Exercise Testing and Training of Apparently Healthy Individuals: A Handbook for Physicians

THE COMMITTEE ON EXERCISE

American Heart Association

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Foreword

This handbook was prepared by a group of physicians with broad experience in exercise stress testing and in the clinical application of exercise for evaluating and rehabilitating patients with heart disease. Produced at the invitation of the American Heart Association's Central Committee for Medical and Community Program, it is offered as an aid to the physician whose patient asks for medical advice before beginning a regular program of exercise. It is not a blanket recommendation for stress testing of all individuals, nor is it a position paper on the virtues of exercise.

For the sedentary individual there is serious risk in the sudden, unregulated and injudicious use of strenuous exercise. But it is a risk that can be minimized and perhaps even eliminated through proper preliminary testing and the individualized prescribing of exercise programs. Realistic guidelines are given here for exercise testing and prescribing among apparently healthy persons. Means are suggested for deriving maximal benefit from physical activity programs and for minimizing the hazards associated with inappropriate increases in activity. In the continuing effort to raise the general level of cardiovascular health, these are important considerations.

These recommendations are made in response to numerous inquiries from the medical profession that reflect a mounting public interest in physical fitness. The demand for more information about exercise is prompted as much by an intuitive conviction that it is beneficial as by the evidence of its accepted role in maintaining physical fitness and in producing certain rehabilitative effects.

Still, much remains to be learned about the physiology of exercise. The mechanisms by which it may prevent or delay clinical manifestations of ischemic heart disease are unknown, as are those levels of intensity, frequency and duration that are most effective in achieving these results. Whether or not physical activity contributes to improved

handling of psychic stress is yet to be determined. There is urgent need for continuing research in these areas.

There is a parallel need to assess the responsibilities of health professionals in developing effective preventive and therapeutic heart disease control measures. Professional education in the techniques of testing and of prescribing exercise programs must be extended to reach physical educators and health personnel as well as many more physicians. Community support of exercise testing and training will be basic to the realization of health benefits from physical activity programs. Certainly, this kind of teamwork is needed if the benefits of cardiorespiratory fitness are to be made available to large segments of the public. We encourage the cooperation of physicians, health personnel and community organizations, as well as Heart Associations, in meeting this need.

THE COMMITTEE ON EXERCISE

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Exercise Testing and Training of Apparently Healthy Individuals

The Committee on Exercise believe that regular, vigorous exercise enhances the quality of life by increasing the physical capability for work and play. We believe that such exercise is an important therapeutic tool in rehabilitating patients who have angina pectoris or are recovering from myocardial infarction. Current knowledge points to high blood pressure, elevated serum lipids, hyperglycemia and cigarette smoking as factors of primary concern in reducing the risk of coronary heart disease. In the hope of reducing such risk in all individuals, the Committee advocate physical activity *as an adjunct to* the elimination of cigarette smoking and the control of blood pressure, serum lipid levels and obesity.

Some epidemiologic evidence supports the view that maintenance of a high physical activity level is in itself an effective preventive against the development of coronary heart disease. But this has not yet been adequately investigated in controlled research. Therefore, we do not consider it justifiable to advocate widespread adoption of vigorous exercise programs purely on the grounds that exercise alone will prevent heart disease. We do, however, encourage the widespread adoption of exercise programs *tailored to the capacity and interest of individuals*, because of the probability that they will enrich the quality of life and, in combination with other measures, help reduce coronary risk. At the same time, the Committee recognize that moderately high-intensity exercise embodies risk for a small fraction of the middle-aged male population. This statement contains guidelines that are intended to minimize that risk.

Procedure—Before, During and After Exercise Testing

Before beginning an exercise program that will demand a major increase in physical activity, an individual should be evaluated by his physician. The examination should include a review of individual and

family history for the presence of heart disease, and evaluation of symptoms and signs including a resting electrocardiogram to detect manifestations of overt or subclinical heart disease. Any existing, remediable risk factors of coronary heart disease such as hypertension, hypercholesterolemia, cigarette smoking and obesity should be identified.

Persons with increased risk factors but without manifest heart disease are, nonetheless, considered coronary-prone. These individuals should undergo exercise stress testing for detection of possible asymptomatic, early manifestations of ischemic heart disease. Persons with *identifiable* heart disease should not engage in unsupervised, strenuous physical exertion without first submitting to exercise testing.

Exercise stress testing may reveal the presence of latent ischemic heart disease in persons *without* increased risk factors, although testing in such persons under the age of 35 is not likely to disclose more than one case in a hundred. However, as age progresses, ischemic responses to exercise testing may be expected with increasing frequency, as high as 10% in some series.

For the apparently healthy individual who wishes to enter an exercise training program, the primary objective of exercise testing is to reveal possible latent ischemic heart disease. A multi-stage test with progressively increasing work loads is most effective for this purpose, although in some situations a single-stage test may suffice. Single- and multi-stage tests are discussed in general in Appendix A. Appendix B gives directions for performing specific tests.

A second objective of exercise testing is to determine the subject's cardiovascular functional capacity. This measurement helps to insure selection of an exercise program that does not exceed his capacity. Multi-stage testing is required for this purpose.

Each subject should be instructed in the purpose and potential hazards of exercise testing before testing begins.

Continuous ECG monitoring, *beginning before and continuing until after testing is completed*, ought to be an integral part of any exercise test. Where ECG equipment is unavailable, exercise testing without monitoring may be done only on younger individuals free of clinical abnormalities and increased risk factors. Any exercise test should be supervised by a knowledgeable physician or his trained delegate. Where a delegate supervises the test, the physician should be available to assist in those emergency situations—syncope, cardiac arrest or ventricular fibrillation—that occur infrequently but unpredictably; data indicate that the risk of mortality during the 24 hours following exercise

testing is less than 1 per 10,000 tests while the risk of nonfatal complications requiring hospitalization is about 2.4 per 10,000 tests.*

The physician or his delegate should constantly watch the electrocardiogram for abnormalities during and after testing. An increased probability of significant heart disease is strongly indicated by the following abnormalities: paroxysmal supraventricular dysrhythmia, three or more consecutive ventricular ectopic complexes (ventricular tachycardia), the appearance of bundle-branch block or second- or third-degree A-V block, or ST displacement (either horizontal or downslanting) of 0.1 mv or greater in the usual left precordial leads. Persons exhibiting these ECG responses to testing deserve careful medical study. Pending such study, they must be excluded from *unsupervised* exercise programs. Individuals who complete testing without exhibiting abnormal ECG responses or other evidence of overt or subclinical heart disease can be medically authorized to take part in unsupervised exercise of an intensity that does not exceed that achieved during the clearance test. A supervised program is one in which a physician, supporting staff and equipment are constantly available to handle possible emergencies: to provide acute care, defibrillation and cardiac resuscitation.

Objectives of Exercise Testing

1. To establish a diagnosis of overt or latent heart disease.
2. To evaluate cardiovascular functional capacity, particularly as a means of clearing individuals for strenuous work or exercise programs.
3. To evaluate responses to conditioning and/or preventive programs.
4. To increase individual motivation for entering and adhering to exercise programs.

*Rochmis P, Blackburn H: Exercise Tests. A survey of procedures, safety, and litigation experience in approximately 170,000 tests. *JAMA* **217**:1061-1066, 1971.

Prescribing an Exercise Program

When the physician is satisfied that there is no contraindication to increased physical activity, he may prepare an individualized exercise recommendation. The type, intensity, duration and frequency of the physical activity he recommends should be based on the subject's health, estimated physical capability, physical activity interests and proficiency, and on the athletic facilities available to the subject.

Types of Exercise. To achieve the desired degree of cardiorespiratory adaptation and conditioning, the previously sedentary individual must do exercises that produce sustained increases in metabolic, cardiovascular and respiratory functions. Activities of this type include vigorous walking, stationary and regular cycling, swimming, jogging, running, bench-stepping, rope-jumping, some types of continuous rhythmical calisthenics, and selected active sports.

Highly competitive game situations, or activities that demand bursts of energy, sudden rapid movement or body contact are to be avoided initially. Activities requiring effort against heavy resistance, such as weight lifting at near-maximum exertion and isometric exercises (tensing one set of muscles against another or against an immovable object), do little to improve cardiovascular function, and are not recommended since they provoke an excessive, possibly dangerous pressor response. The subject should be told not to perform the Valsalva maneuver (prolonged effort with a closed glottis) while exercising. A tendency to this maneuver can be counteracted by rhythmic breathing.

Activities that provide pleasure without causing prolonged discomfort or fatigue are recommended. It is wise to place special emphasis on active recreational games and to utilize the exercise potential of commonplace activities that might otherwise be avoided, such as walking instead of riding, climbing stairs instead of using an elevator, and gardening. Even modest amounts of such exercise are better than none at all.

Intensity and Duration. Intensity and duration of an exercise session will depend upon an individual's capacity for the type of exercise he plans to do. Physiologic studies indicate that a certain amount of "exertional overload" is necessary to improve cardiovascular performance in the sedentary person. This means imposing an intensity and duration of activity that exceed those mild demands usually made on such persons, but that fall short of producing prolonged or excessive fatigue, breathlessness or mental confusion.

A previously sedentary individual should begin his program at a low intensity, gradually increasing the level of exertion over days or weeks. For a given activity, duration sufficient to increase cardiorespiratory fitness will depend to some extent on intensity and frequency. Exercise intensity should not exceed a level that elicits symptoms, signs, heat or energy expenditure greater than those achieved during testing. Activity at a lower intensity will probably require greater duration to produce conditioning of a similar magnitude. In the initial stages of an exercise program, intensities that demand more than 75% of an individual's maximally attainable heart rate are not well tolerated and, hence, not recommended. Exercise sessions of no more than 15 to 20 minutes' duration each usually will produce appreciable physiological and psychological effects.

It is extremely important for an individual to work through a gradual warm-up of three, five or more minutes at the beginning of any single exercise session. The longer buildup is appropriate for the older person, for the less well conditioned, and for the person who wishes to move promptly to high levels of activity such as those required in competitive games. Any strenuous exertion should be followed by a tapering-off period of gradually diminishing activity lasting at least several minutes.

As aids in prescribing and regulating the intensity of a training program, the physician may use objective measurements such as the subject's heart rate at specified work levels (determined during exercise testing), or the maximal work level achieved during testing. Or he may use the more subjective method of noting which types of training activities produce transient fatigue, breathlessness, weakness or other symptoms. Instructions for using such means are given in Appendix A.

Frequency of Exercise. A daily exercise routine is desirable, but cardiovascular fitness may be enhanced by properly regulated sessions at least three days a week. Once achieved, a satisfactory level of fitness can be maintained in less frequent sessions, at least twice a week but preferably not on successive days. *To maintain the health benefits of exercise, an individual must make a lifetime commitment to a regular program.* Fitness rapidly deteriorates with resumption of sedentary habits.

Precautions. Whenever there is a possibility that exercise may aggravate a minor illness, injury or infection, an individual should temporarily interrupt his program. Even if he is simply not feeling well, "working it off" can be dangerous; such feelings may indicate incipient

illness. For these reasons, the physician should warn patients against exercising when they feel below par, and advise the patient who has just recovered from illness to resume exercising at a level of exertion below that achieved before illness.

Aching muscles, joints and tendons are common in the early stages of exercise and are usually the result of inappropriate conditioning at too fast a pace. Most musculoskeletal complaints respond promptly to reduced pace or to temporary discontinuance of exercise. By beginning at a moderate pace and gradually increasing it, and by wearing proper shoes,* the new trainee can avoid many problems with his feet and legs. Overweight individuals must be particularly careful not to attempt too much at the start of a program.

In unusual environmental conditions (high ambient relative humidity and temperature or unaccustomed altitude), in times of stress or emotional turmoil, or following ingestion of a heavy meal, exercise must be decreased in intensity or even entirely abandoned.

Excessively hot showers are to be avoided during the immediate post-exercise period; in rare instances they have been associated with *immediate* manifestations of myocardial infarction.

Supervision. Unsupervised exercise programs can be followed at minimal cost to the individual, but experience indicates that many persons quickly lose interest in them and stop exercising. On the other hand, programs that allow participation in supervised group activities may actually encourage adherence. Such programs are offered by many community organizations, and physicians should familiarize themselves with the ones in their own areas. While community facilities may furnish excellent means for carrying out exercise recommendations, the physician should determine whether they offer well supervised, endurance-developing activities free of hazardous competitive pressure. Only then can he be sure when he recommends a program that his patient will remain free to modify the pace. Exercise, if it is to be healthful for the sedentary man, must *not* be highly competitive. The individual who understands the importance of proper exercise and who is encouraged to participate in regular physical activity tailored to his needs and interests can help himself toward more vigorous health.

*Canvas sneakers are not suitable for running, jogging or walking. Special shoes have been designed specifically for these activities. The correct shoes have good arch support with pliable tops and firm soles; ripple or crepe soles are excellent on hard surfaces. The shoes should not fit tightly.

Physicians can demonstrate the correct way to maintain fitness by becoming active participants in good community exercise programs. As such, they can advise on the quality of the programs, help to establish optimal safety conditions, and even provide emergency care when necessary (as in a few instances of exercise-associated cardiac arrest where immediate resuscitative measures by a physician resulted in excellent recovery). While taking part in exercise programs, physicians can also help to stimulate community interest in all aspects of coronary disease, especially the preventive ones of risk factor reduction. These and other contributions to community education may be made by the medical professional in cooperation with the local Heart Association.

APPENDIX A
Exercise Testing: Performance and Interpretation

Physiology of Exercise

The basic physiologic response to exercise is an increase in total body oxygen consumption made possible by increases in pulmonary ventilation, cardiac output and oxygen extraction by the tissues. Greater cardiac output is the result primarily of accelerated heart rate and to a lesser extent, greater stroke volume.

A given work load requires a specific amount of energy; therefore, equally efficient persons of equal body weight performing the same work load will require the same amount of oxygen, even though one of them might be poorly conditioned physically and the other well conditioned. The difference is that the trained individual performs the task with a slower heart rate, pumping more blood with each beat. His tissues may also extract more oxygen from the blood that is pumped to them. As the work load increases, the unconditioned person will reach his maximum heart rate and be forced by fatigue to stop at a lower work level than the conditioned subject. The well conditioned person will be able to do work at much higher intensities than the poorly conditioned one and will have a much higher oxygen uptake when he reaches the point of exhaustion. But the two persons will have almost the same maximal heart rate if they are the same age.

The highest achievable level of exercise intensity is determined by the maximal amount of oxygen that can be transported from the lungs to the working muscles. The body's maximal oxygen uptake during an all-out physical effort is a measure of fitness. This measurement, known as the maximum O_2 uptake ($\dot{V}o_2$ max), or aerobic capacity, can be increased with physical conditioning but decreases with advancing age, disease and deconditioning. Parallel decreases in maximally attainable heart rate and cardiac output occur with advancing age. While illness and deconditioning also result in a lower maximal cardiac output, maximal heart rate may actually *increase* slightly under such conditions. In

all types of exercise testing, the tester must take these physical changes into consideration, since he should be able to form some estimate of probable test results on the basis of the subject's age and state of health.

The purpose of testing has been served upon determining the work load at which the oxygen-transport system has reached the limit of its capacity, or come close to it, without the intervention of pathologic responses. Physiologic measurements made during an exercise test relate the magnitude of response to the work imposed. Cardiac output and stroke volume at various work loads provide useful information, while failure of an appropriate response identifies a pathologic or a deconditioned state. But because cardiac output is not easily determined, clinical testing must employ readily measured variables, such as heart rate and systolic blood pressure, as partial indices of cardiac output. Electrocardiographic monitoring, besides being a ready source of information on changes in heart rate and rhythm, may also reveal the ischemic ST pattern indicative of myocardial hypoxia. Persons displaying pathologic ECG responses should be studied further without being subjected to intensive work loads.

A convenient and useful index of increased myocardial oxygen requirement during exercise in most patients is the increase in the mathematical product of heart rate and systolic blood pressure (the pressure-rate product), a quantity usually related to the magnitude of the load imposed on the left ventricle. In general, poorly conditioned subjects and cardiac patients have a *higher* product for any given *submaximal* work load than do conditioned individuals of the same age and sex.

Types of Tests

Exercise tests, whether single- or multi-stage, may be aimed at eliciting maximal performance or some level short of maximal. In a single-stage test the work load is held constant throughout, while in a multi-stage test it is increased at regular intervals until the endpoint is reached. Multi-stage approaches to performance evaluation may be based on continuous or on intermittent exertion, the latter incorporating pauses for partial or complete rest between each test stage.

In testing for maximal exertion, a preliminary warm-up is mandatory before the subject begins the definitive series of escalating work loads that will eventually compel him to stop. The normal subject, whose limit is imposed primarily by his maximally attainable cardiac

output, will be stopped by fatigue. (The subject who is halted by symptoms such as chest pain, dyspnea or faintness is likely to harbor a disorder of physiologic capacity and a disease state.)

In a submaximal test, the subject usually does *not* attain his top performance or functional aerobic capacity, but stops at some *arbitrary* endpoint such as a predetermined target heart rate based on his age and activity adjustments. Often this is sufficient to permit detection of occult disease and provide the physician with guidelines for prescribing exercise. Mandatory endpoints may be imposed by dyspnea, chest pain or cerebral dysfunction, pathologic ECG changes, or inappropriate blood pressure response (a decline in systolic pressure or failure of pressure to rise during increasing exercise). Submaximal testing is usually terminated at the appearance of any one of these symptomatic or dysfunctional endpoints, or of any other signs of poor exercise tolerance.

This appendix includes information on maximal, near-maximal, submaximal, single-stage and even nonmonitored exercise testing as recommended by various authorities.

The Committee on Exercise agree that multi-stage exercise testing (with successively increasing work loads) accompanied by continuous ECG monitoring and periodic blood pressure determination is the most informative type of testing. The initial cost of equipment is greater, however. Where it is necessary to economize, exercise testing without ECG monitoring but with monitoring of blood pressure and pulse rate could be done using a simple step test to the point of fatigue or the appearance of cardiac symptoms, arrhythmia or other endpoints. With this method, asymptomatic ischemic ECG manifestations are not detectable, but the occurrence of anginal distress, inappropriate dyspnea, arrhythmia or a heart murmur indicate the probable existence of heart disease and the need for further clinical study. The physician may use the pulse rate, determined at the moment symptoms occur, to prescribe an exercise program of an intensity below the symptomatic threshold. By counting the number of steps required to produce the symptomatic endpoint, he can roughly define a level of fitness from which to assess future improvement.

In the opinion of this Committee, however, exercise testing without electrocardiographic monitoring and recording is unwarranted in middle-aged Americans.

The single-stage test, exemplified by the double Master two-step test, is not the optimal procedure for assessing physical fitness, but it is an established one for detecting myocardial ischemia. It requires only

the specific staircase, an electrocardiograph and a watch or clock. It may be expected to disclose ECG characteristics consistent with asymptomatic myocardial ischemia in 2 to 3% of middle-aged males.[1]

Bruce advocates the use of maximal testing to define cardiovascular capacity.[2] Comparison of a subject's capacity with that expected in a healthy person of the same sex and similar age and activity status may readily be estimated from duration of standardized multi-stage exercise by means of a nomogram. Some mechanisms of impairment may be identified from changes in rhythm, heart rate, systolic blood pressure and ECG responses during and immediately following exercise. Maximal testing reveals asymptomatic myocardial ischemia in about 8 to 12% of a middle-aged male population, a higher yield than in the less demanding tests.[3]

Submaximal testing is preferred by some authorities who believe it is safer than maximal testing and encourages greater subject cooperation. Submaximal testing takes several forms; some tests are based on achieving a target heart rate, others on reaching a submaximal symptomatic endpoint. Sheffield (Appendix B) employs increasing work loads on a treadmill either until the subject is stopped by the *onset* of symptoms or until his heart rate reaches 90% of the expected maximal heart rate predicted according to his age. Hellerstein[4] uses a bicycle ergometer measurement of the amount of work that must be done by middle-aged persons to achieve a heart rate of 150 beats per minute. Kattus[5] considers his six-stage treadmill test to be near-maximal because it is formulated on an endpoint of moderately severe or 3+ discomfort rather than on maximally severe or 4+ discomfort.

Maximal and submaximal exercise tests generally employ the treadmill, the bicycle ergometer or steps. The treadmill is more expensive and requires more space. But it has the advantages of using a familiar mode of exercise, walking, and of bringing into play large muscle masses, resulting in less localized fatigue of the quadriceps muscles for the amount of work done. It is the only technique that involuntarily controls the rate of energy expenditure.

The bicycle ergometer is relatively inexpensive and occupies little space, but most Americans are not accustomed to bicycle riding, and develop fatigue in the thigh muscles at relatively low working rates.

Equipment for the variable-height step test can be manufactured at low cost and occupies little room, but requires the subject to maintain a steady pace, often with the use of a metronome. Both step tests and bicycle tests require strong subject motivation, while the treadmill automatically regulates the pacing and setting of the work level as long