 1989;80:846–852)

In 1971, Rochmis and Blackburn published results of a survey on the techniques, safety, and litigation experience in 170,000 exercise stress tests performed in 73 medical centers.¹ The overall mortality rate from these centers was one death per 10,000 tests, and the rate of serious cardiac complications (morbidity plus mortality) was four per 1,000. Before the publication of these survey results, there was very limited information available on the safety of exercise testing.

Since the publication of this paper more than 17 years ago, the use of exercise testing by physicians has expanded greatly, and in addition, exercise testing is now used extensively in a variety of settings by nonphysicians. This has resulted in the administration of millions of exercise tests in the United States alone.

During these intervening years, several studies and a few books have been published that have attempted to update and clarify safety issues in exercise testing.^{2–10} Despite these later publications, when the subject of exercise test safety is discussed, it is usually the Rochmis and Blackburn data that are cited.

These data, collected during 1969, are now 20 years old. These data were needed greatly at the time of publication, but even so, the usefulness of the data was limited by the variety of testing vehicles, the mix of submaximal with maximal tests, and the difference in types of patients tested as well as the variety of indications for test termination and

other variability in test protocols from the different centers surveyed in the report.

These same limitations are present in less-often quoted surveys published since this landmark paper.^{3–6} The variety of patient types and testing protocols lumped together in the same analysis makes it difficult to apply the survey results to specific testing conditions and also makes it more difficult to know which methods might carry the greatest risk.

Despite a general consensus that an exercise test carried out by qualified professionals is a safe procedure, there may be continued attitudes that maximal exercise testing is dangerous and that many complications go unreported.

Our study presents results on 71,914 maximal exercise tests conducted in a single exercise testing center under uniform conditions and helps to overcome some of the limitations of previous studies. Our major focus is the safety of testing, and we present data on all the exercise tests performed on a large population of patients who were given maximal exercise tests.

Methods

Subjects for our study included 26,471 men and 7,824 women (age range, 24–84). After obtaining informed consent, these volunteers were administered a maximal exercise test at The Cooper Clinic in Dallas, Texas, from June 1971 through June 1987. The Cooper Clinic is a preventive medicine clinic where clients receive comprehensive diagnostic evaluations and recommendations for achieving and maintaining good health. The subjects were of moderate to high socioeconomic status. Only a small percentage of the population had a firm diagnosis of heart disease at the time of the initial clinic visit.

From The Cooper Clinic, Dallas, and The Institute for Aerobics Research, Dallas.

Address for correspondence: Dr. Larry Gibbons, The Cooper Clinic, 12200 Preston Road, Dallas, TX 75230.

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Less than 4% of the men and only 2% of the women came to the clinic with this definite history. In a larger percentage of the population, however, there were indications of probable or possible heart disease at the time of the first visit; often, the diagnosis of coronary disease was first confirmed during the initial clinic evaluation. Fifteen percent of first-visit patients had a history of high blood pressure, 19.5% had a history of chest pain, and 5.9% came with a prior diagnosis of some type of "heart trouble." A total of 71,914 tests were conducted.

Most of the subjects reported for testing in the morning while in a 12-hour fasting state, with a few reported after a 3-hour fast. Tests were conducted in air-conditioned rooms with an ambient temperature of $22 \pm 1^\circ \text{C}$. Before testing, the subjects completed an extensive medical history questionnaire that included present and past medical history, family history, and smoking and exercise habits. The subjects were then given a physical examination and a resting 12-lead electrocardiogram (ECG).

Persons with any of the following conditions were excluded from testing: unstable angina pectoris, myocardial infarction within the past 4 months, resting blood pressure (BP) of more than 200 mm Hg systolic or 120 mm Hg diastolic, aortic stenosis, acute systemic illness, fever, uncontrolled atrial or ventricular arrhythmia, congestive heart failure, active pericarditis or myocarditis, thrombophlebitis, or exercise-limiting orthopedic problems.

The subjects were given a maximal treadmill test according to a modified Balke and Ware protocol.¹¹ The grade of the treadmill was set at 0° for the first minute, was raised 2% at the end of the first minute, and was increased 1% every minute thereafter until the 25th minute with no further increases in elevation thereafter. The speed was 3.3 mph until 25 minutes at which point the speed was increased 0.2 mph/min until termination of the test.

During the years of investigation, the ECG recorders and lead systems became more sophisticated. Initially, a five- or seven-lead system was used on some patients. Later, a 12- or 15-lead cable system with a three-channel ECG was used (this latter system was used in approximately 80% of the total number of tests).

Multilead ECG recordings and BP measurements were taken at rest; every 5 minutes during the test; the last 30 seconds of the test; immediately after the test; and 1, 3, 5, 7, and 10 minutes during recovery. In addition, if an ECG abnormality was noted on the oscilloscope, a tracing was recorded.

The physician monitoring the test was present at the onset of the test, for the last 1 or 2 minutes of exercise, and during early and late recovery. If ECG or BP abnormalities or symptoms occurred, the physician was present to evaluate those and to continue observation. Most exercise test technologists were certified by the American College of Sports Medicine. A comprehensive training program including ECG recognition, lead placement, BP mon-

itoring, cardiopulmonary resuscitation, equipment calibration, and more was ongoing.

The subjects were instructed to continue the exercise test as long as possible. The endpoints for the test were volitional exhaustion, 2 mm of ST-segment depression, grade 3+ angina pectoris (on a scale of 1+ to 4+), R-on-T premature ventricular complexes (PVCs), ventricular tachycardia (≥ 3 consecutive PVCs), systolic blood pressure drop of more than 10 mm Hg from the highest previously recorded pressure, multifocal PVCs, or frequent PVCs ($> 20\%$ of total beats) in a patient with chest pain or ECG evidence of ischemia. The most common specific reasons for stopping were leg weakness (54.3%), general fatigue (28.4%), and dyspnea (5.5%).

The criteria used for determining an abnormal exercise tolerance test are chest pain typical of angina pectoris, induced or increased by exercise; significant drop (> 10 mm Hg) in systolic blood pressure during exercise measured from the peak pressure reached during exercise; systolic blood pressure of more than 250 mm Hg or diastolic of more than 120 mm Hg; exercise-induced ST-segment depression or elevation of 1 mm or more lasting 0.08 second or more from the J point, measured from the PR segment; ventricular tachycardia (three or more consecutive PVCs); exercise-induced left bundle branch block (LBBB) or right bundle branch block (RBBB); multifocal PVCs; R-on-T PVCs; exercise-induced second- or third-degree heart block; sustained supraventricular tachycardia; couplets with other ventricular irritability; and frequent (20% in any minute) PVCs. Equivocal tests were those in which there was ST-segment depression between 0.5 and 1.0 mm in amplitude lasting at least 0.08 seconds.

The purpose of our study was to examine the frequency of *major* complications, defined as myocardial infarction, ventricular fibrillation, ventricular tachycardia requiring treatment, atrial arrhythmias requiring treatment, asystole, stroke, and death. Less serious complications such as unsustained supraventricular arrhythmias, transient ventricular tachycardia not requiring intervention, chest pain, systolic blood pressure drop that rose with cessation of exercise, and severe vasovagal bradycardia not requiring intervention were not considered as complications for our purposes.

Statistical Analysis

Maximum risks of a cardiac event were calculated for the total number of tests as well as for the number of first-visit tests.

Maximal risk estimates (MRE) of a cardiac event were calculated as the upper 95% confidence limit of a Poisson distributed probability.

Results

During the years from 1971 to 1987, a total of 71,914 maximal exercise tests were conducted. Of

this total, 59,294 (82%) were on men and 12,620 (18%) were on women (many patients had multiple tests). Because it is more likely that those with abnormal or equivocal tests would have follow-up tests, an analysis of only the tests performed on the first visit more accurately describes the testing population. Considering only first-visit tests and thereby excluding multiple tests, there was a total of 34,295 tests, 77% of which were performed by men. Of that first-visit population, 13,186 patients had multiple tests; 21,109 patients were tested only once. Table 1 lists descriptive information on the population tested.

The total number of tests by decade for each sex is listed in Table 2.

Based on the ECG and BP criteria listed earlier, 87.7% of the first tests in men were normal, 5.9% were equivocal, and 6.4% were abnormal. In women, 87.6% were normal, 8.6% were equivocal, and 3.8% were abnormal.

These tests were maximal, full-effort tests. Only 3.7% of patients failed to reach 85% of predicted maximum heart rate (calculated with the Robinson formula)⁵; 56% exceeded 100% of predicted maximum heart rate; 52% of those more than 60 years old achieved or exceeded 100% of predicted maximum heart rate; and 60% of those more than 50 years old did the same.

Complication rates were calculated on both the total of 71,914 tests and the first-visit population. Six complications occurred, five in men and one in a woman. Three complications occurred during the initial clinic visit, three during subsequent visits. Two persons had ventricular fibrillation, one had a myocardial infarction during the 10 minute monitoring of recovery, and three had infarctions later, after electrodes were removed. One of these delayed myocardial infarctions occurred 1 hour after testing, one occurred 12 hours after testing, and one occurred the day after testing. In five of the six patients who had complications, there was a definite history of known coronary disease. The other patient had a history of rheumatoid arthritis. Details on patients who had complications are outlined in Table 3.

TABLE 1. Patient Demographic Information for First Visit 1971-1987

	Men (n=26,471)			Women (n=7,824)		
	Mean	SD	%	Mean	SD	%
Age (yr)	42.3	10.2		41.3	10.7	
Height (in)	70.3	2.6		64.7	2.3	
Weight (lb)	183.2	28.5		133.1	23.2	
Total cholesterol	213.7	40.8		200.9	39.5	
Systolic blood pressure	121.7	14.9		111.6	14.6	
Treadmill time (sec)	1,028.2	316.8		748.3	274.9	
Currently smoke			19.5			14.5
Currently exercise			57.4			61.5

Here is a brief clinical summary of the six patients who had exercise test complications.

Patient 1, a 67-year-old diabetic woman, was seen at the clinic 2 years after an inferior myocardial infarction. She was experiencing occasional left arm and left chest discomfort after meals and had an episode of arm discomfort the night before her evaluation. She was taking insulin, propranolol, and isosorbide dinitrate on a regular basis and took nitroglycerin as needed sublingually. On physical examination, she had a grade 2/6 systolic murmur. At a speed of 1.7 mph and a flat surface, she developed ST segment depression followed by ventricular tachycardia and ventricular fibrillation. A precordial thump was administered, and the patient returned to sinus rhythm. She had no further episodes of ventricular tachycardia or fibrillation.

Patient 2, a 58-year-old man, was seen at the clinic 7 years after he suffered an anteroseptal myocardial infarction after playing handball. At the time of his evaluation, he was asymptomatic and was playing handball 5 days a week for 1 hour. He was taking isosorbide dinitrate and dextrothyroxine. The physical examination of his heart was normal. He walked 14 minutes reaching a heart rate of 145 beats/min, and the test was terminated because ST segment depression exceeded 2 mm. He had slight upper substernal chest tightness at 9 minutes into exercise. At 3 minutes of recovery, he developed a sinus bradycardia at a rate of 53 beats/min. There were, first, multifocal PVCs and then an R-on-T PVC followed by ventricular tachycardia at 4 minutes and 45 seconds of recovery. Within 10 seconds, this progressed to ventricular fibrillation. He was defibrillated at 1 minute and 45 seconds after the onset of the ventricular tachycardia. After being given IV lidocaine and bicarbonate, he returned to normal sinus rhythm alternating with atrial flutter. He recovered with no complications.

TABLE 2. Total Number of Tests by Age and Sex

	Total tests
Men (yr)	
30	4,133
30-39	14,342
40-49	20,705
50-59	14,534
60+	5,580
Total	59,294
Women	
30	1,504
30-39	3,588
40-49	3,868
50-59	2,603
60+	1,057
Total	12,620

TABLE 3. Complications of Maximal Exercise Testing

Patient	Age (yr)/gender	History	Problem	Result	Max hr
1	67 F	Angina, previous myocardial infarction	Ventricular tachycardia, ventricular fibrillation	CPR successful	117
2	58M	Previous myocardial infarction	Ventricular tachycardia, ventricular fibrillation	Defibrillation successful	145
3	71M	Angina, Paroxysmal atrial tachycardia	Subendocardial myocardial infarction	Successful rehabilitation	130
4	34M	Rheumatoid arthritis	Inferior myocardial infarction	Successful rehabilitation	180
5	52M	Angina	Post-test myocardial infarction (24 hr)	Successful treatment	136
6	63M	Myocardial infarction	Post-test myocardial infarction (12 hr)	Deceased after 1 wk	138

from this episode. Coronary artery bypass surgery was later performed.

Patient 3, a 71-year-old man, was evaluated in 1976. He had a history of hypertension, angina, and an arrhythmia for which he was taking digitalis. He also was taking isosorbide dinitrate, propranolol, and a reserpine-hydralazine-hydrochlorothiazide combination as well as nitroglycerin p.r.n. The physical examination of the heart showed a sinus tachycardia, a grade I/VI systolic murmur, and a possible S₃ gallop. Blood pressure was 175/94 mm Hg. He completed 5 minutes of a low-level exercise test with a treadmill speed at 1.7 mph and 1° increase in incline each minute. The exercise test was terminated due to increasing left chest discomfort and 1 mm of ST depression. During recovery the chest pain disappeared and the ECG reverted to normal. At 9 minutes of recovery, however, he developed ST elevation in leads V₁ and V₂ and T wave inversion in leads V₄ and V₅. He was hospitalized with a diagnosis of anterolateral subendocardial myocardial infarction and recovered with no complications.

Patient 4, a 34-year-old man, was seen at the clinic in 1976. He reported a history of rheumatoid arthritis that was being treated with gold. There was no history of any cardiovascular disease or symptoms suggesting any cardiovascular problem. The results of a physical examination of this heart were normal. He completed a maximal test reaching a heart rate of 180 beats/min, with no significant ST segment depression and no symptoms. Between 30 and 45 minutes after completing the treadmill test, he experienced the onset of severe substernal chest pain. A resting ECG showed an inferior myocardial infarction. After transfer to the coronary care unit, he developed ventricular fibrillation that was rap-

idly converted to sinus rhythm with a single 400-W second shock. He had no other complications. Coronary angiography showed total occlusion of the right coronary artery in its proximal portion with no other significant lesions. He was treated medically and did well.

Patient 5, a 52-year-old man, was seen at the clinic in 1976 with a history of exertional chest discomfort typical of angina. He was significantly overweight. Blood pressures were elevated. The results of a physical examination of his heart were normal. He walked 5 minutes and 10 seconds on the treadmill reaching a heart rate of 136 beats/min. He experienced chest pain typical of angina without any associated ST segment depression. The chest discomfort subsided during recovery. The day after his evaluation, he had severe chest pain. He went to the hospital and was found to have had a myocardial infarction. He recovered, but the hospitalization period was prolonged.

Patient 6, a 63-year-old man, was seen at the clinic 7 years after an inferior myocardial infarction. There was also a history of high blood pressure treated with hydrochlorothiazide and triamterene and some episodes of angina, although he played racquetball regularly and was not on antianginal medication. He completed 8 minutes of a treadmill test reaching a heart rate of 138 beats/min. The test was stopped because of significant ST segment depression that reached 4 mm. The patient was unhappy that the exercise test was stopped because he reported that he generally exceeded that level of exertion during his racquetball. He had no chest discomfort during the test. The ST depression resolved during recovery. At 12:00 midnight after his examination, he awakened with chest pain and was taken to the hospital where he was found to have had an acute anterior infarction. He had ventricular fibrillation after admission to the hospital and was successfully treated. He initially did well but died of complications of the infarction 10 days after his evaluation.

All of the complications occurred before 1979. In 45,000 tests since then, there have been no complications. In late 1978, a mandatory cool-down pro-

TABLE 4. Risk of Complications—95% Confidence Intervals

	Rate per 10,000 tests
Men	0.3–2.0
Women	0.04–2.9
Total	0.3–1.8

cedure was implemented in which, on conclusion of testing, patients walk for 3 minutes before lying down. A 5-minute walk is performed before the patient lies down when the test results are abnormal.

These data show a risk of complication with maximal exercise testing of one complication per 11,859 tests in men (0.8 complications per 10,000 tests) and one complication per 12,620 tests in women (0.8 complications per 10,000 tests). Ninety-five percent confidence intervals for complications are 0.3–2.1 per 10,000 tests in men and 0.04–5.1 per 10,000 tests in women, with an overall 95% confidence interval of 0.3–1.9 complications per 10,000 tests.

If first-visit tests are considered separately, the risk of a complication is one per 12,048 tests (0.8 complications per 10,000 tests) with 95% confidence intervals of 0.2–2.5 complications per 10,000 tests.

In subjects with no history of vascular disease (if one accepts rheumatoid arthritis as a vascular disease because it does fit in the collagen-vascular category), there have been no complications.

Discussion

Previous studies on the safety of exercise testing from a single institution have included a relatively small number of subjects.^{2,7–10} Studies reporting on larger numbers of tests have been surveys that include results from many different facilities with different types of patients and different testing protocols.^{3–6} Although probably reasonably accurate, these surveys cannot provide the firsthand assurance of the authors that numbers of reported tests or reported complications were complete from the surveyed institutions.

Our study describes the largest number of exercise tests done at a single institution ever reported. The tests were performed using the same protocol throughout the entire study period except for the institution of a mandatory cool-down procedure 9 years ago. All tests were symptom limited maximal tests.

All complications were witnessed firsthand by the authors or were reported to the authors immediately as they occurred (in the two instances where infarction occurred 12 and 24 hours after testing). The composition of the patient population, which for the most part consisted of middle-age men and women, most of whom had no history or symptoms of heart disease, did not change during the course of the study.

It is clear that exercise is a safe activity for those without coronary disease.^{13–15} Cardiac events in association with vigorous exercise, including exercise that occurs in conjunction with an exercise test, occur in those with heart disease (either known or unknown), not in healthy individuals. Those without heart disease can be exercised to exhaustion without fear of cardiovascular problems. The complication rate during exercise testing would be

expected, therefore, to be closely related to the prevalence of disease in the population being tested.

Our population was, for the most part, a population without known coronary disease. It is somewhat difficult, however, to know the prevalence of coronary disease in such a population because most coronary heart disease is asymptomatic and many of our patients likely came for a cardiovascular evaluation because of some concern about risk factors or the possibility of disease being present. As a rule, coronary disease is far advanced before symptoms occur.¹⁶ It is well known that far-advanced, multivessel coronary disease can exist in the asymptomatic patient. Thus, exercise testing in a middle-aged population would seem to carry with it some risk, even in a population of individuals where only a small percentage have a known history of heart disease.

In the surveys on exercise testing safety published since the Rochmis and Blackburn study, reported complications rates vary greatly. The rate of complications in a group of healthy student athletes described in a German study was no complications in 385,000 tests.⁶ The rate in a population of patients with malignant ventricular arrhythmias, on the other hand, was 32 complications in 1,377 exercise tests, which yields a rate of 23 complications per 10,000 tests.⁷ This is the highest complication rate reported in any study.

The largest survey on the safety of exercise testing comes from Germany. In an expanded sequel to an earlier study, Wendt et al⁶ reported on 1,356,168 exercise tests performed in patients in German clinics. In this population, the rate of complications was one in 9,000.

In one of the few prospective studies on complications from exercise testing, Atterhog and colleagues⁴ reported on complications from 20 hospital-based exercise testing centers in Sweden. Complications of the type outlined earlier occurred in 24 of 50,000 tests; there were two deaths. Thus, the rates were 4.8 per 10,000 complications and 0.4 per 10,000 rate of mortality. A prospective study such as this helps to ensure that all complications are reported and that the numerator in calculating complication rates is accurate. The fact that these rates are similar to those reported from retrospective studies helps to allay the concerns of those who fear that retrospective studies may not have accurate enough records to include all the complications that have occurred.

From our own experience and from analysis of these studies, it is clear that most serious complications occur during recovery and not during the exercise portion of the test. ECG monitoring must continue for at least 10 minutes after the cessation of exercise or longer if required to allow the ECG to return to normal. Ischemic ST depression, if it occurs in recovery, is generally at its peak at 5–7 minutes. A period of observation of at least 1 hour after testing of high-risk patients would seem pru-

dent, particularly in those who have manifested severe ischemia or significant ventricular irritability during the test. Events that occur several hours after testing may or may not be related to the exercise test.

Based on our experience, it is possible that a gradual cool down rather than a sudden stop after testing may decrease the risk of complications during recovery. There are data to suggest that sudden cessation of exercise significantly increases catecholamine levels, which could in turn increase ventricular irritability and ischemia and precipitate cardiac complications. At the time the last complication occurred in 1978, a 3-minute gradual cool down after normal tests and a 5-minute gradual cool down after abnormal tests were instituted instead of stopping patients suddenly. Since that time, there have been no complications in more than 45,000 tests, although this certainly does not establish that the cool down increases safety. Stopping suddenly may result in venous pooling and bradycardia, which may produce significant discomfort and presyncopal conditions in some people.

Whether a gradual cool down on the treadmill or bicycle after an exercise test will reduce the sensitivity of testing by obscuring some of the abnormal findings that might appear with a more sudden stop is unknown. Safety and comfort make this cool down worthwhile, in our opinion, even if some abnormalities might be missed as a result. It is unlikely that significant abnormal findings would be obscured.

The rate at which exercise intensity increases during the test itself may also play a role in the safety of testing. Some have suggested that the slower rate of increase in treadmill speed and elevation of the Balke protocol may be safer than the more widely used Bruce protocol. These data support the safety of the Balke protocol, but insufficient data are available to establish which protocol is safer.

Submaximal testing (e.g., stopping a test at 85% of predicted maximal heart rate) does not by itself ensure safe exercise testing. It is much more important to follow guidelines for contraindications to testing and indications for stopping. Froelicher makes the point that stopping a test arbitrarily at 85% of predicted maximum heart rate creates the paradox that the most vulnerable patients are taxed to a relatively greater extent while those with less impairment are limited by the submaximal target heart rates.⁹

It is reported that complication rates are no higher in maximal than in submaximal tests.¹ This reported finding may be true, but it is misleading. Complications that occur in exercise testing occur in those with heart disease. Those with significant heart disease are less likely to be able to reach predicted maximal heart rates; therefore, complications that occur in these patients occur most commonly at submaximal heart rates. The submaximal

heart rates and the complications are both a result of the underlying disease and are not, thus, independent variables. Even though the majority of our tests reached or exceeded 100% of predicted maximum heart rates, five of the six complications occurred in tests where the heart rates were far below predicted maximal heart rates and the tests were stopped because of ECG abnormalities or symptoms. If appropriate indications for stopping exercise tests are observed (which identifies and pulls from testing those with severe disease for whom proceeding to maximal heart rates would appear to increase risk), maximal testing appears safe.

When none of the accepted reasons for stopping an exercise test occurs, it appears to be worthwhile to continue the test to a symptom limited endpoint. A study published in 1981 reported on the time of occurrence of the first abnormality during exercise testing.¹² In 552 consecutive abnormal tests in men, it was found that if tests had been stopped at 85% of predicted maximum heart rate, 39% of the first abnormalities that occurred would have been missed. And in those with no history of heart disease, these abnormalities were as predictive of subsequent coronary events as those that occurred at lower heart rates.

It appears that exercise testing is becoming safer with time. Stuart and Ellestad report in their 1980 survey of 1,375 US testing centers an overall complication rate of 8.9 complications per 10,000 tests, but the rate was much lower than that in the years just before publication.⁵ The large, German study by Wendt et al reports the same trend toward lower complication rates.⁶ It would seem reasonable to postulate that better patient selection, more skilled personnel, and better technology are responsible for at least some of the drop, although no controlled studies are available to support this supposition.

Even though the percentage of abnormal tests in patients seen at our clinic has not changed significantly since 1971, it is known that there is less coronary disease in the US population now compared with 18 years ago. It is also very likely that exercise testing today is used on a broader and perhaps healthier population than previously, due to an increase in testing as a part of exercise screening and prescription. Both of these trends would be expected to decrease the complication rate of exercise testing.

Even though serious complications in association with exercise testing are rare, it is nonetheless important to have proper equipment, including a defibrillator immediately available, to be able to handle any complication that might occur; five of our patients had ventricular fibrillation. Well-trained personnel must also be present.

Summary

Exercise testing is a safe procedure if contraindications to testing are followed, indications for stop-

ping are observed, and well-trained personnel administer the test. Maximal tests can be carried out safely. A brief cool-down before total cessation of exercise may be prudent.

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