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Chapters 1 through 3

Exercise Testing and Prescription

Seventh Edition

by

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part I

Definitions

chapter 1

Physical Fitness and Health Defined

Over the years, I have come to look upon physical fitness as the trunk of a tree that supports the many branches which represent all the activities that make life worth living: intellectual life, spiritual life, occupation, love life and social activities.

—Thomas Kirk Cureton, Jr.

Although many definitions of physical fitness have been proposed, there still is much disagreement among physical educators and exercise scientists as to its real meaning. During the first half of the twentieth century, for example, muscular strength was emphasized by many fitness leaders as the primary goal of an exercise program. During the 1970s and 1980s, the pendulum swung the other way toward a focus on cardiorespiratory fitness through aerobic activity. Today, there is more of a focus on health-related physical fitness.

Among physical educators, a furious debate has raged since the late 1800s as to whether youth fitness programs should stress the development of skills important for athletic ability (e.g., hand–eye coordination, agility, balance, speed) or attributes that some researchers feel are more important to health (e.g., cardiorespiratory endurance, optimal body composition, flexibility). Since the mid-1980s, several organizations have attempted to redefine physical fitness and exercise in light of modern evidence and understanding. This chapter discusses the contemporary definitions of physical fitness terms important to sport and exercise science. Box 1.1 summarizes the definitions of key terms that are explored in this chapter and other chapters of this book.

PHYSICAL ACTIVITY

Physical activity has been defined as any bodily movement produced by the contraction of skeletal muscles that increases energy expenditure above a basal level and enhances health.[1–3] The energy expenditure can be measured in kilocalories (kcal) or kilojoules (kJ). One kcal is equivalent to 4.184 kJ. In this book, we also use the term *Calories* to denote kcals. One banana, for example, provides about 100 Calories (Cal), approximately the amount of energy expended in running a mile.

Everyone performs physical activity in order to sustain life. The amount, however, varies considerably from one individual to another, based on personal lifestyles and other factors. A compendium of physical activities has been developed to provide researchers and practitioners with an estimation of the energy cost for a wide variety of human physical activities.[4] Physical activity can be classified as "low" (fewer than 150 minutes a week), "medium" (150–300 minutes a week), and "high" (more than 300 minutes a week).[5]

Measurement of physical activity is difficult, and researchers have utilized a wide array of methods. Over 50 different measures have been described and can be classified into four general categories:[2]

- *Calorimetry*—direct heat exchange (in an insulated chamber or suit), or indirect measurement through measurement of oxygen consumption and carbon dioxide production
- *Physiological markers*—heart rate monitoring and use of doubly labeled water (DLW)
- *Mechanical and electronic motion detectors*—pedometers, in-shoe step counters, electronic motion sensors, and accelerometers
- *Occupational and leisure-time survey instruments*—job classification, activity diaries or records, and physical activity recall questionnaires

Box 1.1

Glossary of Terms Used in Physical Fitness

aerobic training: Training that improves the efficiency of the aerobic energy-producing systems and that can improve cardiorespiratory endurance.

agility: A skill-related component of physical fitness that relates to the ability to rapidly change the position of the entire body in space, with speed and accuracy.

anaerobic training: Training that improves the efficiency of the anaerobic energy-producing systems and that can increase muscular strength and tolerance for acid–base imbalances during high-intensity effort.

balance: A skill-related component of physical fitness that relates to the maintenance of equilibrium while either stationary or in motion.

body composition: A health-related component of physical fitness that relates to the relative amounts of muscle, fat, bone, and other vital body tissues.

calorimetry: Methods used to calculate the rate and quantity of energy expenditure when the body is at rest and during physical exertion.

- **direct calorimetry:** A method that gauges the body's rate and quantity of energy production by direct measurement of the body's heat production; the method uses a *calorimeter*, which is a chamber that measures the heat expended by the body.
- **indirect calorimetry:** A method of estimating energy expenditure by measuring respiratory gases; given that the amount of O_2 and CO_2 exchanged in the lungs normally equals that used and released by body tissues, caloric expenditure can be measured by CO_2 production and O_2 consumption.

cardiorespiratory endurance (cardiorespiratory fitness): A health-related component of physical fitness that relates to the ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity.

coordination: A skill-related component of physical fitness that relates to the ability to use the senses, such as sight and hearing, together with body parts, in performing motor tasks smoothly and accurately.

detraining: Changes the body undergoes in response to a reduction or cessation of regular physical training.

endurance training and endurance activities: Repetitive aerobic use of large muscles (e.g., walking, bicycling, swimming).

exercise (exercise training): Planned, structured, and repetitive bodily movement done to improve or maintain one or more components of physical fitness.

flexibility: A health-related component of physical fitness that relates to the range of motion available at a joint.

kilocalorie (kcal): A measurement of energy: 1 kilocalorie = 1 Calorie = 4,184 joules = 4.184 kilojoules.

kilojoule (kjoule or kJ): A measurement of energy: 4.184 kilojoules = 4,184 joules = 1 Calorie = 1 kilocalorie.

maximal heart rate (HR_{max}): The highest heart rate value attainable during an all-out effort to the point of exhaustion.

maximal heart rate reserve: The difference between maximal heart rate and resting heart rate.

maximal oxygen uptake ($\dot{V}O_{2max}$): The maximal capacity for oxygen consumption by the body during maximal exertion; also known as aerobic power, maximal oxygen consumption, and cardiorespiratory endurance capacity.

metabolic equivalent of task (MET): A unit used to estimate the metabolic cost (oxygen consumption) of physical activity, 1 MET equals the resting metabolic rate of approximately 3.5 ml O_2 per kilogram of body weight per minute.

muscular endurance: The ability of the muscle to continue to perform without fatigue.

physical activity: Bodily movement that is produced by the contraction of skeletal muscle and that substantially increases energy expenditure.

physical fitness: A set of attributes that people have or achieve, which relates to the ability to perform physical activity.

power: A skill-related component of physical fitness that relates to the rate at which one can perform work.

rating of perceived exertion (RPE): A person's subjective assessment of how hard he or she is working; the Borg scale is a numerical scale for rating perceived exertion.

reaction time: A skill-related component of physical fitness that relates to the time elapsed between a stimulus and the beginning of the reaction to it.

resistance training: Training designed to increase strength, power, and muscle endurance.

resting heart rate: The heart rate at rest, averaging 60 to 80 beats per minute.

retraining: Recovery of conditioning after a period of inactivity.

speed: A skill-related component of physical fitness relating to the ability to perform a movement within a short period of time.

strength: The ability of the muscle to exert force.

training heart rate (THR): A heart rate goal established by using the heart rate equivalent to a selected training level (percentage of $\dot{V}O_{2max}$). For example, if a training level of 75% $\dot{V}O_{2max}$ is desired, the $\dot{V}O_{2max}$ at 75% is determined and the heart rate corresponding to this $\dot{V}O_2$ is selected as the THR.

Source: U.S. Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General*. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, 1996.

Figure 1.1 The K4b2 (COSMED Ltd., Rome, Italy) is a fully portable breath-by-breath pulmonary gas exchange system for measuring energy expenditure away from the lab.

Questionnaire methods are currently the most popular and practical approaches for large groups of individuals. A collection of physical activity questionnaires for health-related research has been published.[6]

Calorimetry and DLW can provide accurate measurements of average daily energy expenditure under controlled laboratory conditions for small groups of subjects. Measurement of energy expenditure away from the laboratory has been enhanced with the development of light metabolic units that can be worn on the chest (see Figure 1.1). DLW is an effective but expensive method for measuring energy expenditure in free-living humans.[7] Briefly, the DLW method requires that the subject ingest a dose of water containing both the isotope deuterium ($^2H_2$) and the stable oxygen isotope ^{18}O (as $^2H_2{}^{18}O$). The technique is safe because the isotopes employed are naturally occurring rather than radioactive. Subjects provide urine, blood, or saliva samples before and 3 hours after ingestion, as well as each day for several days. Through use of mass spectrometers, energy expenditure is calculated by measuring the difference in the rate of loss between the two isotope labels (which is related to carbon dioxide production and through calculation to oxygen consumption).

EXERCISE

Exercise is not synonymous with *physical activity*.[1–3] It is a subcategory of physical activity. Exercise is physical activity that is planned, structured, repetitive, and purposive, in the sense that improvement or maintenance of physical fitness is an objective.[3] Virtually all conditioning and many sports activities are considered exercise because they are generally performed to improve or maintain physical fitness. Household and occupational tasks are usually accomplished with little regard to physical fitness. However, a person can structure work and home tasks in a more active form and thus build up physical fitness at the same time the tasks are accomplished. Many people find this more motivating than "running in circles" for exercise.

A COMPREHENSIVE APPROACH TO PHYSICAL FITNESS

During the boom years of the aerobic movement in the 1970s and 1980s, development of cardiorespiratory fitness was emphasized, often to the detriment of musculoskeletal fitness. Although this was a much needed reform from the undue preoccupation with muscular strength and size, which had dominated since the late 1800s, most fitness experts today believe in a more balanced approach to all the components of fitness.[8–13] The focus today is on a comprehensive approach to physical fitness in which three major components—cardiorespiratory fitness, body composition, and musculoskeletal fitness (comprising flexibility, muscular strength, and muscular endurance)—are given equal attention (see Figure 1.2).

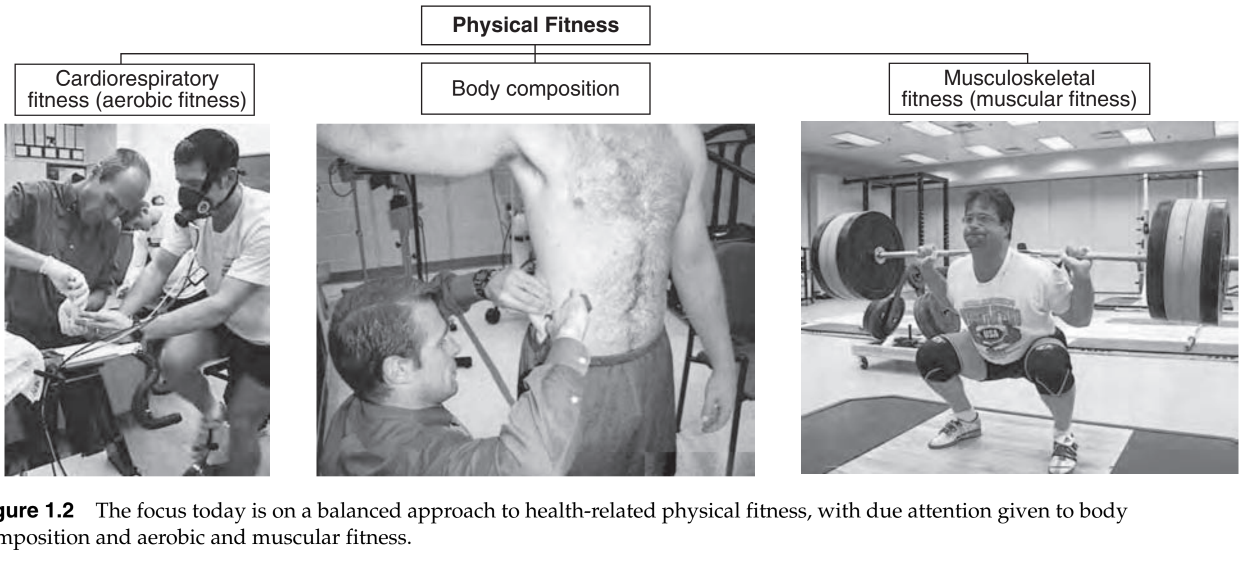

Figure 1.2 The focus today is on a balanced approach to health-related physical fitness, with due attention given to body composition and aerobic and muscular fitness.

The Meaning of Physical Fitness

Several organizations have submitted philosophical definitions of physical fitness. The World Health Organization (WHO) in 1971, for example, has defined it simply as "the ability to perform muscular work satisfactorily."[14] The Centers for Disease Control and Prevention (CDC) sponsored a workshop in 1985, bringing together a group of experts who concluded that physical fitness "is a set of attributes that people have or achieve that relates to the ability to perform physical activity."[3] The American College of Sports Medicine (ACSM) in 1990 proposed that "fitness is the ability to perform moderate to vigorous levels of physical activity without undue fatigue and the capability of maintaining such ability throughout life."[15]

The President's Council on Physical Fitness and Sports in 1971 offered one of the more widely used definitions, describing physical fitness as the "ability to carry out daily tasks with vigor and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies."[16] Dr. H. Harrison Clarke wrote that "physical fitness is the ability to last, to bear up, to withstand stress, and to persevere under difficult circumstances where an unfit person would give up. Physical fitness is the opposite to being fatigued from ordinary efforts, to lacking the energy to enter zestfully into life's activities, and to becoming exhausted from unexpected, demanding physical exertion. . . . It is a positive quality, extending on a scale from death to 'abundant life.'"[17]

In 1996, the surgeon general's report *Physical Activity and Health* adopted the 1985 definition of physical fitness proposed by the CDC, and most other organizations have followed suit.[1,3,8,11]

All of these definitions place an emphasis on having vigor and energy to perform work and exercise. Vigor and energy are not easily measured, however, and physical fitness experts have debated for more than a century the important measurable components of physical fitness.[17,18]

The most frequently cited components fall into two groups, one related to health and the other related to athletic skills.[3,11,12,18] Figure 1.3 summarizes the components of health- and skill-related fitness, with examples of the continuum of physical activities that represent each group. Box 1.2 summarizes key concepts related to health.

It is felt by some researchers that while the elements of skill-related fitness are important for participation in various dual and team sports, they have little significance for the day-to-day tasks of Americans or for their general health.[3,18] On the other hand, individuals who engage in regular physical activity to develop cardiorespiratory endurance, musculoskeletal fitness, and optimal body fat levels appear to improve their basic energy levels and place themselves at lower risk for the common diseases of our time, including heart disease, cancer, diabetes, osteoporosis, and other chronic disorders.[2]

Athletes who excel in throwing a ball or swinging a golf club should understand that they may not have optimal levels of body fat or cardiorespiratory fitness, and as a consequence may be at higher risk for chronic disease. Also, even though individuals may possess poor coordination, they can still be physically fit and healthy by engaging regularly in aerobic and musculoskeletal exercise. Of course, there are athletes who by the nature of their sport (e.g., soccer or basketball) would be rated high in both the health- and skill-related elements.

Among the general population, many individuals would rather play sports while getting fit than engage in "pure" fitness activities such as running, swimming, or using indoor exercise equipment. Fitness leaders need to individualize

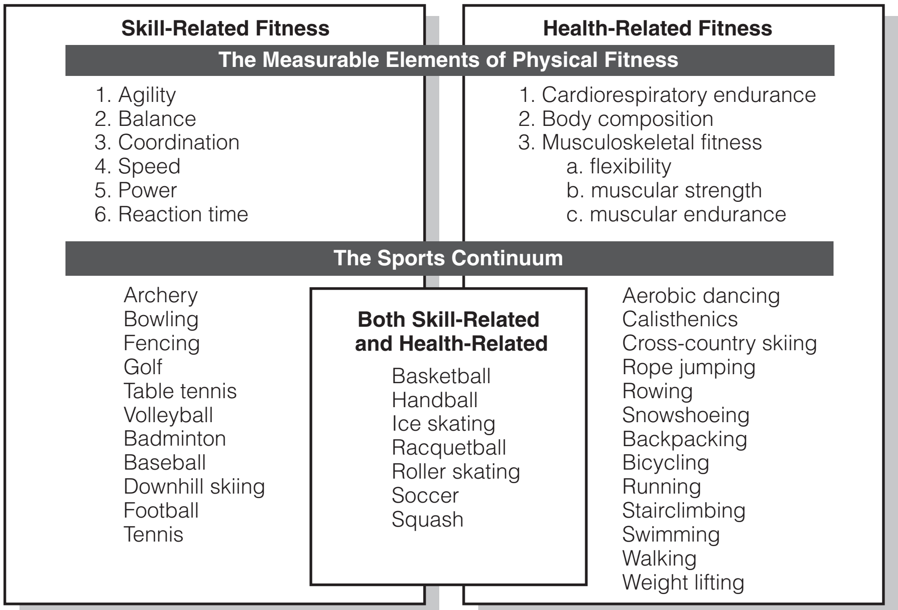

Figure 1.3 Most physical activities exist on a continuum between health- and skill-related fitness. Source: Adapted from Caspersen CJ, Powell KE, Christenson GM. Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Rep* 100:126–131, 1985.

Box 1.2

Health Definitions

The most notable, and undoubtedly still the most influential, definition of health is that of WHO. The definition appeared in the preamble of its constitution in 1948: "*Health* is a state of complete physical, mental, and social well-being, and not merely the absence of disease."[5,19]

This definition stemmed from a conviction of WHO organizers that the security of future world peace would lie in the improvement of physical, mental, and social health. The definition suggests that health goes beyond the mere avoidance of disease and extends to how one feels and functions physically, mentally, and socially.

Wellness is an approach to personal health that emphasizes individual responsibility for well-being through the practice of health-promoting lifestyle behaviors. In other words, wellness is an all-inclusive concept that encourages good health behaviors to improve quality of life and reduce the risk of premature disease. *Health behavior* is defined as the combination of knowledge, practices, and attitudes that together contribute to motivate the actions people take regarding health and wellness. *Health promotion*, a term that gained favor during the 1970s, is defined as the science and art of helping people change their lifestyle to move toward a state of optimal health.[19]

Health has three dimensions: mental, physical, and social. Each individual is a complex mixture of mental, physical, and social factors, all of which interact and are dependent on each other. When one of the dimensions is neglected or overemphasized, the other areas are negatively influenced.

The three dimensions of health are tightly interdependent, and quality of life demands that each receives balanced attention (see Figure 1.4).

- Mental health refers to both the absence of mental disorders (e.g., depression, anxiety, and dependence on drugs) and the individual's ability to negotiate the daily challenges and social interactions of life without experiencing mental, emotional, or behavioral problems. Mental health is enhanced as people learn and grow intellectually and cope with daily circumstances and emotions in a positive, optimistic, and constructive manner.
- Physical health is defined as the absence of physical disease (e.g., premature heart disease or cancer), while having energy and vigor to perform moderate to vigorous levels of physical activity without undue fatigue and the capability of maintaining such ability throughout life. This energy and vigor is gained by following several good health habits such as getting regular sleep and physical activity, keeping body fat down and the muscles in good tone, and eating a balanced diet.
- Social health refers to the ability to interact effectively with other people and the social environment (e.g., social groups and networks), engaging in satisfying personal relationships. To gain social health, people should avoid social isolation and instead become involved with family, friends, neighbors, clubs, a church, and other social groups and organizations.

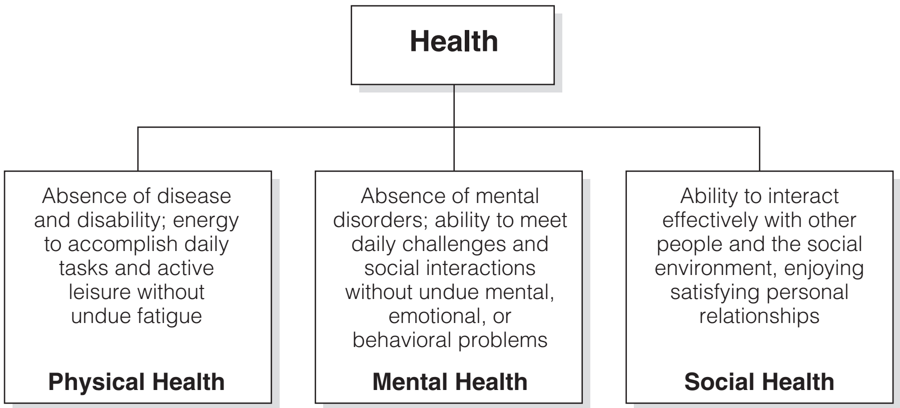

Figure 1.4 According to the World Health Organization, "Health is physical, mental, and social well-being, not merely the absence of disease and infirmity."

their recommendations to fit the goals and interests of their clients, realizing that many need the socialization and "fun" of sports to participate regularly in exercise.

The skill-related components of physical fitness have been defined as follows:[1,3]

Agility—the ability to rapidly change the position of the entire body in space, with speed and accuracy

Balance—the maintenance of equilibrium while stationary or in motion

Coordination—the ability to use the senses, such as sight and hearing, together with body parts, in performing motor tasks smoothly and accurately

Speed—the ability to perform a movement within a short period of time

Power—the rate at which a person can perform work (strength over time)

Reaction time—the time elapsed between a stimulus and the beginning of the reaction to it

The trend today in public policy recommendations is to emphasize the development of the health-related fitness elements, and to push for their prominence in school, worksite, and community programs.[1,2,3,13,19] Exercise testing batteries have been developed for children and adults to ensure that each of the health-related fitness elements is measured, followed by appropriate counseling to improve areas that may be deficient.[13,20–26]

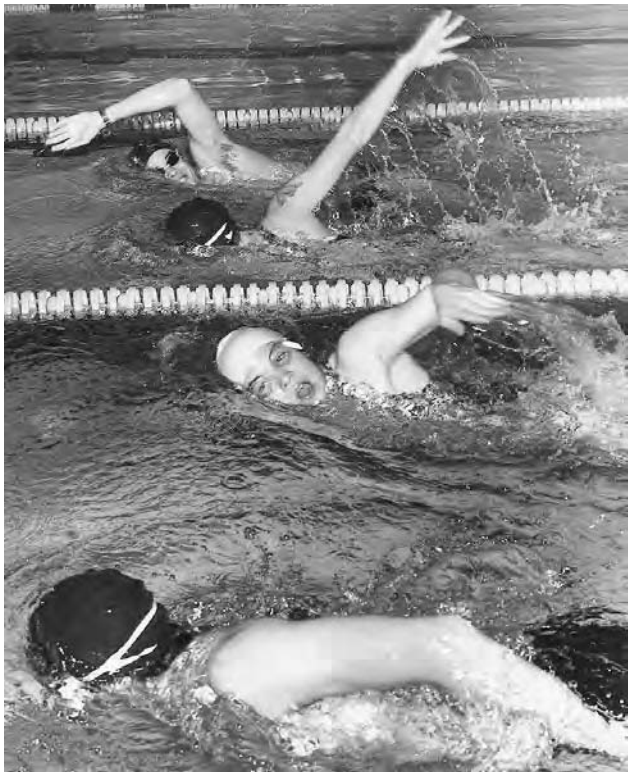

Figure 1.5 Cardiorespiratory endurance can be defined as the ability to continue or persist in strenuous tasks involving large muscle groups for extended periods of time. Swimming is one example.

The Elements of Health-Related Physical Fitness

Each of the components of health-related physical fitness can be measured separately from the others, and specific exercises may be applied to the development of each component.[11] In other words, the degree to which each of the five health-related components of physical fitness is developed in any one particular individual can vary widely. For example, a person may be strong but lack flexibility or may have good cardiorespiratory endurance but lack muscular strength. To develop "total" physical fitness for health, each of the components (cardiorespiratory endurance, body composition, and musculoskeletal fitness) must be tested separately and then included within the exercise prescription.

Cardiorespiratory Endurance

Cardiorespiratory endurance or *aerobic fitness* can be defined as the ability of the circulatory and respiratory systems to supply oxygen during sustained physical activity.[1,3,27,28] According to the ACSM, cardiorespiratory endurance is considered health related because low levels have been consistently linked with markedly increased risk of premature death from all causes, especially heart disease.[11]

For many people, being in good shape means having good cardiorespiratory endurance, exemplified by such feats as being able to run, cycle, and swim for prolonged periods of time (see Figure 1.5). High levels of cardiorespiratory endurance indicate a high physical work capacity, which is the ability to release relatively high amounts of energy over an extended period of time. To many fitness leaders, cardiorespiratory endurance is the most important of the health-related physical fitness components.

The laboratory test generally regarded as the best measure of cardiorespiratory endurance is the direct measurement of oxygen uptake during maximal, graded exercise. The exercise is usually performed using a bicycle ergometer or treadmill, which allows the progressive increase in workload from light to exhaustive (maximal) exercise. However, laboratory measurement of maximum oxygen uptake ($\dot{V}O_{2max}$) is expensive, time-consuming, and requires highly trained personnel and therefore is not practical for mass testing situations or the testing of most patients on a day-to-day basis.

Various tests to estimate $\dot{V}O_{2max}$ have been developed as substitutes. These include field tests, stair-climbing tests, submaximal bicycle tests, and maximal treadmill and cycle ergometer tests. These tests are described in detail in Chapter 3.

Figure 1.6 *Body composition* is the body's relative amounts of fat and lean body tissue, or fat-free mass (muscle, bone, water). Chapter 4 reviews procedures for measuring body fat through the use of skinfold calipers.

Based on existing evidence concerning exercise prescription for the enhancement of health and cardiorespiratory fitness, the ACSM has recommended that moderate-to-vigorous large-muscle-group activity be engaged in for 20–60 minutes, 3–5 days a week.[11] The U.S. Department of Health and Human Services (HHS) recommends that adults engage in a minimum of 150 minutes a week of moderate-intensity physical activity.[5] Exercise prescription is discussed in Chapter 6.

Body Composition

Body composition refers to the body's relative amounts of fat and lean body tissue or fat-free mass (e.g., muscle, bone, water).[1–3] Body weight can be subdivided simply into two components: fat weight (the weight of fat tissue) and fat-free weight (the weight of the remaining lean tissue). *Percent body fat*, the percentage of total weight represented by fat weight, is the preferred index used to evaluate a person's body composition. *Obesity* is defined as an excessive accumulation of fat weight. Men have optimal body fat levels when the percentage of body fat is 15% or less; they are considered obese when the body fat percentage is 25% and higher. The optimal body fat level for women is 23% or less, and they are considered obese when their body fat percentage is 33% or higher (see Chapter 4).

Interest in measurement of body composition has grown tremendously since the mid-1970s, largely because of its relationship to both sports performance and health. Elite athletes, individuals seeking to reach or maintain optimal body weight, and patients in hospitals have all benefited from the increased popularity and accuracy of body composition measurement.

Research to establish ways of determining body composition through indirect methods began during the 1940s. Since then, a wide variety of methods have been developed. The most precise measure for assessing body composition using the two-compartment model is hydrostatic (underwater) weighing, although skinfold testing is the method of choice for many physical educators and exercise scientists (see Figure 1.6). When conducted appropriately, estimation of percent body fat from skinfold measurements correlates well with hydrostatic weighing ($r > .80$). Chapter 4 deals with these methods, as well as some newer techniques for determining body composition.

Musculoskeletal Fitness

Musculoskeletal fitness or muscular fitness has three components: flexibility, muscular strength, and muscular endurance.

1. *Flexibility* is the functional capacity of the joints to move through a full range of movement.[1–3,11] Flexibility is specific to each joint of the body. Muscles, ligaments, and tendons largely determine the amount of movement possible at each joint (see Figure 1.7).
2. *Muscular strength* relates to the ability of the muscle to exert force. In other words, it is the maximal one-effort force that can be exerted against a resistance, or the maximum amount of force that one can generate in an isolated movement of a single muscle group.[1–3,11] The stronger the individual the greater the amount of force that can be generated. Lifting heavy weights maximally once or twice, or exerting maximal force when gripping a hand dynamometer,

Figure 1.7 *Flexibility* is defined as the functional capacity of the joints to move through a full range of movement.

provides measurements of muscular strength (see Figure 1.8).

3. *Muscular endurance* relates to the muscle's ability to continue to perform without fatigue.[1–3,11] In other words, it is the ability of the muscles to apply a submaximal force repeatedly or to sustain a submaximal muscular contraction for a certain period of time. Common muscular-endurance exercises are sit-ups, push-ups, chin-ups, or lifting weights 10–15 times in succession (see Figure 1.9).

Elaborate and expensive musculoskeletal fitness testing equipment is available, and books have been written describing the sophisticated testing that can be done with it.[28] For most people, however, simple and inexpensive musculoskeletal fitness tests such as the sit-and-reach flexibility test, push-ups, sit-ups, pull-ups, and various weight-lifting measures are available with extensive norms.[20–25] These are described in Chapter 5. Most of the health-related benefits of musculoskeletal fitness have focused on the contribution of abdominal muscle strength and endurance and lower back–hamstring flexibility for the prevention of low-back pain, a topic also explored in Chapter 5. Muscular fitness is also important in reducing the loss of muscle size and strength leading to frailty in old age (see Chapter 13).

Chapter 6 deals with conditioning principles to improve musculoskeletal fitness. The ACSM recommends that static stretching exercises be sustained for 10–30 seconds and then repeated two to four times, at least two to three times per week, to develop flexibility.[11] It is also recommended that an active aerobic warm-up precede vigorous stretching exercises.

For the development of muscular strength and endurance, the ACSM recommends two to four sets of 8–12 repetitions of 8–10 exercises that condition the major muscle groups at least 2 to 3 days per week.[11] Optimal gains in strength are provided by three sets of 5–7 repetitions of a weight-resistance exercise.

Figure 1.8 *Strength* relates to the ability of the muscle to exert force.

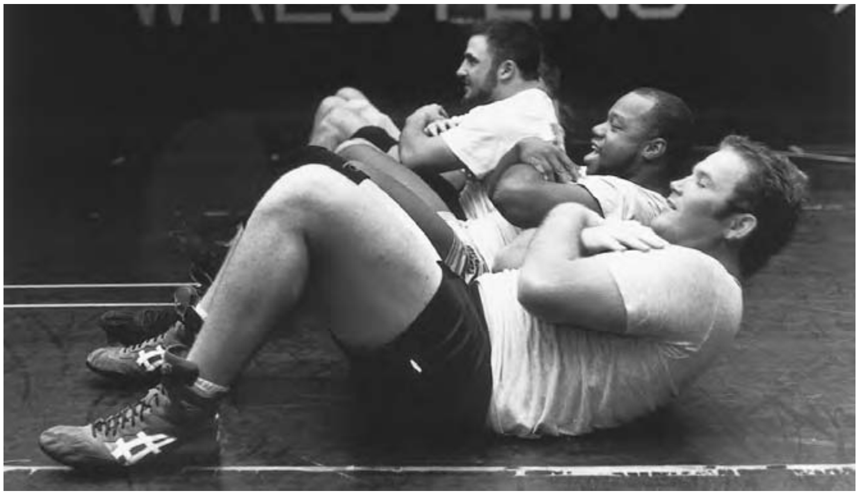

Figure 1.9 *Muscular endurance* relates to the muscle's ability to continue to perform without fatigue.

SPORTS MEDICINE INSIGHT

Physical Activity and the Health of Young People

The U.S. Department of Health and Human Services (HHS) recommends that young people (ages 6–17) participate in at least 60 minutes of physical activity daily[5] (Figure 1.10). Most of the 60 or more minutes a day should be either moderate- or vigorous-intensity aerobic physical activity, and should include vigorous-intensity physical activity at least 3 days a week. Running, hopping, skipping, jumping rope, swimming, dancing, and bicycling are all examples of aerobic activities. Young people should participate in physical activities that are appropriate for their age, that are enjoyable, and that offer variety.

Figure 1.10 Young people need at least 60 minutes of physical activity daily.

(continued)

SPORTS MEDICINE INSIGHT *(continued)*

Physical Activity and the Health of Young People

As part of their 60 or more minutes of daily physical activity, children and adolescents should include muscle-strengthening physical activity on at least 3 days of the week.[5] Muscle-strengthening activities can be unstructured and part of play, such as playing on playground equipment, climbing trees, and playing tug-of-war, or can be structured, such as lifting weights or working with resistance bands.

As part of their 60 or more minutes of daily physical activity, children and adolescents should include bone-strengthening physical activity on at least 3 days of the week.[5] Bone-strengthening activities produce a force on the bones that promotes bone growth and strength. Running, jumping rope, basketball, tennis, and hopscotch are all examples of bone-strengthening activities, and can also be classified as aerobic and muscle-strengthening.

Regular physical activity in childhood and adolescence improves strength and endurance, helps build healthy bones and muscles, helps control weight, reduces anxiety and stress, increases self-esteem, and may improve blood pressure and cholesterol levels.[5] Positive experiences with physical activity at a young age help lay the basis for being regularly active throughout life.[5]

Currently, 35% of high school students participate in at least 60 minutes per day of physical activity 5 days a week, and only 30% attend physical education class daily. Participation in physical activity declines strikingly as children age.[5] The prevalence of obesity among children ages 6–11 more than doubled in the past 20 years, going from 6.5% in 1980 to 17.0% in 2006. The rate among adolescents ages 12–19 more than tripled, increasing from 5.0 to 17.6%.[5]

Many children and adolescents are naturally physically active, and they need opportunities to be active and to learn skills. They benefit from encouragement from parents and other adults. Adults can promote age-appropriate activities in youths through these steps:[5]

- *Provide time for both structured and unstructured physical activity during school and outside school*. Examples include recess, physical activity breaks, physical education classes, after-school programs, and active time with family and friends.
- *Provide children and adolescents with positive feedback and good role models*. Parents and teachers should model and encourage an active lifestyle for children.
- *Help young people learn skills required to do physical activity safely*. Youths need to understand how to regulate the intensity of activity, increase physical activity gradually over time, set goals, use protective gear and proper equipment, follow rules, and avoid injuries.
- *Promote activities that set the basis for a lifetime of activity*. Children and adolescents should be exposed to a variety of activities, including active recreation, team sports, and individual sports.

SUMMARY

1. *Physical activity*, *exercise*, and *physical fitness* are terms that describe different concepts. Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure.
2. Exercise is a subcategory of physical activity and is planned, structured, repetitive, and purposive, in the sense that improvement or maintenance of physical fitness is an objective.
3. Several organizations have proposed definitions of physical fitness, most of them emphasizing attributes that people have or achieve, that relate to the ability to perform physical activity.
4. The measurable elements of physical fitness fall into two groups: skill-related fitness and health-related fitness. The former includes agility, balance, coordination, speed, power, and reaction time. The latter includes cardiorespiratory endurance, body composition, and musculoskeletal fitness, which includes flexibility, muscular strength, and muscular endurance.

Review Questions

1. ***Based on the information of this chapter, which activity listed scores highest in the development of all five of the measurable elements of health-related physical fitness?***

   A. Badminton **B.** Running
   C. Bowling **D.** Rowing
   E. Baseball

2. ***____ is physical activity that is planned for purposes of improving health.***

   A. Physical fitness **B.** Exercise
   C. Work **D.** Aerobics

3. ***Musculoskeletal fitness has three components, including flexibility, muscular strength, and____ .***

   A. cardiovascular endurance
   B. muscular endurance
   C. agility
   D. coordination
   E. speed

4. ***____ has been defined as any bodily movement produced by skeletal muscles that results in energy expenditure.***

   A. Flexibility **B.** Physical activity
   C. Muscular endurance **D.** Power
   E. Body composition

5. ***Which one is* not *a measurable element of health-related physical fitness?***

   A. Flexibility
   B. Cardiorespiratory endurance
   C. Muscular endurance
   D. Coordination
   E. Body composition

6. ***The HHS recommends that every U.S. adult engage in at least _____ minutes of moderate-intensity physical activity per week.***

   A. 25 **B.** 50 **C.** 75 **D.** 150 **E.** 300

7. ***____ relates to the rate at which one can perform work (strength over time).***

   A. Reaction time **B.** Power
   C. Agility **D.** Flexibility
   E. Cardiorespiratory endurance

8. ***Body composition refers to the body's relative amounts of fat and _____.***

   A. fat-free mass **B.** muscle
   C. bone **D.** total body weight
   E. body water weight

9. ***____ is the maximal one-effort force that can be exerted against a resistance.***

   A. Flexibility **B.** Muscular endurance
   C. Muscular strength **D.** Agility
   E. Coordination

10. ***____ is the functional capacity of the joints to move through a full range of movement.***

    A. Flexibility **B.** Muscular endurance
    C. Muscular strength **D.** Agility
    E. Coordination

11. ***Who has defined physical fitness as "the ability to perform moderate to vigorous levels of physical activity without undue fatigue and the capability of maintaining such ability throughout life"?***

    A. World Health Organization
    B. Centers for Disease Control and Prevention
    C. Dr. Kenneth H. Cooper
    D. American College of Sports Medicine
    E. President's Council on Physical Fitness and Sports

12. ***For the development of muscular strength and endurance, the ACSM recommends two to four sets of 8–12 repetitions of _____ exercises that condition the major muscle groups at least 2–3 days per week.***

    A. 8–10 **B.** 4–5 **C.** 15–20 **D.** 12–17 **E.** 2–3

13. ***The ACSM recommends that static stretching exercises be sustained for 10–30 seconds and then repeated two to four times, at least ______ times per week, to develop flexibility.***

    A. one or two **B.** two or three
    C. three or four **D.** five to seven

Answers

1. D
2. B
3. B
4. B
5. D
6. D
7. B
8. A
9. C
10. A
11. D
12. A
13. B

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PHYSICAL FITNESS ACTIVITY 1.1

Ranking Activities by Health-Related Value

As discussed in this chapter, there are five measurable elements of health-related fitness:

Cardiorespiratory endurance
Body compostion
Musculoskeletal fitness } **Flexibility**, **Muscular endurance**, **Muscular strength**

Sports and other forms of physical activity vary in their capacity to develop each component. In this Physical Fitness Activity, you will be ranking different sports and exercises in terms of their capacity to promote such development, using a 5-point scale for each of the five health-related fitness components. Answer the questions to the best of your ability, and then *compare* your answers in a group session with your teacher or your local fitness expert.

Rate each physical activity or sport in terms of its capacity to develop each of the five health-related components: 1 = not at all; 2 = somewhat or just a little bit; 3 = moderately; 4 = strongly; 5 = very strongly. Then answer the following question.

What five activities received the highest total score (add the five component scores for each activity)?

#1 Overall activity ____________________
#2 Overall activity ____________________
#3 Overall activity ____________________
#4 Overall activity ____________________
#5 Overall activity ____________________

Physical Activity—Recreational	Cardiorespiratory Endurance	Body Composition	Flexibility	Muscular Endurance	Muscular Strength	Total
Archery						
Backpacking						
Badminton						
Basketball						
Nongame						
Game play						
Bicycling						
Pleasure						
15 mph						
Bowling						
Calisthenics						
Canoeing, rowing, kayaking						
Dancing						
Social and square						
Aerobic						
Fencing						
Fishing						
Bank, boat, or ice						
Stream, wading						
Football (touch)						

Physical Activity—Recreational	Cardiorespiratory Endurance	Body Composition	Flexibility	Muscular Endurance	Muscular Strength	Total
Golf						
Power cart						
Walking, with bag						
Handball						
Hiking, cross-country						
Horseback riding						
Paddleball, racquetball						
Rope jumping						
Running						
12 min per mile						
6 min per mile						
Sailing						
Scuba diving						
Skating						
Ice						
Roller						
Skiing, snow						
Downhill						
Cross-country						
Skiing, water						
Sledding, tobogganing						
Snowshoeing						
Soccer						
Squash						
Stair climbing						
Swimming						
Table tennis						
Tennis						
Volleyball						
Walking briskly						
Weight training, circuit						
Physical Activity—Nonrecreational						
Bricklaying, plastering						
Digging ditches						
Shoveling light earth						
Splitting wood						

part II

Screening and Testing

chapter 2

Testing Concepts

Exercise professionals should understand that while there is an increased risk of sudden cardiac death and acute myocardial infarction with vigorous exercise, the physically active adult has between one-fourth to one-half the risk of developing cardiovascular disease.

—ACSM, 2010

Much has been learned about exercise and health during the past 40 years since the fitness movement first began. In general, exercise has been found to be both safe and beneficial for most people. However, there are some individuals who can suffer ill health from exercise. There's probably not a single fitness enthusiast in America who has not read the reports of famous athletes dying on basketball courts, runners found dead with their running shoes on, executives discovered slumped over their treadmills, or middle-aged men suffering heart attacks while shoveling snow.

Whether exercise is beneficial or hazardous to the heart depends on who the person is. For most people, regular exercise reduces the risk of heart disease by about one fourth to one half compared to those who are physically inactive (see Chapter 8 and Figure 2.1). However, for those who are at high risk for heart disease to begin with, vigorous exercise bouts can trigger fatal heart attacks. About 6 out of 100,000 middle-aged men die during or after exercise each year.[1] Studies show that these victims tend to be men who were sedentary, over age 35, already had heart disease or were at high risk for it, and then exercised too hard for their fitness levels (see Box 2.1).[1,2] And for patients with heart disease, the incidence of a heart attack or death during exercise is 10 times that of otherwise healthy individuals.[1]

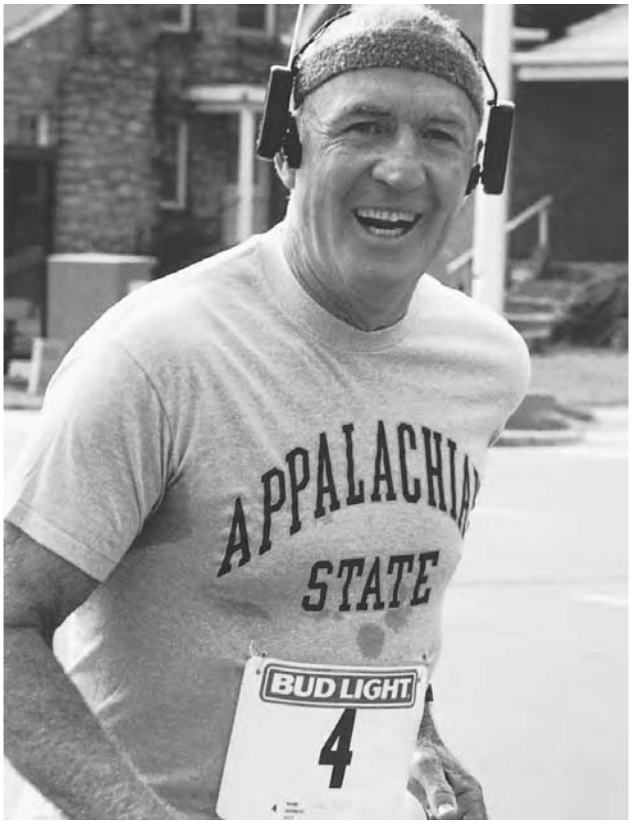

Figure 2.1 For most people, regular exercise reduces the risk of heart disease by about one half compared to those who are physically inactive.

Also of concern is congenital cardiovascular disease (CVD), now the major cause of athletic death in high school and college. Of athletes who die young and in their prime, most have heart or blood vessel defects that are present at birth.[3] Most common is hypertrophic cardiomyopathy, a thickening of the heart's main pumping muscle. In other

Box 2.1

The Saga of Jim Fixx

In northern Vermont, late on the afternoon of Friday, July 20, 1984, a passing motorcyclist discovered a man lying dead beside the road. He was clad only in shorts and Nike running shoes. The man was Jim Fixx, author of *The Complete Book of Running*. This amazingly successful book had stayed on the best-seller list for nearly 2 years, helping to accelerate the running boom of the late 1970s. Fixx had become one of the leading spokespersons on the health benefits of running. Now he lay dead—with his running shoes on—and this is why so many Americans were disturbed. Fixx died of cardiac arrest pounding the pavement to gain the fitness and health he advocated for all.

On autopsy, it was discovered that all of Fixx's blood vessels were partially or nearly completely blocked from atherosclerotic plaque buildup. The left circumflex coronary artery was 99% occluded, and scar tissue indicated that three other heart attacks had occurred within 2 months of his death. How could a man in seemingly peak condition, having run 60–70 miles per week for more than 12 years, be stricken by a disease most strongly associated with a sedentary life?

Fixx, despite his running, was at extremely high risk for heart disease—yet he chose to ignore the warning signals. His father had died of a heart attack at age 43. (Family history of heart disease, especially before age 55 for men, is an extremely potent risk factor; see Chapter 8.)

Up to his mid-30s, Fixx was smoking two packs of cigarettes per day, was a "steak-and-potatoes" man, weighed 220 pounds, and had a high-stress, executive job. At age 35, he suddenly tried to turn his life around by running a lot of miles. He lost weight and soon began racing marathons. He decided there was no need to see a doctor, however, even when experiencing heart disease warning signals such as throat and chest tightness. (Six months before Fixx's death, Fixx was invited to undergo a stress test, but he declined.) In addition, Fixx was not handling well the strain, stress, and pressure of notoriety.

Seventeen years later, at age 52, Fixx lay dead by the side of that Vermont back road, dead of a heart attack. Running may have lengthened his life a bit, but it probably ended up killing him as well.

---

words, when a young athlete dies during or shortly after exercise, it is most often due to a birth defect of the cardiovascular system.[1–3] The absolute risk of exercise-related death among high school and college athletes is 1 per 133,000 men and 769,000 women.[2]

Health screening is a vital process of first identifying individuals at high risk for exercise-induced heart problems and then referring them to appropriate medical care.[1,2] Despite the proven benefits of screening, efforts to screen new members at enrollment into health/fitness facilities are limited and inconsistent.[1]

Efforts to promote physical activity will result in increasing numbers of individuals with and without risk of heart disease joining health/fitness facilities and community exercise programs. Surveys reveal that 50% of health/fitness facility members are older than 35 years, and the fastest growing segments are middle-aged and elderly participants.[1] According to the American Heart Association, one third of all Americans have some form of cardiovascular disease (including high blood pressure), and the prevalence rises with age.[4] To ensure safe exercise participation, it is essential that people with underlying cardiovascular disease be identified before they initiate exercise programs.

The first half of this chapter focuses on guidelines health and fitness professionals can use to help protect participants when initiating exercise or athletic programs and emphasizes several key issues:

1. Always obtain a medical history or pre-exercise health risk appraisal on each participant.
2. Stratify individuals according to their disease risk.
3. Refer high-risk individuals to a health-care provider for medical evaluation and a graded exercise test.

PREPARTICIPATION HEALTH SCREENING

All facilities offering exercise equipment or services should conduct preparticipation health screening of all new members and/or prospective users, regardless of age.[1,2,5] The screening procedure should be simple, easy to perform, and not so intensive that it discourages participation. The screening questionnaires should be interpreted and documented by qualified staff to limit the number of unnecessary medical referrals and avoid barriers to participation.

The health appraisal questionnaire is useful in classifying a potential exercise participant according to disease risk and in facilitating the exercise prescription process. In general, the background information obtained from the questionnaire improves the exercise leader's ability to adjust the program to meet individual needs.

There are many questionnaires available for pre-exercise screening (see Physical Fitness Activity 2.2 for a comprehensive questionnaire). A comprehensive medical/health questionnaire should include the following:[2]

- Medical diagnoses
- Previous physical examination findings
- History of symptoms
- Recent illness, hospitalization, new medical diagnoses, or surgical procedures
- Orthopedic problems
- Medication use and drug allergies
- Lifestyle habits
- Exercise history
- Work history
- Family history of disease

When testing large numbers of individuals in a short period of time, or in most health/fitness facility settings, a shorter, simpler medical/health questionnaire is preferable. A brief, self-administered medical questionnaire called the Physical Activity Readiness Questionnaire (PAR-Q) has been used very successfully (see Figure 2.2).[6–8] The PAR-Q was designed in the 1970s by Canadian researchers and used in conjunction with the Canadian fitness testing program. After years of successful use and a revision in 1994, the PAR-Q is a safe pre-exercise screening measure for those who plan to engage in low-to-moderate (but not vigorous) exercise training.[7] Participants are directed to contact their personal physician if they answer "yes" to one or more questions.

In 1998, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) published a slightly more complex questionnaire than the PAR-Q[1] (see Physical Fitness Activity 2.1). The ACSM–AHA questionnaire uses history, symptoms, and risk factors to direct an individual to either initiate an exercise program or contact his or her physician. Persons at higher risk are directed to seek facilities providing appropriate levels of staff supervision. The questionnaire takes only a few minutes to complete, identifies high-risk participants, documents the results of screening, educates the consumer, and encourages and fosters appropriate use of the health-care system.

The ACSM recommends that all individuals interested in participating in organized exercise programs be evaluated for CVD risk factors, using guidelines from the National Cholesterol Education Program.[2] These include the following risk factors (which should not be viewed as an all-inclusive list, but are used by the ACSM for counting risk factors prior to risk stratification):

- *Age*. Men 45 and older; women 55 and older.
- *Family history*. Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative or before 65 years of age in mother or other female first-degree relative.
- *Cigarette smoking*. Current cigarette smoker or those who have quit within the previous 6 months.
- *Hypertension*. Systolic blood pressure (SBP) of ≥140 millimeters of mercury (mm Hg) or diastolic blood pressure (DBP) ≥90 mm Hg, confirmed by measurements on at least two separate occasions, or on antihypertensive medication.
- *Dyslipidemia*. Total serum cholesterol of >200 milligrams per deciliter (mg/dl) or high-density lipoprotein cholesterol of <40 mg/dl, or on lipid-lowering medication. If low-density lipoprotein cholesterol is available, use >130 mg/dl rather than the total cholesterol of <200 mg/dl. If the high-density lipoprotein cholesterol is >60 mg/dl subtract one risk factor from the sum of positive risk factors (negative risk factor).
- *Pre-diabetes*. Fasting blood glucose of ≥100 mg/dl but <126 mg/dl confirmed by measurements on at least two separate occasions.
- *Obesity*. Body mass index of ≥30 kilograms per square meter (kg/m^2), or waist girth of >102 centimeters (cm) for men and >88 cm for women.
- *Sedentary lifestyle*. Persons not participating in a regular exercise program (≥30 minutes of moderate activity, ≥3 days per week for ≥3 months).

The ACSM also recommends that preparticipation questionnaires include the following list of major signs or symptoms suggestive of cardiovascular and pulmonary disease:[2]

- Pain, discomfort (or other anginal equivalent) in the chest, neck, jaw, arms, or other areas that may be due to ischemia
- Shortness of breath at rest or with mild exertion
- Dizziness or syncope (loss of consciousness)
- Orthopnea (discomfort in breathing that is brought on or aggravated by lying flat) or paroxysmal nocturnal dyspnea (acute difficulty in breathing appearing suddenly at night, usually waking the patient after an hour or two of sleep)
- Ankle edema
- Palpitations (forcible or irregular pulsation of the heart perceptible to the individual, usually with an increase in frequency or force, with or without irregularity in rhythm) or tachycardia (rapid beating of the heart, typically over 100 beats per minute at rest)
- Intermittent claudication (a condition caused by lack of blood flow and oxygen to the leg muscles, characterized by attacks of lameness and pain, brought on by walking)
- Known heart murmur
- Unusual fatigue or shortness of breath with usual activities

Physical Activity Readiness
Questionnaire-PAR-Q
(revised 1994)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition *and* that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of *any other reason* why you should not do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want—as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to *all* PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active—begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in the fitness appraisal—this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively.

DELAY BECOMING MUCH MORE ACTIVE:

- If you are not feeling well because of a temporary illness such as a cold or a fever—wait until you feel better; or
- If you are or may be pregnant—talk to your doctor before you start becoming more active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

You are encouraged to copy the PAR-Q but only if you use the entire form.

Note: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.

NAME ____

SIGNATURE ________________________________ DATE ______________________

SIGNATURE OF PARENT ___________________________ WITNESS ______________________
or GUARDIAN (for participants under the age of majority)

Supported by: Health Canada Santé Canada

Figure 2.2 The Physical Activity Readiness Questionnaire (PAR-Q) offers an easy, brief evaluation of an individual's readiness to exercise before the individual starts an exercise program.

USING SCREENING RESULTS FOR RISK STRATIFICATION

Once symptom and risk factor screening has been conducted using questionnaires, the individual considering exercise testing and prescription should be stratified according to disease risk. Stratification according to disease risk is important for several reasons:

- To identify those in need of referral to a health-care provider for more extensive medical evaluation
- To ensure the safety of exercise testing and participation
- To determine the appropriate type of exercise test or program

The ACSM recommends using these risk stratification levels:[2]

- *Low risk*. Men and women who are asymptomatic and have no more than one risk factor for CVD.
- *Moderate risk*. Men and women who are asymptomatic and have two or more risk factors for CVD.
- *High risk*. Individuals with one or more signs or symptoms or with known cardiovascular, pulmonary, or metabolic disease.

Once individuals have been stratified according to risk, decisions can be made regarding the need for medical examination and exercise testing. The depth of the medical or physical examination for any individual considering an exercise program depends on the disease risk stratification. When a medical evaluation or recommendation is advised or required, written and active communication by the exercise staff with the individual's personal physician is strongly recommended.

Current medical examination and exercise testing is not necessary for low-risk individuals or those at moderate risk desiring to initiate a moderate-intensity exercise program (40–60% $\dot{V}O_{2max}$), but are recommended for high-risk individuals and those at moderate risk desiring to initiate a vigorous exercise program (>60% $\dot{V}O_{2max}$) and for high-risk individuals desiring to initiate a moderate exercise program.[1,2] During exercise testing, physician supervision is only recommended for high-risk individuals undergoing submaximal or maximal tests, and those at moderate risk undergoing maximal tests. Although the pre-exercise and testing guidelines are less rigorous for those at low risk, exercise testing still provides valuable information for establishing a safe and effective exercise prescription[2] (see Figure 2.3). A comprehensive physical fitness testing battery is recommended with body composition, aerobic fitness, and muscular fitness tests to help plan a total fitness exercise program.[2]

In general, most individuals, except for those with known serious disease, can begin a moderate exercise program such as walking without a medical evaluation or graded exercise test. Whenever people are in doubt about their own personal health and safety while exercising, a medical evaluation is recommended. Diagnostic exercise testing is not recommended as a routine screening

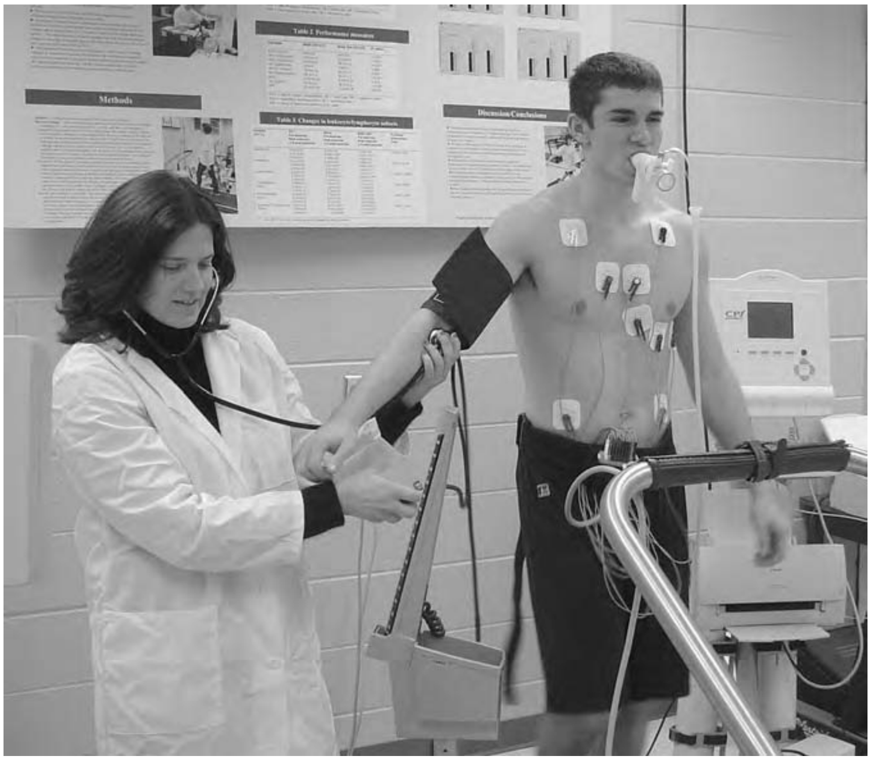

Figure 2.3 For people of all ages, information from the maximal graded exercise test is valuable in establishing an effective and safe exercise prescription.

Figure 2.4 For individuals at increased risk without symptoms, an exercise test or medical evaluation may not be necessary if moderate exercise is undertaken gradually, with appropriate guidance.

procedure in adults who have no evidence of heart disease (see Figure 2.4). As emphasized earlier in this chapter, risk of serious medical complications during exercise is low unless an individual is at high risk for cardiovascular disease. The celebrated exercise physiologist Dr. Per Olaf Astrand has emphasized:

> Anyone who is in doubt about the condition of his health should consult his physician. But as a general rule, moderate activity is less harmful to the health than inactivity. You could also put it this way: A medical examination is more urgent for those who plan to remain inactive than for those who intend to get into good physical shape.

Contraindications for Exercise and Exercise Testing

Although most people in the United States can safely undergo exercise testing and prescription, there are some who should not exercise. The risks for such people outweigh the benefits. The ACSM has established contraindications for exercise and exercise testing in out-of-hospital settings.[2] An absolute *contraindication* means that most experts would agree that it is inadvisable for the individual to be exercise tested or to engage in active exercise until such conditions are stabilized. These contraindications should be diagnosed only by medical doctors. Examples of absolute contraindications include recent heart attack, unstable angina, uncontrolled heart dysrhythmias, acute lung clots or infarction, acute heart muscle infection, dissecting aneurysm, and acute systemic infection with fever and swollen lymph glands.[2]

CARDIOVASCULAR SCREENING OF COMPETITIVE ATHLETES

An average of 12–20 athletes, most of them high school students, die suddenly each year from congenital heart defects that are not detected during normal physical examinations.[9–15] About a third of the cases of sudden cardiac death are caused by a congenital heart defect called hypertrophic cardiomyopathy (thickened heart muscle), with the next most frequent cause being congenital coronary anomalies (see Figure 2.5).

In the United States, there are nearly 10 million scholastic athletes. Although most states require a regular physical once every 1 or 2 years for these athletes, the cost for the more sensitive tests (e.g., two-dimensional echocardiography) that would detect heart defects ranges from $400 to $2,000 a screening. However, even with echocardiography, some athletes are incorrectly classified (e.g., false-positive or false-negative).[9]

The sudden death of a young athlete is tragic, but the financial, ethical, medical, and legal issues involved in preparticipation screening have created huge barriers. In 2007, the AHA published a consensus statement on this issue from a panel of experts.[9] The AHA developed a 12-item screening tool for CVD among athletes.[9] Any positive response or finding of the following 12 elements should prompt further cardiovascular testing. These elements include:

- Personal history
  - Exertional chest pain/discomfort
  - Unexplained syncope/near-syncope
  - Excessive exertional dyspnea/fatigue or unexplained dyspnea
  - Prior recognition of a heart murmur
  - Elevated systemic blood pressure
- Family history
  - Premature cardiovascular death before age 50 in at least one relative
  - Disability due to heart disease in at least one relative younger than 50 years
  - Family history of hypertrophic cardiomyopathy, long-QT syndrome, or significant arrhythmia

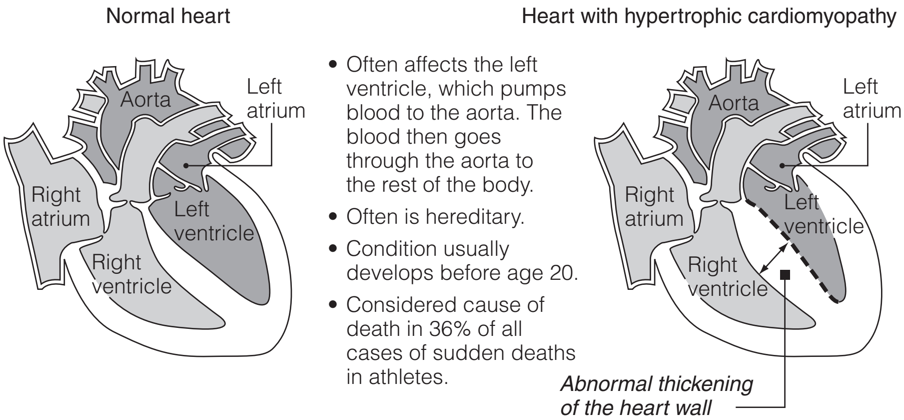

Figure 2.5 Hypertrophic cardiomyopathy is an abnormal thickening of the left ventricle muscle wall that typically goes undetected during routine physical exams and can cause sudden death in young athletes. Medical experts consider hypertrophic cardiomyopathy the most common fatal heart defect among young athletes. An athlete with this condition can compete for years without showing any symptoms and suddenly suffer a heart attack.

- Physical examination
  - Heart murmur
  - Diminished femoral pulses
  - Signs of Marfan syndrome
  - Elevated brachial blood pressure

The AHA recommends that the medical history of minors be completed by parents, and that licensed clinicians perform the screening examinations. In summary, AHA current guidelines indicate that routine preparticipation examination of young athletes in the United States should include the 12 elements of the AHA screening history and physical examination, but not an electrocardiogram (ECG), an echocardiogram, or stress testing.

INFORMED CONSENT

Like it or not, we live in an increasingly litigious society. Today's exercise program director, recreation administrator, or exercise testing program director is much more likely to be sued than his or her predecessors. In general, legal claims against exercise professionals are based on either alleged violations of contract law or tort principles.[2,5] A legal contract is a promise or performance bargained for and given in exchange for another. Most tort claims affecting the exercise professional are based on allegations of either negligence or malpractice, and commonly involve the following:[2,16–20]

- Failure to monitor an exercise test properly
- Failure to evaluate physical impairments competently
- Failure to prescribe a safe exercise intensity or program
- Failure to provide appropriate supervision
- Rendition of advice later construed to represent medical diagnosis
- Failure to refer participants to physician
- Failure to respond adequately to an untoward event
- Failure to disclose certain information in the informed-consent process

By law, any subject, patient, or client who is exposed to possible physical, psychological, or social injury must give informed consent prior to participation in a program.[2,5] *Informed consent* can be defined as the knowing consent of an individual or that person's legally authorized representative, with free power of choice and the absence of undue inducement or any element of force, fraud, deceit, duress, or other form of constraint or coercion.

The subject should read the informed-consent form and then sign it in the presence of a witness, indicating that the document has been read and consent given to participation under the described conditions. The consent form should be written so that it is easily understood by each participant, in the language in which the person is fluent.

No sample form should be adopted unless approved by local legal counsel. The following items should be included in the informed-consent form:[2,5]

1. A general statement of the background of the program and objectives
2. A fair explanation of the procedures to be followed
3. A description of any and all risks attendant to the procedures
4. A description of the benefits that can reasonably be expected
5. An offer to answer any of the subject's queries
6. An instruction that the subject, client, or patient is free to withdraw consent and to discontinue participation in the program at any time without prejudice to the person
7. An instruction that in the case of questionnaires and interviews, the participant is free to refuse to answer specific items or questions
8. An explanation of the procedures to be taken to ensure the confidentiality of the information derived from the participant

While it should be understood that execution of an informed-consent form does not protect the exercise or medical director from legal action, if the program is in accordance with established guidelines and run by a qualified staff, and the participant voluntarily assumes risk as outlined in the consent form, the possibility of legal action is minimized.[2,5]

HEALTH/FITNESS FACILITY STANDARDS AND GUIDELINES

In 1997, the ACSM established six standards and nearly 500 guidelines for health/fitness facilities, which have had a rather dramatic effect on the industry.[5,20] These standards were updated in 2007, and should be regarded as a benchmark of competency that probably will be used in a court of law to assess performance and service.[20] The ACSM has provided an extensive list of guidelines for physical plant safety, effective signage, organizational structure and professional staffing, user screening, emergency and safety procedures, external grounds, the control desk, laundry room, locker rooms, fitness testing and wellness areas, exercise classrooms, pool areas, and specialty areas (e.g., the spa, physical therapy area, climbing walls).[5]

The ACSM has established user screening guidelines for health/fitness facilities. Preactivity screening should be conducted for all users of health/fitness facilities using ACSM guidelines. In regard to staffing, the ACSM has recommended that each person who has supervisory responsibility for a physical activity program or area at a facility must have demonstrable professional competence in that physical activity program or area.[5] The ACSM defines demonstrable professional competence as some combination of education and professional experience that would be recognized by both the industry and the public at large as representing a relatively high level of competence and credibility.[5]

All health/fitness facilities must be prepared to handle situations that arise unexpectedly and have a comprehensive emergency plan that provides guidelines for the staff. These guidelines must be capable of handling basic first-aid and emergency cardiac events, and include a public access defibrillation (PAD) program.[5] Staff must have current automated external defibrillation (AED) and cardiopulmonary resuscitation (CPR) certifications.

CONCEPTS AND PURPOSES IN PHYSICAL FITNESS TESTING

Reduced to its simplest terms, the function of measurement is to determine status.[2,22–24] Ideally, status should be determined before individualized exercise counseling is conducted. The information from the physical fitness testing can be used along with the medical test information to better meet the individual's needs.

When conducting physical fitness tests, several important test criteria should be considered:[22–24]

1. *Validity*. Refers to the degree to which the test measures what it was designed to measure; a valid test is one that measures accurately what it is used to measure.
2. *Reliability*. Deals with how consistently a certain element is measured by the particular test; concerned with the repeatability of the test. If a person is measured two separate times by the same tester or by two different people, the results should be close to the same.
3. *Norms*. Represent the achievement level of a particular group to which the measured scores can be compared; norms provide a useful basis for interpretation and evaluation of test results.
4. *Economy*. Refers to ease of administration, the use of inexpensive equipment, the limitation of time needed to administer the test, and the simplicity of the test so that the person taking it can easily understand the purpose and results.

So in other words, a good physical fitness test accurately measures what it is supposed to measure, can be consistently used by different people, produces results that can be compared to a data set, and is relatively inexpensive, simple, and easy to administer.

In a complete physical fitness program, testing of participants before, during, and after participation is important for several reasons:[2,22–24]

1. To assess current fitness levels (both strengths and weaknesses)
2. To identify special needs for individualized counseling
3. To evaluate progress
4. To motivate and educate

Test results are best viewed as a means to an end, not as an end in themselves. In other words, the testing process should be used to help individuals know more about themselves so that appropriate health and fitness goals can be established. Expensive, elaborate, and lengthy testing is seldom needed (except in research) and can be distractive (Figure 2.6). Scores on the various items of the simple and inexpensive test batteries noted at the end of this chapter are adequate to identify the strengths and weaknesses of participants, so that special attention can be given to individualized goals and objectives. If anything, it is better to undertest than overtest so that more time and attention can be given to counseling and guiding each participant through the exercise program.

Figure 2.6 Expensive and elaborate testing such as direct measurement of $\dot{V}O_{2max}$ during graded exercise testing is seldom needed for the average fitness participant.

PHYSICAL FITNESS TESTING BATTERIES

The very process of administering a fitness test draws attention to what is considered worthy of special attention in a person's lifestyle. The test results can therefore be used to educate, motivate, and stimulate interest in exercise and other health-related topics.

Recommended Order for Fitness-Evaluation Tests

The evaluation procedure has a recommended order for both safety and efficiency. In general, it is best for the participant to fill out the medical/health status questionnaire at home before coming to the testing center. The testing batteries listed at the end of this chapter usually take only about 1 hour.

Precise instructions should be given to the participants before they come to the testing site. In general they should come in exercise attire (and bring a swimsuit if necessary); avoid eating or drinking for 3 hours before the test; avoid alcohol, tobacco, and coffee for at least 3 hours before the test; avoid exercise the day of the test; try to get a good night's sleep; and bring the medical/health status questionnaire.

If blood is to be analyzed, alcohol consumption and vigorous exercise should be avoided for 24 hours beforehand, and a 12-hour fast is recommended. Diabetics should be allowed to keep their dietary habits and injections of insulin as regular as possible. According to the ACSM, patients should continue their medication regimen on their usual schedule so that the exercise test responses will be consistent with responses expected during exercise training.[2]

The organization of the testing session is important. It should begin with the quiet, resting tests (heart rate, blood pressure, blood drawing, all after a 5-minute rest). Body composition measures should follow next, and then the graded exercise test for cardiorespiratory endurance. Finally, the musculoskeletal tests should be given.

If musculoskeletal tests precede the graded exercise test, the heart rate can be elevated, giving false information on fitness status, especially when submaximal tests are conducted.

Immediate feedback and counseling should follow the testing. Follow-up evaluations should be conducted after 3–6 months, after 1 year of training, and yearly thereafter.[2,22–24]

Health-Related Fitness Testing Batteries

The YMCA, Canadian Society for Exercise Physiology, American Fitness Alliance, and President's Council on Physical Fitness and Sports have each developed physical fitness testing batteries that follow the recommended criteria of testing outlined in this chapter. They are valid, reliable, and economical, and they have sound norms. In addition, most follow a comprehensive health-related fitness approach, testing each of the five components.[25]

The norms for the various tests within these batteries are found in Appendix A. Descriptions of how to conduct the tests are found in the following chapters of this book. A brief outline of each testing battery is listed in this section.

YMCA

The YMCA physical fitness testing battery for adults is administered in the following order:[26]

- Standing height
- Weight
- Resting heart rate
- Resting blood pressure
- Skinfold tests for men and women (at three or four sites)
- Submaximal cycle test for cardiorespiratory endurance; 3-minute step test for mass testing
- Sit-and-reach test (for flexibility)
- Bench-press test (35 pounds [lb], women; 80 lb, men) at a rate of 30 times per minute for muscular endurance and strength
- Timed (1 minute) sit-ups for abdominal muscular endurance; or abdominal curl-ups

The YMCA also has a testing manual for youths:[27]

- Skinfolds (triceps and calf)
- Run (1 mile [mi])
- Sit-and-reach test (for flexibility)
- Modified pull-ups
- Curl-ups (40 maximum)

Canadian Physical Activity, Fitness & Lifestyle Appraisal (CPAFLA)

In 1981, the Canada Fitness Survey was initiated and funded by Fitness and Amateur Sport in Canada.[7] A major objective of the survey was to provide reliable statistics on physical activity patterns and fitness levels of the Canadian population. The survey sample consisted of 11,884 households that had been identified by Statistics Canada and that were located in urban and rural areas of each province. Members of these households, 15,519 between the ages of 7 and 69, undertook the Canadian Standardized Test of Fitness; this was the largest and most comprehensive study of physical activity and fitness ever undertaken. In 1996 and 2003, these data were repackaged by the Canadian Society for Exercise Physiology as the "Canadian Physical Activity, Fitness & Lifestyle Appraisal" (CPAFLA).[7] (See Appendix A for norms.) The CPAFLA is administered in the following order (after pretest screening using the PAR-Q and a consent form):[7]

- Resting heart rate
- Resting blood pressure
- Standing height
- Body mass (weight)
- Waist girth
- Skinfolds (triceps, biceps, subscapular, iliac crest, medial calf)
- Canadian aerobic fitness step test
- Grip strength (right and left hands)
- Push-ups
- Trunk-forward flexion
- Partial curl-ups
- Vertical jump

AAHPERD: Health-Related Fitness Test for College Students

AAHPERD released the results of its testing program for college students in 1985.[28] The study population consisted of 5,158 young adults in colleges from all geographic regions of the United States. The data for the study were collected under the supervision of 24 coinvestigators. The test items in order are as follows (see Appendix A for norms):

- Two-site skinfold test (triceps and subscapular)
- Mile run or 9-minute run for cardiorespiratory endurance
- Sit-and-reach test for flexibility
- Timed (1 minute) sit-ups for abdominal muscular endurance

FITNESSGRAM

FITNESSGRAM is a youth fitness testing system developed by the Cooper Institute for Aerobics Research and now a part of the testing program of the American Fitness Alliance.[29–32] The test items are health related and use criterion-referenced standards for each age and sex group. These standards are thought to represent minimum levels of performance that most often correlate with health. Physical Best is a companion product to FITNESSGRAM, and is the educational component of a comprehensive health-related physical fitness education program sponsored by the American Fitness Alliance (AAHPERD, the Cooper Institute, and Human Kinetics).[29–32]

Recommended test items of the FITNESSGRAM include:

- Aerobic capacity (select one)

  The pacer. A 20-meter (m) progressive, multistage shuttle run set to music

  One-mile walk/run.

  Walk test. For students 13 years of age and older

- Body composition (select one)

  Percent body fat. Calculated from triceps and calf skinfold measurements or bioelectrical impedance

  Body mass index. Calculated from height and weight

- Muscle strength, endurance, and flexibility

  Abdominal strength. Curl-up test

  Trunk extensor strength and flexibility. Trunk lift

Upper Body Strength (select one). 90-degree (°) push-up, flexed arm hang, or modified pull-up

Flexibility (select one). Back-saver sit-and-reach, or shoulder stretch

The Brockport Physical Fitness Test is a health-related test developed specifically for youths with physical and mental disabilities.[33]

The President's Challenge

The President's Council on Physical Fitness and Sports School Population Fitness Survey was conducted in 1985. Data were collected to assess the physical fitness status of American public school children ages 6–17. A four-stage probability sample was designed to select approximately 19,200 boys and girls from 57 school districts and 187 schools.

Data from this survey provide the norms for the current Presidential Physical Fitness Award Program, or "President's Challenge" (about 3 million awards distributed each year).[34] The test battery consists of five required items:

1. *Curl-ups*. A test of muscular endurance: Perform for 1 minute, knees bent, arms crossed, hands on opposite shoulders, and feet anchored by a partner. Partial curl-ups are allowed as an option to curl-ups (knees bent, feet not anchored, reach fingertips to knees every 3 seconds).
2. *Shuttle run*. A total-body coordination test, with parallel lines marked 30 feet (ft) apart, and the students timed as they race to pick up two blocks from the distant line and run them to the starting line.
3. *One-mile run/walk*. To measure heart/lung endurance by the fastest time to cover a 1-mi distance. Alternative distances for younger children are ¼ mi for those ages 6–9 years.
4. *Pull-ups*. To measure upper-body strength and endurance by maximum number of pull-ups completed using either an overhand or underhand grasp of the bar. Right-angle push-ups are an optional test to pull-ups, with the body lowered until there is a 90° angle at the elbows, with the body and legs straight.
5. *V-sit reach*. To measure flexibility of the lower back and hamstrings by reaching forward in the V position, and legs held flat by a partner. The sit-and-reach test can be used as an option to the V-sit reach, using a specially constructed flexibility box.

Young people ages 6–17 can receive one of four awards as part of the President's Challenge:

1. *Presidential Physical Fitness Award*. Score at or above the 85th percentile on all five items.
2. *National Physical Fitness Award*. Score at or above the 50th percentile on all five items.
3. *Participant Physical Fitness Award*. Attempt all five items but score below the 50th percentile on one or more of them.
4. *Health Fitness Award*. Test scores meet or exceed the specified health criteria on each of these five items—partial curl-ups, 1-mi run (or distance option), V-sit reach (or sit-and-reach), right-angle push-ups (or pull-ups), and body mass index (derived from height and weight).

SPORTS MEDICINE INSIGHT

Certification for Health and Fitness Professionals

Certification provides health/fitness professionals with public recognition of their knowledge, technical skills, and experience in their particular field. It certifies that the individual is qualified to practice in accordance with the standards deemed to be essential by the certifying body.[35,36]

The most prestigious health and fitness certification program is conducted by the American College of Sports Medicine (ACSM). This Sports Medicine Insight provides a description of the ACSM's certification program. See www.acsm.org for more information. This textbook was written to help individuals prepare for the ACSM Certified Health Fitness Specialist certification. The ACSM offers two health/fitness certifications and two clinical certifications, each of which is accredited by the National College Athletic Association (NCAA).

HEALTH/FITNESS CERTIFICATIONS

ACSM Certified Personal Trainer

ACSM Certified Personal Trainers are qualified to develop and implement exercise programs for apparently healthy individuals or those who have medical clearance to exercise. Using a variety of teaching techniques, the ACSM Certified Personal Trainer is proficient in leading and demonstrating safe and effective methods of exercise by applying the fundamental principles of exercise science, writing appropriate exercise recommendations, leading and demonstrating safe and effective methods of exercise, and motivating individuals to begin and to continue with their healthy behaviors. Minimum

(continued)

SPORTS MEDICINE INSIGHT *(continued)*

Certification for Health and Fitness Professionals

requirements include being 18 years of age or older, having a high school diploma or equivalent, and having a current adult CPR certification.

ACSM Certified Health Fitness Specialist

This advanced personal trainer certification allows the professional to work with a wider variety of clients, including those with health risks. The ACSM Certified Health Fitness Specialist (HFS) is skilled to conduct risk stratification and physical fitness assessments, provide appropriate exercise prescriptions, and motivate apparently healthy individuals with medically controlled diseases to adopt and maintain healthy lifestyle behaviors. Minimum requirements include an associate's or bachelor's degree in a health-related field from a regionally accredited college or university, and a current adult CPR certification.

CLINICAL CERTIFICATIONS

ACSM Certified Clinical Exercise Specialist

ACSM Certified Clinical Exercise Specialists are health care professionals with a bachelor's degree in an allied health field who typically work in cardiovascular/pulmonary rehabilitation programs, physicians' offices, or medical fitness centers. The ACSM Certified Clinical Exercise Specialist (CES) may also provide exercise-related consulting for research, public health, and other clinical and nonclinical services and programs, and is certified to deliver exercise assessment, training, rehabilitation, risk-factor identification, and lifestyle management services. Other than a bachelor's degree, applicants must have a minimum of 600 hours of practical experience in a clinical exercise program (e.g., cardiac/pulmonary rehabilitation programs), and current certification as a Basic Life Support Provider or CPR for the Professional Rescuer (available through the American Heart Association or the American Red Cross).

ACSM Registered Clinical Exercise Physiologist

This certification is for graduate students or clinical professionals with a master's degree who are interested in working with clients currently under the care of a physician for cardiovascular, pulmonary, metabolic, orthopedic/musculoskeletal, neuromuscular, or immunological/hematological disease. ACSM Registered Clinical Exercise Physiologists (RCEPs) work individually, or as part of an interdisciplinary team in clinical, communication, and public health settings, and their practice is guided by published professional guidelines, standards, and applicable state and federal regulations. The RCEP performs exercise testing, prescription, counseling, and supervision; provides health promotion counseling; and evaluates exercise and physical activity outcome measures. Minimum requirements include a master's degree from a college or university in exercise science, exercise physiology, or kinesiology; current certification as a Basic Life Support Provider or CPR for the Professional Rescuer; and an ACSM Exercise Specialist Certification (current or expired) or 600 hours of clinical experience.

SUMMARY

1. For those who are at high risk for heart disease to begin with, vigorous exercise bouts can trigger fatal heart attacks. These victims tend to be men who were sedentary, over age 35, already had heart disease or were at high risk for it, and then exercised too hard for their fitness levels.
2. Health screening is a vital process in first identifying individuals at high risk for exercise-induced heart problems, and then referring them to appropriate medical care.
3. All facilities offering exercise equipment or services should conduct a health and cardiovascular screening of all new members and/or prospective users, regardless of age.
4. Several types of health appraisal questionnaires are available including a comprehensive medical/health questionnaire, the Physical Activity Readiness Questionnaire (PAR-Q), and the 1998 ACSM–AHA questionnaire.
5. When a medical evaluation or recommendation is advised or required, written and active communication by the exercise staff with the individual's personal physician is strongly recommended.
6. The ACSM recommends that the information gathered from the screening process be used to stratify participants into one of three risk strata: low risk, moderate risk, high risk.
7. The depth of the medical or physical examination for any individual considering an exercise program depends on the disease risk stratification.
8. The AHA recommends that some form of preparticipation cardiovascular screening for high school

and collegiate athletes is justifiable and compelling, based on ethical, legal, and medical grounds.

9. We live in an increasingly litigious society. Proper informed-consent forms and the adoption of appropriate strategies for reducing liability exposure are needed.
10. The function of measurement is to determine health and fitness status. Tests should be valid, reliable, have sound norms, and be economical in terms of money, time, and testing expertise.
11. Physical fitness tests have several purposes, including assessment of status, identification of special needs, evaluation of progress, and motivation.
12. Evaluation procedures should follow a certain order for both safety and efficiency.
13. The YMCA, Canadian Society for Exercise Physiology, American Fitness Alliance, and President's Council on Physical Fitness and Sports have developed health-related physical fitness testing batteries.

Review Questions

1. ***About ______ out of 100,000 middle-aged men die during or after exercise each year.***

   A. 6 **B.** 20 **C.** 50 **D.** 78 **E.** 97

2. ***The major cause of athletic death in high school and college each year is ______.***

   A. major injury
   B. congenital cardiovascular disease
   C. ischemic heart disease
   D. exercise-induced stroke
   E. cocaine-related cerebral hemorrhage

3. ***If a male 40 years of age smokes 20 cigarettes per day, has normal blood pressure, and a father who died at age 48 of a heart attack, the American College of Sports Medicine would classify that individual as ______.***

   A. low risk **B.** moderate risk **C.** high risk

4. ***Which symptom listed below is* not *suggestive of heart, lung, or metabolic disease?***

   A. Pain or discomfort in the chest or surrounding areas
   B. Headache after exercise
   C. Unaccustomed shortness of breath
   D. Dizziness or fainting
   E. Severe pain in leg muscles during walking

5. ***Pre-diabetes is classified when the fasting blood glucose is ______.***

   A. >140 mg/dl
   B. <100 mg/dl
   C. ≥126 mg/dl
   D. 100–125 mg/dl
   E. 60–99 mg/dl

6. ***Which individual(s) described below should have a medical exam and graded exercise test prior to starting a moderate walking program?***

   A. A 60-year-old obese and sedentary woman with no symptoms of heart disease
   B. A 40-year-old male who smokes and has chest pain and difficulty breathing after climbing stairs
   C. A 55-year-old sedentary female with high blood pressure
   D. A 22-year-old male student with a father who died at age 50 from a heart attack
   E. All of the above

7. ***Which risk factor listed below is* not *on the American College of Sports Medicine's list for classifying individuals prior to exercise?***

   A. Serum cholesterol >200 mg/dl
   B. HDL cholesterol ≤45 mg/dl
   C. Body mass index ≥30 kg/m^2
   D. SBP ≥140 or DBP ≥90 mm Hg
   E. Family history of heart disease in parents or siblings prior to age 55 for males and age 65 for females

8. ***______ deals with how consistently a certain element is measured by a particular test, in other words, the repeatability of the test.***

   A. Validity **B.** Reliability **C.** Economy

9. ***If the HDL-C is >______ mg/dl, subtract one risk factor from the sum of positive risk factors.***

   A. 60 **B.** 45 **C.** 40 **D.** 70 **E.** 30

10. ***Moderate exercise, according to the ACSM, is defined as less than or equal to a threshold of _____% $\dot{V}O_{2max}$.***

    A. 80 **B.** 40 **C.** 60 **D.** 30 **E.** 75

11. ***Individuals at moderate risk, according to the American College of Sports Medicine, are those with _____ or more major coronary risk factors.***

    A. 1 **B.** 2 **C.** 3 **D.** 4 **E.** 5

12. ***When administering a physical fitness testing battery, body composition measures should come before graded exercise testing for cardiorespiratory endurance.***

    A. True **B.** False

13. ***Physician supervision is recommended during exercise testing for ______.***

A. a low-risk male who is undergoing maximal testing
B. a moderate-risk female who is undergoing maximal testing
C. an individual at moderate risk undergoing submaximal testing
D. a low-risk, 57-year-old male who is undergoing submaximal testing

14. ***How many risk factors does a 55-year-old male have, according to the ACSM, if he has no family history of heart disease, does not smoke, has a blood pressure of 134/84 mm Hg, a serum cholesterol of 244 mg/dl, a sedentary lifestyle, and a body mass index of 32 kg/m²?***

A. 1 **B.** 2 **C.** 3 **D.** 4 **E.** 5

15. ***About 12–20 athletes, most of them high school students, die suddenly each year from congenital heart defects. About a third of the cases of sudden cardiac death are caused by a congenital heart defect called ______.***

A. myocardial infarction
B. stroke
C. echocardiography
D. hypertrophic cardiomyopathy
E. ischemia

Answers

1. A
2. B
3. B
4. B
5. D
6. B
7. B
8. B
9. A
10. C
11. B
12. A
13. B
14. D
15. D

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PHYSICAL FITNESS ACTIVITY 2.1

Are You Ready to Exercise?

Name ______________________________

Age ______________________________

Sex ______ M ______ F

1. Turn to the questionnaire on the following page and carefully answer all of the questions.
2. Based on your questionnaire responses, in what ACSM category would you put yourself?
   ______ Low risk
   ______ Moderate risk
   ______ High risk
3. Based on your ACSM category, and whether you plan to exercise moderately or vigorously, what guidelines for exercise testing and participation apply to you?
   ____
   ____
   ____
   ____
   ____
4. Do you need a medical exam and diagnostic exercise test prior to starting your exercise program?
   ______ Yes
   ______ No

AHA–ACSM Preparticipation Screening Questionnaire (AHA/ACSM, 1998)[1]

Assess Your Health Needs by Marking All *True* Statements

History

You have had:

☐ A heart attack
☐ Heart surgery
☐ Cardiac catheterization
☐ Coronary angioplasty (PTCA)
☐ Pacemaker/implantable cardiac
☐ Defibrillator/rhythm disturbance
☐ Heart valve disease
☐ Heart failure
☐ Heart transplantation
☐ Congenital heart disease

Other health issues:

☐ You have diabetes.
☐ You have asthma or other lung disease.
☐ You have burning or cramping sensation in your lower legs when walking short distance.
☐ You have musculoskeletal problems that limit your physical activity.
☐ You have concerns about the safety of exercise.
☐ You take prescription medication(s).
☐ You are pregnant.

Recommendations

If you marked any of the statements in this section, consult your health-care provider before engaging in exercise. You may need to use a facility with a **medically qualified staff.**

Symptoms

☐ You experience chest discomfort with exertion.
☐ You experience unreasonable breathlessness.
☐ You experience dizziness, fainting, blackouts.
☐ You take heart medications.

Cardiovascular risk factors

☐ You are a man older than 45 years.
☐ You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.
☐ You smoke or quit smoking within the previous 6 months.
☐ Your blood pressure is greater than 140/90 mm Hg.
☐ You don't know your blood pressure.
☐ You take blood pressure medication.
☐ Your blood cholesterol level is >200 mg/dl.
☐ You don't know your cholesterol level.
☐ You have a blood relative who had a heart attack before age 55 (father/brother) or 65 (mother/sister).
☐ You are diabetic or take medicine to control your blood sugar.
☐ You are physically inactive (i.e., you get less than 30 minutes of physical activity on at least 3 days/week).
☐ You are more than 20 pounds overweight.

If you marked two or more of the statements in this section, you should consult your health-care provider before engaging in exercise. You might benefit by using a facility with a **professionally qualified exercise staff** to guide your exercise program.

☐ None of the above is true.

You should be able to exercise safely without consulting your health-care provider in almost any facility that meets your exercise program needs.

PHYSICAL FITNESS ACTIVITY 2.2

Medical/Health Questionnaire

According to the American College of Sports Medicine, a medical examination and clinical exercise test is recommended prior to (1) moderate or vigorous exercise training for those at high risk for disease, and (2) vigorous exercise training for moderate-risk individuals. The ACSM recommends that the pretest medical history be thorough and include 11 components: medical diagnoses, previous physical examination findings, history of symptoms, recent illness, hospitalization or surgical procedures, orthopedic problems, medication use and drug allergies, lifestyle habits, exercise history, work history, and family history of disease. The following medical and health questionnaire meets these criteria and can be used to gain a useful history on clients at fitness-testing facilities located in worksites, hospitals, and universities. In this activity, select a faculty member or member of the community that you feel would benefit from this process. Have the person answer the questions in the medical questionnaire, and then summarize important findings in the following blanks.

1. Symptoms or signs of disease: ______________________________

____

____

____

2. Chronic disease risk factors: ______________________________

____

____

____

3. Personal and family medical history: ______________________________

____

____

____

4. Medications: ______________________________

____

____

____

5. Summary of lifestyle habits: ______________________________

____

____

____

Medical/Health Questionnaire

Personal Information

Today's date _______________ Please print your name ____________________________

How old are you? _________ years Sex ❑ Male; ❑ Female

Please circle the highest grade in school you have completed:

Elementary school	1	2	3	4	5	6	7	8
High school	9	10	11	12				
College/Postgrad	13	14	15	16	17	18	19	20+

What is your marital status? ❑ Single; ❑ Married; ❑ Widowed; ❑ Divorced/Separated

Race or ethnic background:

❑ White, not of Hispanic origin ❑ American Indian/Alaskan native ❑ Asian
❑ Black, not of Hispanic origin ❑ Pacific Islander ❑ Hispanic

What is your job or occupation? Check the one that applies to the greatest percentage of your time.

❑ Health professional ❑ Disabled, unable to work ❑ Service
❑ Manager, educator, professional ❑ Operator, fabricator, laborer ❑ Unemployed
❑ Skilled crafts ❑ Homemaker ❑ Student
❑ Technical, sales, support ❑ Retired ❑ Other

Symptoms or Signs Suggestive of Disease

Place a check in the box if your answer is "yes."

❑ **1.** Have you experienced unusual pain or discomfort in your chest, neck, jaw, arms, or other areas that may be due to heart problems?

❑ **2.** Have you experienced unusual fatigue or shortness of breath at rest, during usual activities, or during mild-to-moderate exercise (e.g., climbing stairs carrying groceries, brisk walking, cycling)?

❑ **3.** Have you had any problems with dizziness or fainting?

❑ **4.** When you stand up, or sometimes during the night while you are sleeping, do you have difficulty breathing?

❑ **5.** Do you suffer from swelling of the ankles (ankle edema)?

❑ **6.** Have you experienced an unusual and rapid throbbing or fluttering of the heart?

❑ **7.** Have you experienced severe pain in your leg muscles during walking?

❑ **8.** Has a doctor told you that you have a heart murmur?

Chronic Disease Risk Factors

Place a check in the box if your answer is "yes."

❑ **9.** Are you a male over age 45 years, or a female over age 55 years, or a female who has experienced premature menopause and is not on estrogen replacement therapy?

❑ **10.** Has your father or brother had a heart attack or died suddenly of heart disease before age 55 years; has your mother or sister experienced these heart problems before age 65 years?

❑ **11.** Are you a current cigarette smoker?

❑ **12.** Has a doctor told you that you have high blood pressure (more than 140/90 mm Hg), or are you on medication to control your blood pressure?

❑ **13.** Is your total serum cholesterol greater than 240 mg/dl, or has a doctor told you that your cholesterol is at a high-risk level?

❑ **14.** Do you have diabetes mellitus?

❑ **15.** Are you physically inactive and sedentary (little physical activity on the job or during leisure time)?

❑ **16.** During the past year, would you say that you experienced enough stress, strain, and pressure to have a significant effect on your health?

❑ **17.** Do you eat foods nearly every day that are high in fat and cholesterol such as fatty meats, cheese, fried foods, butter, whole milk, or eggs?

❑ **18.** Do you tend to avoid foods that are high in fiber such as whole-grain breads and cereals, fresh fruits, or vegetables?

❑ **19.** Do you weigh 30 or more pounds more than you should?

❑ **20.** Do you average more than two alcoholic drinks each day?

Medical History

21. Please check which of the following conditions you have had or now have. Also check medical conditions in your family (father, mother, brother[s], or sister[s]). Check as many as apply.

Personal	Family	Medical Condition
❏	❏	Coronary heart disease, heart attack, coronary artery surgery
❏	❏	Angina
❏	❏	High blood pressure
❏	❏	Peripheral vascular disease
❏	❏	Phlebitis or emboli
❏	❏	Other heart problems (specify: ____________________________)
❏	❏	Lung cancer
❏	❏	Breast cancer
❏	❏	Prostate cancer
❏	❏	Colorectal cancer (bowel cancer)
❏	❏	Skin cancer
❏	❏	Other cancer (specify: ____________________________________)
❏	❏	Stroke
❏	❏	Chronic obstructive pulmonary disease (emphysema)
❏	❏	Pneumonia
❏	❏	Asthma
❏	❏	Bronchitis
❏	❏	Diabetes mellitus
❏	❏	Thyroid problems
❏	❏	Kidney disease
❏	❏	Liver disease (cirrhosis of the liver)
❏	❏	Hepatitis
❏	❏	Gallstones/gallbladder disease
❏	❏	Osteoporosis
❏	❏	Arthritis
❏	❏	Gout
❏	❏	Anemia (low iron)
❏	❏	Bone fracture
❏	❏	Major injury to foot, leg, knee, hip, or shoulder
❏	❏	Major injury to back or neck
❏	❏	Stomach/duodenal ulcer
❏	❏	Rectal growth or bleeding
❏	❏	Cataracts
❏	❏	Glaucoma
❏	❏	Hearing loss
❏	❏	Depression
❏	❏	High anxiety, phobias
❏	❏	Substance abuse problems (alcohol, other drugs, etc.)
❏	❏	Eating disorders (anorexia, bulimia)
❏	❏	Problems with menstruation

❏ ❏ Hysterectomy
❏ ❏ Sleeping problems
❏ ❏ Allergies
❏ ❏ Any other health problems (please specify, and include information on any recent illnesses, hospitalizations, or surgical procedures):

____

____

22. Please check any of the following medications you currently take regularly. Also give the name of the medication.

	Medication	Name of Medication
❏	Heart medicine	________
❏	Blood pressure medicine	________
❏	Blood cholesterol medicine	________
❏	Hormones	________
❏	Birth control pills	________
❏	Medicine for breathing/lungs	________
❏	Insulin	________
❏	Other medicine for diabetes	________
❏	Arthritis medicine	________
❏	Medicine for depression	________
❏	Medicine for anxiety	________
❏	Thyroid medicine	________
❏	Medicine for ulcers	________
❏	Painkiller medicine	________
❏	Allergy medicine	________
❏	Other (please specify)	________

Physical Fitness, Physical Activity/Exercise

23. In general, compared to other persons your age, rate how physically fit you are:

1 ❏ 2 ❏ 3 ❏ 4 ❏ 5 ❏ 6 ❏ 7 ❏ 8 ❏ 9 ❏ 10 ❏

Not at all physically fit — Somewhat physically fit — Extremely physically fit

24. Outside of your normal work or daily responsibilities, how often do you engage in exercise that at least moderately increases your breathing and heart rate and makes you sweat, for at least 20 minutes (such as brisk walking, cycling, swimming, jogging, aerobic dance, stair climbing, rowing, basketball, racquetball, vigorous yard work).

❏ 5 or more times per week ❏ 3–4 times per week ❏ 1–2 times per week
❏ Less than 1 time per week ❏ Seldom or never

25. How much hard physical work is required on your job?

❏ A great deal ❏ A moderate amount ❏ A little ❏ None

26. How long have you exercised or played sports regularly?

❏ I do not exercise regularly ❏ Less than 1 year ❏ 1–2 years
❏ 2–5 years ❏ 5–10 years ❏ More than 10 years

Diet

27. On average, how many servings of fruit do you eat per day? (One serving = 1 medium apple, banana, orange, etc.; ½ cup of chopped, cooked, or canned fruit; ¾ cup of fruit juice.)

❏ None ❏ 1 ❏ 2 ❏ 3 ❏ 4 or more

28. On average, how many servings of vegetables do you eat per day? (One serving = ½ cup cooked or chopped raw, 1 cup raw leafy, ¾ cup of vegetable juice.)

❏ None ❏ 1–2 ❏ 3 ❏ 4 ❏ 5 or more

29. On average, how many servings of bread, cereal, rice, or pasta do you eat per day? (One serving =1 slice of bread, 1 ounce of ready-to-eat cereal, ½ cup of cooked cereal, rice, or pasta.)

❏ None ❏ 1–3 ❏ 4–6 ❏ 7–9 ❏ 10 or more

30. When you use grain and cereal products, do you emphasize:

❏ Whole grain, high fiber ❏ Mixture of whole grain and refined ❏ Refined, low fiber

31. On average, how many servings of red meat (not lean) do you eat per day? (One serving = 2–3 ounces of steak, roast beef, lamb, pork chops, ham, burgers, etc.)

❏ None ❏ 1 ❏ 2 ❏ 3 ❏ 4 or more

32. On average, how many servings of fish, poultry, lean meat, cooked dry beans, peanut butter, or nuts do you eat per day? (One serving = 2–3 ounces of meat, ½ cup of cooked dry beans, 2 tablespoons of peanut butter, or ⅓ cup of nuts.)

❏ None ❏ 1 ❏ 2 ❏ 3 ❏ 4 or more

33. On average, how many servings of dairy products do you eat per day? (One serving = 1 cup of milk or yogurt, 1.5 ounces of natural cheese, 2 ounces of processed cheese.)

❏ None ❏ 1 ❏ 2 ❏ 3 ❏ 4 or more

34. When you use dairy products, do you emphasize

❏ Regular ❏ Low fat ❏ Nonfat

35. How would you characterize your intake of fats and oils (e.g., regular salad dressings, butter or margarine, mayonnaise, vegetable oils)?

❏ High ❏ Moderate ❏ Low

Body Weight

36. How tall are you (without shoes)? ______ feet ______ inches
37. How much do you weigh (minimal clothing and without shoes)? ______ pounds
38. What is the most you have ever weighed? ______ pounds
39. Are you *now* trying to

❏ Lose weight ❏ Gain weight ❏ Stay about the same ❏ Not trying to do anything

Psychological Health

40. How have you been feeling in general during the past month?

❏ In excellent spirits ❏ In very good spirits
❏ In good spirits mostly ❏ I've been up and down in spirits a lot
❏ In low spirits mostly ❏ In very low spirits

41. During the past month, would you say that you experienced ______ stress?

❏ A lot of ❏ Moderate ❏ Relatively little ❏ Almost no

42. In the past year, how much effect has stress had on your health?

❏ A lot ❏ Some ❏ Hardly any or none

43. On average, how many hours of sleep do you get in a 24-hour period?

❏ Less than 5 ❏ 5–6.9 ❏ 7–9 ❏ More than 9

Substance Use

44. Have you smoked at least 100 cigarettes in your entire life?

❏ Yes ❏ No

45. How would you describe your cigarette smoking habits?

❏ Never smoked

❏ Used to smoke

How many years has it been since you smoked? ______ years

❏ Still smoke

How many cigarettes a day do you smoke on average? ______ cigarettes/day

46. How many alcoholic drinks do you consume? (A "drink" is a glass of wine, a wine cooler, a bottle/can of beer, a shot glass of liquor, or a mixed drink.)

❏ Never use alcohol ❏ Less than 1 per week ❏ 1–6 per week

❏ 1 per day ❏ 2–3 per day ❏ More than 3 per day

Occupational Health

47. Please describe your main job duties.

____

____

	All of the time	Most of the time	Some of the time	Rarely or never
48. After a day's work, do you often have pain or stiffness that lasts for more than 3 hours?	❏	❏	❏	❏
49. How often does your work entail repetitive pushing and pulling movements or lifting while bending or twisting, leading to back pain?	❏	❏	❏	❏

chapter 3

Cardiorespiratory Fitness

Cardiorespiratory fitness is considered health-related because (a) low levels of cardiorespiratory fitness have been associated with a markedly increased risk of premature death from all causes and specifically from cardiovascular disease, (b) increases in cardiorespiratory fitness are associated with a reduction in death from all causes, and (c) high levels of cardiorespiratory fitness are associated with higher levels of habitual physical activity, which are, in turn, associated with many health benefits.

—American College of Sports Medicine[1]

The laboratory test generally regarded as the best measure of heart and lung endurance is the direct measurement of oxygen uptake during maximal exercise.[1–4] The exercise is usually performed using a bicycle ergometer or treadmill, which allows the progressive increase in workload from light-to-exhaustive (maximal) exercise. The amount of oxygen consumed during the exercise test is measured using various methods (douglas bag collection of expired air, mixing box and gas-flow meter, or computerized metabolic carts)[5] (see Figure 3.1). Portable metabolic systems that can be strapped to the chest have been developed, which enable measurement of oxygen consumption outside of laboratory settings.[6] Measurement of $\dot{V}O_{2max}$ should be specific to the sport practiced by the individual being tested because of the very unique muscular, circulatory, and metabolic adaptations that occur.

Maximal oxygen uptake ($\dot{V}O_{2max}$) is defined as the greatest rate at which oxygen can be consumed during exercise or the maximal rate at which oxygen can be taken up, distributed, and used by the body during physical activity.[5] ("V" is the volume used per minute, "O_2" is oxygen, and "max" represents maximal exercise conditions.[1–5])

$\dot{V}O_{2max}$ is usually expressed in terms of milliliters (ml) of oxygen consumed per kilogram (kg) of body weight per minute (min) ($ml \cdot kg^{-1} \cdot min^{-1}$). By factoring in body weight, it becomes possible to compare the $\dot{V}O_{2max}$ of people of varying size in different environments. It should be noted that expressing $\dot{V}O_{2max}$ in $ml \cdot kg^{-1} \cdot min^{-1}$ may unfairly underestimate the aerobic fitness of individuals with large amounts of body fat.[7]

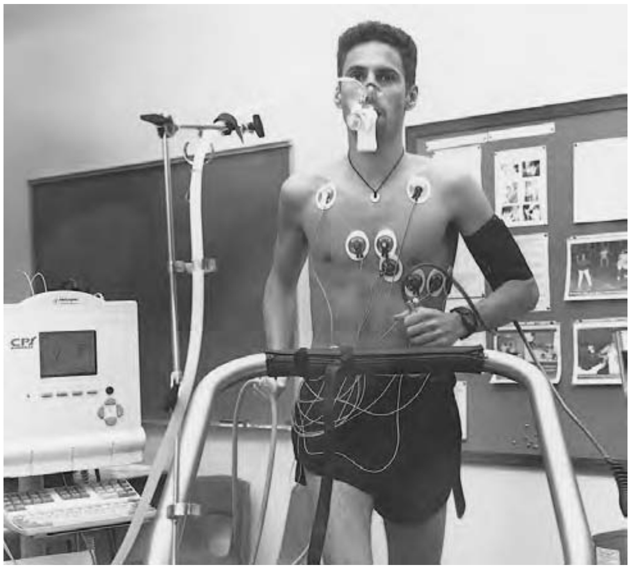


Figure 3.1 $\dot{V}O_{2max}$ is best measured in the laboratory during a maximal exercise test in which the oxygen consumed is measured by a computerized metabolic cart.

A high level of $\dot{V}O_{2max}$ depends on the proper functioning of three important systems in the body:

1. The *respiratory system*, which takes up oxygen from the air in the lungs and transports it into the blood
2. The *cardiovascular system*, which pumps and distributes the oxygen-laden blood throughout the body

3. The *musculoskeletal system*, which uses the oxygen to convert stored carbohydrates and fats into adenosine triphosphate (ATP) for muscle contraction and heat production[5]

In the laboratory, several criteria are used to determine whether an individual's true $\dot{V}O_{2max}$ has been achieved:[8,9]

- Oxygen consumption plateaus during the last minutes of a graded exercise test (defined as a rise of less than 2 ml · kg^{-1} · min^{-1} between the final test stages).
- The *respiratory exchange ratio (RER)* (ratio of the volume of carbon dioxide produced to the volume of oxygen consumed) increases to 1.15 or higher.
- The subject's heart rate increases to within 10 beats of the age-predicted maximum (maximum heart rate is estimated by subtracting the age from 220).
- Blood lactate levels rise above 8 millimoles per liter (mmol/l).

Laboratory measurement of $\dot{V}O_{2max}$ is expensive and time-consuming, requires highly trained personnel, and therefore is not practical for most testing situations. Various formulas and tests have been developed as substitutes and are the focus of this chapter:

- Nonexercise test $\dot{V}O_{2max}$ prediction equations
- Field tests of cardiorespiratory endurance
- Submaximal laboratory tests
- Maximal laboratory tests

It is assumed that before these tests are conducted, the preliminary considerations outlined in the previous chapter have been attended to (medical/health status questionnaire, consent form, and for those at high risk, a physical examination by a physician, treadmill test, and possibly a blood lipid analysis). It is also assumed that the order outlined for each testing battery is followed, with subjects following the appropriate pretest preparation routine (abstention from food, tobacco, alcohol, and caffeine for 3 hours, proper hydration, comfortable exercise clothes, adequate sleep, and avoidance of exercise the day of the test).

RESTING AND EXERCISE BLOOD PRESSURE AND HEART RATE DETERMINATION

When conducting a bicycle or treadmill test, the tester should include heart rate, blood pressure, and electrocardiogram (ECG) monitoring on all high-risk individuals. The test can then be used for determination of both cardiorespiratory fitness and potential health problems such as high blood pressure and heart disease (as diagnosed by a physician). Although blood pressure and ECG monitoring are not necessary when testing apparently healthy subjects, some testing facilities do it as an extra precaution.

TABLE 3.1 Classification of Blood Pressure for Adults*

BP Classification	SBP mm Hg	DBP mm Hg
Normal	<120	and <80
Prehypertension	120–139	or 80–89
Stage 1 hypertension	140–159	or 90–99
Stage 2 hypertension	≥ 160	or ≥ 100

*Update expected in 2010.

Source: National High Blood Pressure Education Program. *The Seventh Report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure*. National Heart, Lung, and Blood Institute, National Institutes of Health, NIH Pub. No. 04-5230. Bethesda, MD: National Institutes of Health, 2003.

Resting Blood Pressure

Blood pressure is the force of blood against the walls of the arteries and veins created by the heart as it pumps blood to every part of the body. *Hypertension* is simply a condition in which the blood pressure is chronically elevated above optimal levels. The Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure has established blood pressure classifications[10] (see Table 3.1).

Hypertension is diagnosed for adults when *diastolic* measurements (blood pressure when the heart is resting) on at least two separate visits average 90 mm Hg or higher, or *systolic* measurements (while the heart is beating) are 140 mm Hg or higher. There are two stages of hypertension, with stage 2 diagnosed when measurements are equal to or greater than 160/100 mm Hg. Prehypertension (120–139/80–89) is included as a separate category because this is considered to be a risk factor for future hypertension and cardiovascular disease.[10] Recommended follow-up testing procedures for hypertension are given in Table 3.2.

As many as 65 million people in the United States have hypertension.[10] Prevalence increases with age and is higher among blacks than whites[11] (see Figure 3.2). (See Chapter 8 for more information on hypertension.) Health-care professionals are urged to measure blood pressure at each patient visit.

To take the resting blood pressure, a sphygmomanometer and a stethoscope are needed.[12–14] The *sphygmomanometer* consists of an inflatable compression bag enclosed in an unyielding covering called the cuff, plus an inflating bulb, a manometer from which the pressure is read, and a controlled exhaust valve to deflate the system. The *stethoscope* is made of rubber tubing attached to a device that amplifies the sounds of blood passing through the blood vessels (see Figure 3.3). This equipment can be obtained in most drug stores for about $30, though more expensive blood pressure equipment is available.

Those taking blood pressure should be trained by qualified instructors. For each patient, blood pressure should be measured two or three times until consistency is achieved. A single blood pressure reading does not provide an accurate measure.[12–14] Several blood pressure readings by

TABLE 3.2 Recommendations for Follow-Up Based on Initial Blood Pressure Measurements for Adults Without Acute End Organ Damage

Initial Blood Pressure (mm Hg)*	Follow-Up Recommended†
Normal	Recheck in 2 years
Prehypertension	Recheck in 1 year‡
Stage 1 hypertension	Confirm within 2 months‡
Stage 2 hypertension	Evaluate or refer to source of care within 1 month. For those with higher pressures (e.g., >180/110 mm Hg), evaluate and treat immediately or within 1 week depending on clinical situation and complications.

*If systolic and diastolic categories are different, follow recommendations for shorter time follow-up (e.g., 160/86 mm Hg should be evaluated or referred to source of care within 1 month).

†Modify the scheduling of follow-up according to reliable information about past BP measurements, other cardiovascular risk factors, or target organ disease.

‡Provide advice about lifestyle medications.

Source: National High Blood Pressure Education Program. *The Seventh Report of the Joint National Committee on Detection, Evaluation, and Treatment of High Blood Pressure*. National Heart, Lung, and Blood Institute, National Institutes of Health, NIH Pub. No. 04-5230. Bethesda, MD: National Institutes of Health, 2003.

different observers, or on different occasions by the same observer, are recommended to check the validity of initially high values. See Physical Fitness Activity 3.4.

For best results in taking blood pressure:[12–14]

- Measurements should be taken with a mercury-stand sphygmomanometer, a recently calibrated aneroid manometer, or a validated electronic device. Aneroid and electronic devices should be checked against a mercury manometer at least once a year.
- Two or more readings should be taken 30–60 seconds apart, and averaged. If the first two readings differ by more than 5 mm Hg, additional readings should be obtained.
- Take the measurement in a quiet room with the temperature approximately 70–74° Fahrenheit (F) (21–23° Celsius [C]).
- Having the upper arm bare makes it easier to adjust the cuff.
- With older people, because of potential arterial obstructions, it is best to take readings on both arms. If the pressures differ by more than 10 mm Hg, obtain simultaneous readings in the two arms and thereafter use the arm with the higher pressure.

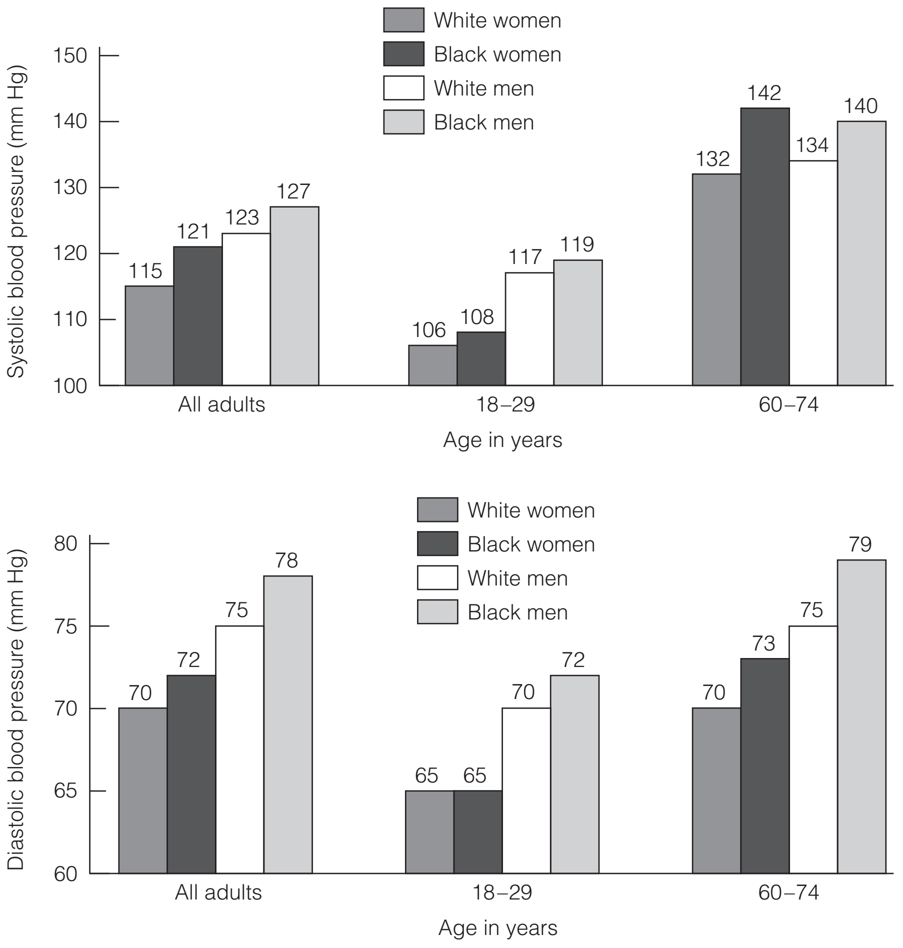


Figure 3.2 Mean systolic (top) and diastolic (bottom) blood pressure by race, sex, and age. The average blood pressure in the United States varies among subgroups, being higher in blacks versus whites and older versus younger adults. Source: National Health and Nutrition Examination Survey III, 1988–1991.[11]

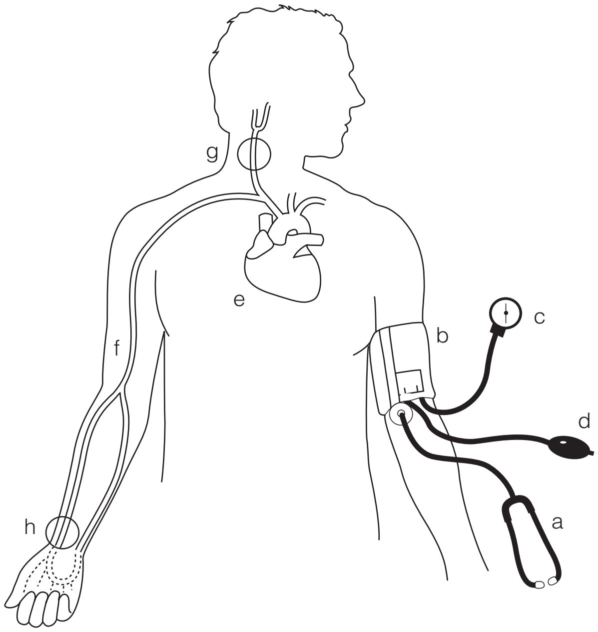


Figure 3.3 Blood pressure is taken with a stethoscope (a) and sphygmomanometer, which consists of an inflatable cuff (b) connected by rubber tubes to a monometer, which measures pressure in millimeters of mercury (c), and a rubber bulb that regulates air during the measurements (d). Blood pressure is the force of blood against the walls of the arteries and veins created by the heart (e) as it pumps. The blood pressure cuff fits over the brachial artery (f). The upper circle (g) represents the common carotid artery, and the lower circle (h) the radial artery, for sensing the heart rate.

- Use the proper size cuff. The rubber bladder should encircle at least 80% of the arm. If the person's arm is large, the adult normal-sized cuff will be too small (making the reading larger than it actually should be) and the obese-sized bladder is strongly recommended.
- Between determinations, allow at least 30 seconds for normal circulation to return to the arm.
- The subject should be comfortably seated with the arm straight (just slightly flexed), palm up, and the whole forearm supported at heart level on a smooth surface.
- Anxiety, emotional turmoil, food in the stomach, bladder distension, climate variation, exertion, and pain all may influence blood pressure, and when possible, should be controlled or avoided. Heavy exercise or eating should be avoided, and the individual being tested should sit quietly for at least 5 minutes before the test. The tested person should also avoid smoking or ingesting caffeine for at least 30 to 60 minutes prior to measurement. If the individual is on medication for hypertension, the time since the prior dose should be noted (it may be useful to take readings at the end of a dosing interval).
- Place the cuff (deflated) with the lower margin about 1 inch above the inner elbow crease (antecubital space). The rubber bag should be over the brachial artery (in the inner part of the upper arm; see Figure 3.3).
- Place the earpieces of the stethoscope into the ear canals, angled forward to fit snugly. For resting blood pressures, switch the stethoscope head to the bell, or low-frequency, position.
- The stethoscope should be applied lightly just above and medial to the antecubital space (but make sure that the head makes contact with the skin around its entire circumference). Excessive pressure on the stethoscope head can erroneously lower diastolic readings. The stethoscope should not touch clothing, the cuff, or the cuff tubing (to avoid unnecessary rubbing sounds). The tubing should come from the top of the cuff to avoid interference.
- With the stethoscope in place, the pressure should be raised 20–30 mm Hg above the point at which the pulse sound disappears. (Listen carefully through the stethoscope as the cuff bladder is inflated. The pressure will close off the blood flow in the brachial artery, causing the pulse sound to stop.)
- The pressure should be slowly released at a rate of 2 mm Hg per second or heart beat. Do not go slower than this, however, because it can cause pain and also raise blood pressure.
- As the pressure is released, the blood pressure sounds (the *Korotkoff sounds*) become audible and pass through several phases. Phase 1 (the systolic pressure) is marked by the appearance of faint, clear tapping sounds, which gradually increase in intensity. This represents the blood pressure when the heart is contracting.
- A true systolic blood pressure cannot be obtained unless the Korotkoff sounds are relatively sharp. Korotkoff sounds can be made louder by having the person open and clench the fist five or six times while the arm is raised and then starting over again.
- To obtain the diastolic blood pressure the following rules should be followed:

  At rest. Diastolic blood pressure equals the disappearance of the pulse sound (also called the fifth sound).

  During exercise testing. Sometimes the disappearance of sound drops all the way to zero. Therefore, the point at which there is an abrupt muffling sound (fourth phase) should be used for the diastolic blood pressure.

Exercise Blood Pressure

Blood pressure should be taken at least every 3 minutes during exercise testing on the treadmill or bicycle (see Figure 3.4).

Figure 3.4 Blood pressure determination during exercise is a difficult skill and requires considerable experience. Korotkoff sounds are easier to hear if the tubes are not allowed to rub or bump the subject or the treadmill. The stethoscope head should be attached to the subject's arm. The manometer should be at the level of the subject's heart.

Several important principles should be followed when taking blood pressure readings during exercise:[15,16]

- If the exercise stages are 3 minutes long (as in the Bruce treadmill protocol, for example), blood pressure readings should be taken at 2 minutes and 15 seconds into each stage. The cuff should be taped onto the person being tested for the entire test, but the inflating bulb should be removed between readings.
- It is best to stand on a stool and have the person being tested raise his or her arm to heart level while you support it. The subject's arm should be relaxed and not grasping a treadmill or cycle bar. If you are using a mercury-stand sphygmomanometer, the mercury column should be elevated to the person's heart level.
- Taking blood pressure during exercise is somewhat difficult because of the noise. It is best to raise the cuff pressure quickly until pulse sounds disappear and then, because the heart rate is higher than at rest, let the cuff pressure fall 5–6 mm Hg per second. Try to focus only on the pulse sounds through the stethoscope and keep the various tubes from flapping and rubbing against objects. Keep ambient noise in the testing room to a minimum. If you can't hear the pulse sounds, it may be necessary to stop the test for 15 seconds for a quick blood pressure determination.
- During exertion, the diastolic reading stays basically the same as the resting diastolic, whereas the systolic rises linearly with the increase in workload (see Figure 3.5).
- Peak exercise blood pressures vary according to age and gender[17] (see Figure 3.6).

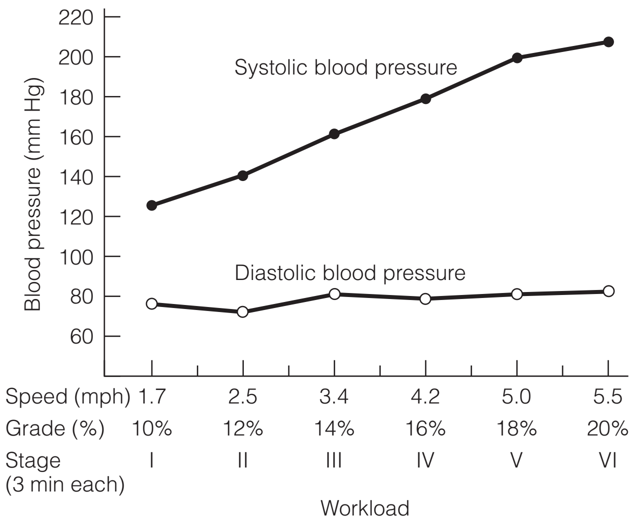


Figure 3.5 Pattern of systolic and diastolic blood pressures during graded exercise testing.

- If the systolic rises above 260 mm Hg, or the diastolic rises above 115 mm Hg, the test should be terminated.[1,18] The test also should be stopped if the systolic blood pressure drops ≥10 mm Hg from baseline with increasing workload.
- During recovery, blood pressure should be taken every 2 to 3 minutes.

Resting Heart Rate

The resting heart rate can be obtained through *auscultation* (using the bell of the stethoscope), *palpation* (feeling the pulse with your fingers), or ECG recordings. When taking heart

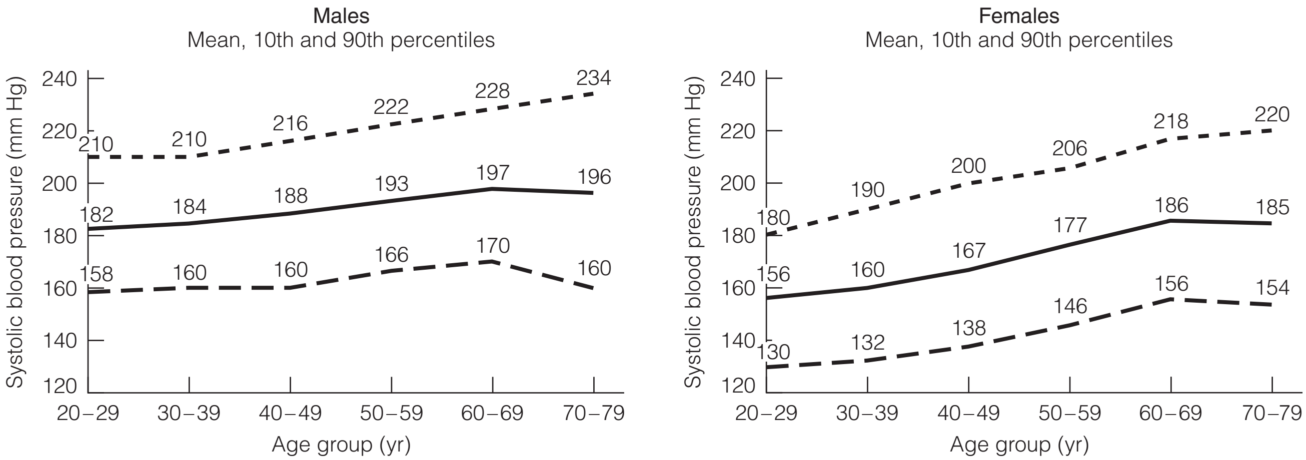


Figure 3.6 Peak exercise systolic blood pressures are higher in men than women, and they increase with advancing age. Data are from 7,863 male and 2,406 female apparently healthy people (Bruce treadmill max test). Source: Daida H, et al. *Mayo Clin Proc* 71:445–452, 1996.

rate by auscultation, the bell of the stethoscope is placed to the left of the sternum, just above the level of the nipple. The heartbeats (lub-dub) can be counted for 30 seconds and then multiplied by 2 to obtain beats per minute (bpm).

In using palpation techniques, the pulse is best determined during rest, at the radial artery (lateral aspect of the palm side of the wrist, in line with the base of the thumb) (see Figure 3.3). The tip of the middle and index fingers should be used (not the thumb, which has a pulse of its own). Start the stopwatch simultaneously with the pulse beat. Count the first beat as zero. Continue counting for 30 seconds and then multiply by 2 to get the total heartbeats per minute. See Physical Fitness Activity 3.3 at the end of the chapter.

During exercise, the carotid artery is easier to palpate because it is bigger than the radial (see Figure 3.3). When palpating the carotid (in the neck just lateral to the larynx), heavy pressure should not be applied because pressure receptors (baroreceptors) in the carotid arteries can detect the pressure and cause a reflex slowing of the heart rate.

The heart rate is a variable that fluctuates widely and easily, due to the same factors that influence blood pressure. Resting heart rate is best determined upon awakening, and averaged from measurements taken on at least three separate mornings. Lower heart rates are usually (but not always) indicative of a heart conditioned by exercise training—a heart able to push out more blood with each beat (having a larger stroke volume) and therefore needing fewer beats (see Appendix A, Table 21). Accordingly, the resting heart rate usually drops with regular exercise, decreasing approximately one beat every 1 or 2 weeks for the first 10 to 20 weeks of the program. Some of the best endurance athletes in the world have resting heart rates as low as 30–45 bpm. For example, Miguel Indurain, one of the best cyclists in history, had a resting heart rate of 28 bpm. Women have slightly higher resting pulse rates than men, while age appears to have little effect.[19] Resting pulse rates are also slightly higher in the fall and winter than in spring and summer, and higher in smokers versus nonsmokers.

Exercise Heart Rate

Heart rate during exercise is best determined through the use of an *electrocardiogram (ECG)*, a record of the electrical activity of the heart. Several methods are used:

- Using a heart rate ruler, count two or three R waves (depending on the ruler) from the reference arrow, and then read the heart rate from the ruler (see Figure 3.7).
- Counting the number of larger squares between R waves and dividing into 300 (for example, if two large blocks are between R waves, then the heart rate is 300/2 or 150 bpm).
- Counting the number of millimeters (mm) between four R waves and dividing into 6,000 (for example, if 40 mm separate four R waves, then the heart rate is 6,000/40, or 150 bpm).

Figure 3.8 shows a form for practicing ECG heart rate determination.

Another method involves auscultation with the stethoscope. The blood pressure cuff can be filled, the systolic blood pressure taken, and then midway between the systolic and diastolic blood pressures (usually around 100 to 110 mm Hg), the release of pressure can be stopped and the pulse counted through the stethoscope for 10 seconds. (Often, the pulse sounds are very loud when this method is used.) The pressure can then be released for diastolic blood pressure determination.

Several types of heart rate measuring devices have been developed. Heart rate monitors using chest electrodes are very accurate, stable, and functional. A telemetry device with permanent electrodes is attached to the chest, with the heart rate signal sent to a receiver worn on the wrist. Heart rate and elapsed time are displayed (the heart rate is updated every 5 seconds). These heart rate monitors can now be purchased for as little as $50.

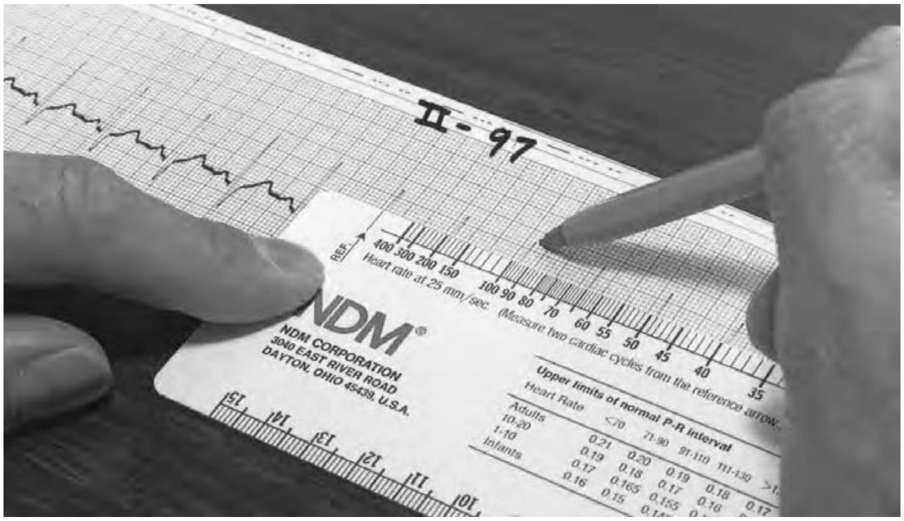
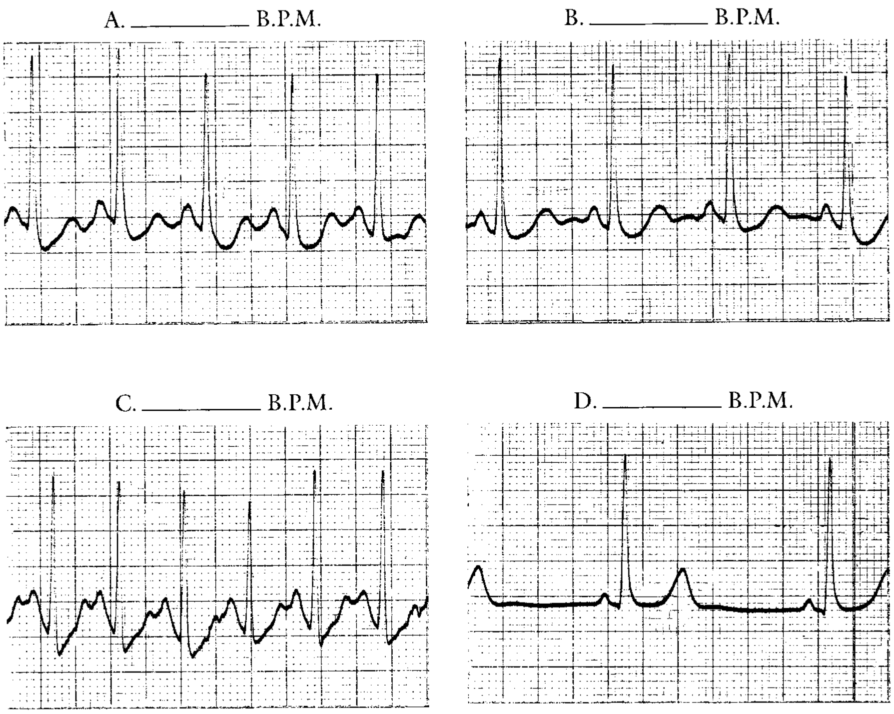


Figure 3.7 The heart rate can be determined from an ECG recording by using a heart rate ruler. With this particular ruler, heart rate is determined by reading the ruler after counting two heart rate cycles to the right of the reference arrow.



Quick Method—Number of squares between R waves divided into 300 gives the rate per minute.
Use of Ruler—Be sure to count the appropriate number of R waves from the reference point.

Figure 3.8 Use this form to practice heart rate determination from ECG recording strips. Practice each of the three methods described in this section (ECG ruler, large-square method, four-R method).

NONEXERCISE TEST $\dot{V}O_{2max}$ PREDICTION EQUATIONS

Direct measurement of $\dot{V}O_{2max}$ with computerized metabolic carts is the most valid and reliable marker of cardiorespiratory fitness. However, the time, expense, and technical supervision required have made laboratory measurements of $\dot{V}O_{2max}$ impractical for large populations involved in epidemiological studies of exercise and disease. Several researchers have developed regression equations that predict $\dot{V}O_{2max}$ using nonexercise test variables such as age, gender, body composition, and level of physical activity.[20–25] Although these prediction equations are not as accurate as laboratory testing of $\dot{V}O_{2max}$, they do allow researchers to broadly classify people as having poor, average, or good cardiorespiratory fitness.

One of the most commonly used nonexercise prediction equations for $\dot{V}O_{2max}$ was developed by researchers at the University of Houston, using age, physical activity status, and percent body fat or body mass index (BMI).[20] See Physical Fitness Activity 3.5 at the end of the chapter. The percent body fat equation is slightly more accurate than the BMI equation. Physical activity is rated from the subject's exercise habits, using the following code:

1. Does not participate regularly in programmed recreation, sport, or physical activity.

   0 points: Avoids walking or exertion (e.g., always uses elevator, drives whenever possible instead of walking)

   1 point: Walks for pleasure, routinely uses stairs, occasionally exercises sufficiently to cause heavy breathing or perspiration

2. Participates regularly in recreation or work requiring modest physical activity, such as golf, horseback riding, calisthenics, gymnastics, table tennis, bowling, weight lifting, or yard work:

   2 points: 10–60 minutes per week

   3 points: More than 1 hour per week

3. Participates regularly in heavy physical exercise (such as running or jogging, swimming, cycling, rowing, skipping rope, running in place) or engages in vigorous aerobic activity (such as tennis, basketball, or handball).

   4 points: Runs less than 1 mi per week or spends less than 30 minutes per week in comparable physical activity

   5 points: Runs 1–5 mi per week or spends 30–60 minutes per week in comparable physical activity

   6 points: Runs 5–10 mi per week or spends 1–3 hours per week in comparable physical activity

   7 points: Runs more than 10 mi per week or spends more than 3 hours per week in comparable physical activity

The physical activity rating (PA − R) is used in the following equations to estimate $\dot{V}O_{2max}$ in $ml \cdot kg^{-1} \cdot min^{-1}$:[20]

- % fat model

(r = .81, SEE = 5.35 $ml \cdot kg^{-1} \cdot min^{-1}$)*

$$\dot{V}O_{2max}\ ml \cdot kg^{-1} \cdot min^{-1} = 50.513 + 1.589\ (PA - R) - 0.289\ (age) - 0.552\ (\%\ fat) + 5.863\ (gender)$$

[gender = 0 for female, 1 for male]

- BMI model

(r = .783, SEE = 5.70 $ml \cdot kg^{-1} \cdot min^{-1}$)

$$\dot{V}O_{2max}\ ml \cdot kg^{-1} \cdot min^{-1} = 56.363 + 1.921\ (PA - R) - 0.381\ (age) - 0.754\ (BMI) + 10.987\ (gender)$$

[gender = 0 for female, 1 for male]

For example, the estimated $\dot{V}O_{2max}$ for a 45-year-old woman with 25% body fat and a physical activity rating of 5 would be

$$\dot{V}O_{2max} = 50.513 + (1.589 \times 5) - (0.289 \times 45) - (0.552 \times 25) + (5.863 \times 0) = 31.7\ ml \cdot kg^{-1} \cdot min^{-1}$$

FIELD TESTS FOR CARDIORESPIRATORY FITNESS

A number of performance tests such as maximal endurance runs on a track have been devised and validated for testing large groups in field situations.[26–41] These tests are practical, inexpensive, less time-consuming than laboratory tests, easy to administer for large groups, and quite accurate when properly conducted. Although outdoor cycling and pool swimming tests have been developed for estimating $\dot{V}O_{2max}$, they do not appear to be as valid as running tests.[30–32]

Endurance runs should be of 1 mile or greater to test the aerobic system. For ease of administration, the 1-mi and 1.5-mi runs are most commonly used. Various set-timed runs such as the 12-minute run are hard to administer because exact distance determination is difficult. With the 1- or 1.5-mi runs, those being tested run the set distance around a track (or exactly measured course) while their time is measured (see Figure 3.9). The objective is to cover the distance in the shortest possible time.[26] The effort should be maximal and only made by those properly motivated and experienced in running.

The 1-mi run is used in several fitness test batteries (see Chapter 2). Norms are found in Appendix A (Tables 9, 10, 17, 18, 20). Researchers from the University of Georgia have developed a generalized equation for prediction of $\dot{V}O_{2max}$ in $ml \cdot kg^{-1} \cdot min^{-1}$ for males and females between the ages of 8 and 25.[26] The equation is based on a total sample of 490 males and 263 females and has a standard error of estimate of 4.8 $ml \cdot kg^{-1} \cdot min^{-1}$, giving it an accuracy that is as good as or better than that of most other field methods for estimating $\dot{V}O_{2max}$ in children and adults. The regression equation for prediction of $\dot{V}O_{2max}$ from the 1-mi run time (MRT) is

$$\dot{V}O_{2max}\ ml \cdot kg^{-1} \cdot min^{-1} = (-8.41 \times MRT) + (0.34 \times MRT^2) + (0.21 \times age \times gender) - (0.84 \times BMI) + 108.94$$

[MRT = mile run time in minutes; gender = 0 for females, 1 for males; BMI = body mass index, kg/m^2]

*r = correlation coefficient.
SEE = standard error of estimate.

Figure 3.9 $\dot{V}O_{2max}$ can be estimated quite accurately from the time taken to run 1 mi as fast as possible. This test is recommended only for those who are apparently healthy and accustomed to running.

For example, if a 15-year-old can run a mile in 6.5 minutes and has a BMI of 21, the equation would estimate a $\dot{V}O_{2max}$ of 54.2 ml · kg^{-1} · min^{-1}:

$$(-8.41 \times 6.5) + (0.34 \times 6.5^2) + (0.21 \times 15 \times 1) - (0.84 \times 21) + 108.94 = 54.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$$

Normative data for the 1.5-mi run are found in Table 3.3 and Appendix A, Table 23. $\dot{V}O_{2max}$ can be estimated from the 1.5-mi run for college students using the following equation:[28]

$$\dot{V}O_{2max} (\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}) = 88.02 + (3.716 \times \text{gender}) - (0.1656 \times \text{kg}) - (2.767 \times \text{time})$$

[gender = 0 for female, 1 for male; kg = body weight; time = total run time in minutes]

For example, if a 70-kg male can run 1.5 mi in 9 minutes, his estimated $\dot{V}O_{2max}$ would be

$$55.2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = [88.02 + (3.716 \times 1) - (0.1656 \times 70) - (2.767 \times 9)]$$

Equations have also been developed to predict $\dot{V}O_{2max}$ from ability to run other distances at maximal speed.[35] Table 3.4 summarizes these equations for various racing distances. Notice that the correlations of calculated values of $\dot{V}O_{2max}$ with actual measured $\dot{V}O_{2max}$ are very high (.88 to .98).

TABLE 3.3 Norms for the 1.5-Mi Run Test (for People Between the Ages of 17 and 35)

Fitness Category	Time: Ages 17–25	Time: Ages 26–35
Superior		
Males	<8:30	<9:30
Females	<10:30	<11:30
Excellent		
Males	8:30–9:29	9:30–10:29
Females	10:30–11:49	11:30–12:49
Good		
Males	9:30–10:29	10:30–11:29
Females	11:50–13:09	12:50–14:09
Moderate		
Males	10:30–11:29	11:30–12:29
Females	13:10–14:29	14:10–15:29
Fair		
Males	11:30–12:29	12:30–13:29
Females	14:30–15:49	15:30–16:49
Poor		
Males	>12:20	>13:29
Females	>15:49	>16:49

Note: Before taking this running test, it is highly recommended that the student or individual be "moderately fit." Sedentary people should first start an exercise program and slowly build up to 20 minutes of running, 3 days per week, before taking this test.

Source: Draper DO, Jones GL. The 1.5 mile run revisited—An update in women's times. *JOPERD*, September 1990, 78–80. Reprinted with permission. *JOPERD* is a publication of the American Alliance for Health, Physical Education, Recreation and Dance, 1990 Association Drive, Reston, VA 20191.

These equations assume that the person being tested has run the distance at maximum speed. The average running speed is computed in kilometers per hour (kmh), and the equation is used to calculate the $\dot{V}O_{2max}$ in METs.

One MET is equal to the resting oxygen consumption of the reference average human, which equals 3.5 ml · kg^{-1} · min^{-1}. To get $\dot{V}O_{2max}$, the number of METs is multiplied by 3.5 ml · kg^{-1} · min^{-1}. (See the example in Table 3.4.)

Table 3.5 summarizes calculations from the equations in Table 3.4. Equivalent relationships between $\dot{V}O_{2max}$ and running performance for races ranging from 1.5 to 42.195 kilometers (km) (marathon) are given. Notice, for example, that running a mile in 6:01 demands the same $\dot{V}O_{2max}$ (56 ml · kg^{-1} · min^{-1}) as running the 5 km in 21:23, the 10 km in 46:17, or the marathon in 3:49:28.

The maximal endurance run tests are only for the healthy (ACSM "apparently healthy" category). Cooper suggests that the 1.5-mi run test should not be taken unless the subject can already jog nonstop for 15 minutes.[32] In addition, there always should be proper warm-up of slow jogging and calisthenics. After the test, there should be an adequate "warm-down" or "cool-down," with several minutes of walking, followed by flexibility exercises.

TABLE 3.4 Estimation of $\dot{V}O_{2max}$ from Average Running Speed During Racing

Racing Distance (km)	Equation to Calculate $\dot{V}O_{2max}$	Correlation
1.5	METs = 2.4388 + (0.8343 × kmh)	.95
1.6093 (mi)	METs = 2.5043 + (0.8400 × kmh)	.95
3	METs = 2.9226 + (0.8900 × kmh)	.98
5	METs = 3.1747 + (0.9139 × kmh)	.98
10	METs = 4.7226 + (0.8698 × kmh)	.88
42.195 (mi—marathon)	METs = 6.9021 + (0.8246 × kmh)	.85

1 MET = 3.5 ml · kg $^{-1}$ · min^{-1}; kmh = average racing speed in competition in kilometers per hour.

Note: To calculate total oxygen power, multiply number of METs times 3.5 ml · kg $^{-1}$ · min^{-1}. For example, if you can run a 5-km race in 18:30 (which is 16.2 kmh, calculated by multiplying the number of kilometers in the race by 60, and then dividing by the race time in decimal form [5 × 60]/18.5 = 16.2 kmh), using the preceding equation, $\dot{V}O_{2max}$ in METs is equal to

METs = 3.1747 + (0.9139 × 16.2) = 18 METs

$\dot{V}O_{2max}$ in ml · kg^{-1} · min^{-1} = 18 METs × 3.5 ml · kg^{-1} · min^{-1} = 63 ml · kg^{-1} · min^{-1}

Source: Tokmakidis SP, Léger L, Mercier D, Péronnet F, Thibault G. New approaches to predict $\dot{V}O_{2max}$ and endurance from running performance. *J Sports Med* 27:401–409, 1987.

TABLE 3.5 Equivalent Performances for Various Distances

$\dot{V}O_{2max}$ (ml · kg^{-1} · min^{-1})	Performance Time for Various Distances (hours:minutes:seconds)				
	1.5 km	1 mi	5 km	10 km	42.2 km
28	13:30	14:46	56:49	2:39:14	31:41:25
31.5	11:27	12:29	47:04	2:02:00	16:35:05
35	9:56	10:49	40:10	1:38:53	11:13:52
38.5	8:46	9:33	35:02	1:23:08	8:29:26
42	7:51	8:33	31:04	1:11:43	6:49:30
45.5	7:07	7:44	27:54	1:03:03	5:42:21
49	6:30	7:03	25:20	0:56:15	4:54:07
52.5	5:59	6:29	23:11	0:50:47	4:17:48
56	5:32	6:01	21:23	0:46:17	3:49:28
59.5	5:09	5:36	19:50	0:42:30	3:26:44
63	4:50	5:14	18:30	0:39:33	3:08:06
66.5	4:32	4:55	17:20	0:36:33	2:52:34
70	4:17	4:38	16:18	0:34:10	2:39:23
73.5	4:03	4:23	15:23	0:32:12	2:28:05
77	3:50	4:09	14:34	0:30:12	2:18:16
80.5	3:39	3:57	13:50	0:28:33	2:09:41
84	3:29	3:46	13:10	0:27:04	2:02:06
87.5	3:20	3:36	12:34	0:25:44	1:55:21

Source: Tokmakidis SP, Léger L, Mercier D, Péronnet F, Thibault G. New approaches to predict $\dot{V}O_{2max}$ and endurance from running performance. *J Sports Med* 27:401–409, 1987.

A 1-mi walk test is available for testing a wide variety of people.[37] Walking is safer than running and more easily performed by most Americans. Three hundred and forty-three males and females, 30 to 69 years of age, were tested using a 1-mi walk test. They walked a mile as fast as possible, performing the test a minimum of two times, with heart rates monitored. They then were given a treadmill $\dot{V}O_{2max}$ test, and the 1-mi walk results correlated very highly with actual measured $\dot{V}O_2$ (r = .93).

The following equation was developed to determine $\dot{V}O_{2max}$ from 1-mi walk test results:[37]

$$\begin{aligned}\dot{V}O_{2max}\ (\mathrm{L \cdot min^{-1}}) &= 6.9652 + (0.0091 \times \text{body weight, lb}) \\ &\quad - (0.0257 \times \text{age}) + (0.5955 \times \text{gender}) \\ &\quad - (0.2240 \times \text{mile walk time in minutes}) \\ &\quad - (0.0115 \times \text{ending heart rate})\end{aligned}$$

For example, if a male subject weighs 150 lb, is 30 years old, and can walk 1 mi in 12 minutes with an ending heart rate of 120 beats · min^{-1} (gender, 1 = male, 0 = female):

$$\dot{V}O_{2max} = 6.9652 + (0.0091 \times 150 \text{ lb}) - (0.0257 \times 30) + (0.5955 \times 1) - (0.2240 \times 12 \text{ min}) - (0.0115 \times 120 \text{ bpm})$$
$$= 4.09 \text{ liters of oxygen per minute } (L \cdot min^{-1})$$

To change the $\dot{V}O_{2max}$ units from liters per minute to milliliters per kilogram body weight (in order to use fitness classification tables), first multiply 4.09 · min^{-1} by 1,000 to get milliliters (4.09 $L \cdot ml \cdot min^{-1} \times 1{,}000 = 4{,}090\ ml \cdot min^{-1}$). Then divide the body weight (lb) by 2.2046 to get kilograms (150 lb/2.2046 lb/kg = 68.04 kg). Next divide the $\dot{V}O_{2max}$ by body weight (4,090 $ml \cdot min^{-1}$/68.04 kg = 60.1 $ml \cdot kg^{-1} \cdot min^{-1}$). Using the $\dot{V}O_{2max}$ norms in Appendix A (Table 24), this 30-year-old male would be classified as being in "athletic" cardiorespiratory shape. The original 1-mi walk equation has been adapted for college students because it overpredicts $\dot{V}O_{2max}$ by 16–23%.[34] This equation is recommended for college students. See Physical Fitness Activity 3.6 at the end of the chapter.

$\dot{V}O_{2max}$ $ml \cdot kg^{-1} \cdot min^{-1}$ = 88.768 + (8.892 × gender with M=1, F=0) − (0.0957 × weight in pounds) − (1.4537 × walk time in minutes) − (0.1194 × ending heart rate).

For example, a college female weighing 128 lb and able to walk 1 mi in 13 minutes with an ending heart rate of 133 bpm would have this estimated $\dot{V}O_{2max}$:

$$\dot{V}O_{2max} = 88.768 + (8.892 \times 0) - (0.0957 \times 128) - (1.4537 \times 13.0) - (0.1194 \times 133) = 41.7\ ml \cdot kg^{-1} \cdot min^{-1}$$

The 1-mi walk test has been shown to be valid for older subjects if they are accustomed to walking.[41,42] This test can be administered outdoors on a track or indoors on a treadmill and will give similar results.[38]

A 1-mi track jog test has been developed for college students.[28] Although the mile run is commonly used to measure cardiorespiratory fitness in the college setting, there is considerable dissatisfaction with it because students dislike the maximum effort required. In the 1-mi track jog test, students self-select a steady, comfortable pace (recommended total mile times are greater than 8 minutes for males and 9 minutes for females, with an ending heart rate of less than 180 bpm). After jogging the mile at the same pace throughout, the ending time and heart rate are recorded, with $\dot{V}O_{2max}$ estimated using this equation:[28]

$$\dot{V}O_{2max}(ml \cdot kg^{-1} \cdot min^{-1}) = 100.5 + (8.344 \times \text{gender}) - (0.1636 \times \text{kg}) - (1.438 \times \text{time}) - (0.1928 \times \text{bpm})$$

[gender = 0 for female, 1 for male; kg = body weight; time = mile jog time; bpm = ending heart rate]

For example, if a female college student weighing 60 kg jogs a mile in 10 minutes with an ending heart rate of 150 bpm, her $\dot{V}O_{2max}$ would be

$$47.4\ ml \cdot kg^{-1} \cdot min^{-1} = [100.5 + (8.344 \times 0) - (0.1636 \times 60) - (1.438 \times 10) - (0.1928 \times 150)]$$

Using Table 24 in Appendix A, her fitness level would be rated "good." This formula has been shown to correlate highly (r = .87) with directly measured $\dot{V}O_{2max}$.

SUBMAXIMAL LABORATORY TESTS

During submaximal testing, physiological responses (usually heart rate) to exercise are measured. The workload is usually fixed—for example, a particular grade and speed on a treadmill, a fixed rate and resistance on a cycle *ergometer* (an apparatus for measuring the amount of work performed), or a fixed rate of stepping and fixed height of bench in a step test. Usually heart rate is measured during and at the end of such exercise.

On the other hand, the physiological response may be fixed and the exercise required to reach the response measured (e.g., work required to reach a heart rate of 170 bpm). The reasoning underlying both types of submaximal tests is that the person with the higher $\dot{V}O_{2max}$ is able to accomplish a given amount of exercise with less effort (or more exercise at a particular heart rate).[43]

The submaximal exercise test makes three assumptions:[3,5,43–45]

1. That a linear relationship exists between heart rate, oxygen uptake, and workload
2. That the maximum heart rate at a given age is uniform
3. That the mechanical efficiency (oxygen uptake at a given workload) is the same for everyone

These assumptions are not entirely accurate, however, and can result in a 10–20% error in estimating $\dot{V}O_{2max}$. Figure 3.10 shows that in most submaximal tests, heart rates at submaximal workloads are plotted, then extrapolated to an estimated maximum heart rate level, and then further extrapolated to an average oxygen consumption. These extrapolations can result in substantial error.

The *maximum heart rate* is the fastest heart rate that can be measured when the individual is brought to total exhaustion during a graded exercise test. A formula has been developed to represent the average maximum heart rate in humans:

Maximum heart rate = 220 − age

The maximum heart rate varies substantially among different people of the same age, however. (One standard

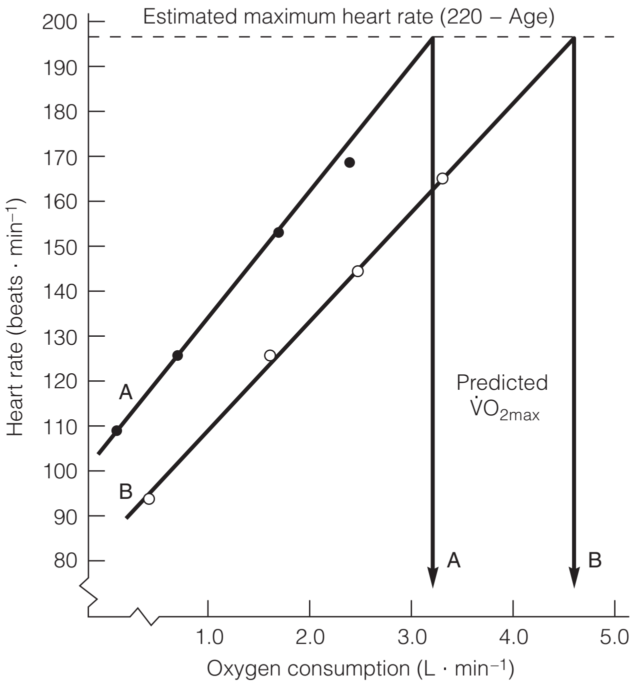


Figure 3.10 In most submaximal tests, heart rates at submaximal workloads are plotted (A or B), then extrapolated to an estimated maximum heart rate level, and then further extrapolated to an estimated workload that has been associated with an average oxygen consumption. These extrapolations can result in substantial error. Source: McArdle WO, Katch FI, Katch VL. *Exercise Physiology: Energy, Nutrition, and Human Performance.* Philadelphia: Lea & Febiger, 1991.

deviation is ±12 bpm, which means that two thirds of the population varies an average of plus-or-minus 12 heartbeats from the average.) (See Chapter 6 for other equations used to estimate maximum heart rate.) If the line connecting submaximal heart rates is extrapolated to an average maximum heart rate level that is really 12 beats lower than the real maximum heart rate in an individual, the final extrapolation to the workload and estimated oxygen consumption will underestimate the true cardiorespiratory fitness of the individual (see Figure 3.10).

Oxygen uptake at any given workload can vary 15% among different people.[44,45] In other words, people vary in the amount of oxygen they require to perform a certain exercise workload. Some are more efficient than others, and thus the average oxygen consumption associated with a given workload may differ significantly from one person to another.

For these reasons, $\dot{V}O_{2max}$ predicted by submaximal stress tests tends to be overestimated for those who are highly trained (who respond with a low heart rate to a given workload and are mechanically efficient), and underestimated for the untrained (those with a high heart rate for a given workload, who are also inefficient).

Nonetheless, submaximal exercise testing has its place in cardiorespiratory fitness determination.[1,43] Sometimes large populations are required to be tested, and the time, equipment, and skill needed to measure $\dot{V}O_{2max}$ are prohibitive. The measurement of $\dot{V}O_{2max}$ through maximal testing requires an all-out physical effort. For some people, such effort can be hazardous and at the very least often requires medical supervision and evaluation. Also, maximal testing, while definitely the most accurate way to determine fitness status, requires a high level of motivation. Submaximal exercise testing, though not as valid, can still give a somewhat accurate picture of fitness status without the expense, risk, and hard effort.

Step Tests

Prior to the widespread use of treadmills and cycle ergometers for exercise testing, maximal step-testing protocols were recommended by the American Heart Association.[46,47] However, adjustable steps were required and the extreme up and down stepping action for fit subjects made measurement of heart rate and blood pressure extremely difficult. Maximal step testing constitutes a safety hazard for some subjects and is no longer a recommended protocol for estimation of aerobic fitness. Submaximal step-test protocols, however, have been developed for estimation of aerobic fitness and $\dot{V}O_{2max}$, the two most common ones being the modified Canadian Aerobic Fitness Test (mCAFT) and the YMCA 3-minute step test.

The Modified Canadian Aerobic Fitness Test

The modified Canadian Aerobic Fitness Test (mCAFT) is a practical, fairly accurate, inexpensive, and fun way to determine cardiorespiratory endurance.[48–52]

The original CAFT was developed in the mid-1970s, when the Canadian government suggested that many Canadians would be motivated to increase their habitual exercise if there were a simple exercise test that indicated their current physical condition.[49]

The CAFT was designed using double steps each 8 inches (in.) high and wide, as in a domestic staircase. The double step is climbed to an age- and sex-specific rhythm set by a CD. Fitness is assessed from test duration and the radial or carotid pulse count immediately following exercise.

Since the 1970s, the CAFT has been used by millions worldwide, with the only reported complications being a very small number of minor muscle pulls (caused by stumbling) and very rare episodes of dizziness or transient loss of consciousness (arising from preexisting conditions).[48,49] The test has been well received and has achieved its primary objective of stimulating an interest in endurance exercise.

Figure 3.11 The modified Canadian Aerobic Fitness Test is a step test performed on two 8-in. (20.3-cm) steps.

Using the CAFT with an electrocardiogram or chest heart rate monitor for heart rate determination gives a closer approximation of aerobic fitness than the Astrand–Rhyming bicycle test.[50] A properly administered mCAFT, with postexercise heart rate accurately recorded, offers a convenient submaximum tool for evaluating cardiorespiratory fitness, particularly in such settings as employee fitness programs.[52] With the relatively high correlation with directly measured maximum oxygen uptake, it provides a means of accurately testing large populations without sophisticated equipment.[48]

The Canadian Physical Activity Fitness & Lifestyle Appraisal (CPAFLA), which includes all the instructions on how to take the mCAFT test, plus the CD and other fitness materials, can be obtained from the Internet site of the Canadian Society for Exercise Physiology (www.csep.ca).

The mCAFT is a modified step test performed on two 8-in. (20.3-cm) steps (see Figure 3.11). Based on the age of the person being tested, the CD is set at a certain stepping tempo. The person then steps up and down the steps at the given rate for 3 minutes. The CD gives instructions and time signals as to when to start and stop exercising and how to measure the postexercise heart rate.

Table 3.6a gives the stepping cadence for the modified CAFT.[52] After an initial stepping level is chosen according to the age group (Table 3.6b), subjects step for 3 minutes on the double steps in time to the musical CD or metronome, set at the proper cadence. Subjects step at progressively higher cadences until they reach a ceiling

TABLE 3.6a Stepping Cadences for Men and Women Performing the Modified Canadian Aerobic Fitness Test (mCAFT)

	Cadence (steps/min)	
Exercise Level	Males	Females
1	66	66
2	84	84
3	102	102
4	114	114
5	132	120
6	144	132
7	118*	144
8	132*	118*

*All exercise levels use two 8-in. (20.3-cm) steps except for levels 7 and 8 in men, and 8 in women, which use a single 16-in. step. The double-step exercise levels use a six-step cycle, whereas for single-step levels there are four steps per cycle.

TABLE 3.6b Starting Levels for Performing the mCAFT in Each Gender and Age Group

	Starting Level	
Age Group (yr)	Males	Females
15–19	4	3
20–29	4	3
30–39	3	3
40–49	3	2
50–59	2	1
60–69	1	1

TABLE 3.6c Oxygen Cost in $ml \cdot kg^{-1} \cdot min^{-1}$ for Stages of the mCAFT

Stage	Males	Females
1	15.9	15.9
2	18.0	18.0
3	22.0	22.0
4	24.5	24.5
5	29.5	26.3
6	33.6	29.5
7	36.2	33.6
8	40.1	36.2

Source: The Canadian Physical Activity, Fitness & Lifestyle Approach: CSEP-Health & Fitness Program's Health-Related Appraisal and Counseling Strategy, 3rd Edition © 2003. Reprinted with permission of the Canadian Society for Exercise Physiology.

heart rate (85% of age-predicted maximum heart rate) or the end of level 8. Notice from Table 3.6a that a single 16-in. step is used during the highest exercise levels to provide a suitable intensity for the very fit. Some people need a bit of coaching to get used to the rhythm of the beat. The stepping procedure for the double step follows a six-count format:

1. Right foot on the first step
2. Left foot on top of the second step
3. Right foot on top of the second step along with the left
4. Left foot down to the first step
5. Right foot down to the floor
6. Left foot down to the floor along with the right

For the highest exercise levels (7 and 8 for men, 8 for women), a four-step cycle is used on the single 16-in. step.

The pulse is taken immediately after each 3-minute stepping exercise level, while the participant stands motionless. If the pulse is low enough (below 85% of maximum heart rate), another 3-minute stepping exercise is undertaken at a faster rate, with the process continuing until the ceiling heart rate or top exercise level is reached.

The mCAFT should not be taken after a large meal, after performing vigorous exercise, after using alcohol, coffee or tobacco, or in hot rooms. Once the mCAFT has been completed, an aerobic fitness score should be established, using the following equation:[52]

$$\text{Aerobic fitness score} = 10[17.2 + (1.29 \times O_2 \text{ cost}) - (0.09 \times \text{kg}) - (0.18 \times \text{age})]$$

The oxygen cost for the different stages of the mCAFT are given in Table 3.6c. For example, if a male subject 35 years of age and weighing 70 kg (154 lb) begins stepping at stage 4 and completes stages 5, 6, and 7 (oxygen cost of 36.2 liters per minute [L/min]) before reaching his heart rate ceiling of 157 bpm (85% of maximum heart rate), then the aerobic fitness score would be

$$\begin{aligned}\text{Aerobic fitness score} &= 10[17.2 + (1.29 \times 36.2) - (0.09 \times 70) - (0.18 \times 35)] \\ &= 513\end{aligned}$$

Table 3.7 summarizes the classification system used by CPAFLA for the mCAFT.[52] An aerobic fitness score of 513 for a 35-year-old male is classified as "excellent" (an aerobic fitness level that is generally associated with optimal health benefits). The mCAFT step test should be discontinued if subjects begin to stagger, complain of dizziness, extreme leg pain, nausea or chest pain, or if they show facial pallor.

The YMCA 3-Minute Step Test

The YMCA uses the 3-minute step test for mass testing of participants (see norms, Appendix A, Table 22).[53]

Table 3.7 Health Benefit Zone from Aerobic Fitness Score

Zone	Males	Females
Ages 15–19		
Excellent	574+	490+
Very good	524–573	437–489
Good	488–523	395–436
Fair	436–487	368–394
Needs improvement	<436	<368
Ages 20–29		
Excellent	556+	472+
Very good	506–555	420–471
Good	472–505	378–419
Fair	416–471	350–377
Needs improvement	<416	<350
Ages 30–39		
Excellent	488+	454+
Very good	454–487	401–453
Good	401–453	360–400
Fair	337–400	330–359
Needs improvement	<337	<330
Ages 40–49		
Excellent	470+	400+
Very good	427–469	351–399
Good	355–426	319–350
Fair	319–354	271–318
Needs improvement	<319	<271
Ages 50–59		
Excellent	418+	366+
Very good	365–417	340–365
Good	301–364	310–339
Fair	260–300	246–309
Needs improvement	<260	<246
Ages 60–69		
Excellent	384+	358+
Very good	328–383	328–357
Good	287–327	296–327
Fair	235–286	235–295
Needs improvement	<235	<235

Source: The Canadian Physical Activity, Fitness & Lifestyle Approach: CSEP-Health & Fitness Program's Health-Related Appraisal and Counseling Strategy, 3rd Edition © 2003. Reprinted with permission of the Canadian Society for Exercise Physiology.

The equipment involved includes a 12-in. high, sturdy bench; a metronome set at 96 bpm (four clicks of the metronome equals one cycle, up 1,2, down 3,4), which should be properly calibrated with a wrist watch; a timing clock for the 3-minute stepping exercise and 1-minute recovery; and preferably a stethoscope to count the pulse rate.[53]

It is important to first demonstrate the stepping technique to the person to be tested (four counts—right foot up onto the bench on 1, left foot up on 2, right foot down to the floor on 3, and left foot down on 4). The exerciser should have some preliminary practice and should be well rested with no prior exercise of any kind.

The test involves stepping up and down at the 24-steps-per-minute rate for 3 minutes, and then immediately sitting down. Within 5 seconds the tester should be counting the pulse with the stethoscope and should *count for 1 full minute.* The person being tested can take her or his own pulse at the same time by palpating the radial artery, providing a double check of the count. The 1-minute count limit reflects the heart's ability to recover quickly, with a low versus high count reflecting better fitness.

The total 1-minute postexercise heart rate is the score for the test and should be recorded. It can be affected by many factors other than fitness, such as emotion, tiredness, prior exercise, resting and maximum heart rates that differ from population averages, and miscounting.

Other Step Tests

McArdle and colleagues have devised a step test (the Queens College Step Test) for college students to predict $\dot{V}O_{2max}$.[54] Subjects step at a rate of 22 steps per minute (females) or 24 steps per minute (males) for 3 minutes. The bench height is 16.25 in. (about the height of a gymnasium bleacher). After exercise, the subject remains standing, waits 5 seconds, and takes a 15-second heart rate count. See Physical Fitness Activity 3.7 at the end of the chapter. The $\dot{V}O_{2max}$ (ml · kg^{-1} · min^{-1}) is predicted using this equation:

Males

$$\text{Predicted } \dot{V}O_{2max} = 111.33 - (0.42 \times \text{heart rate})$$

Females

$$\text{Predicted } \dot{V}O_{2max} = 65.81 - (0.1847 \times \text{heart rate})$$

The standard error of prediction using the equation is within plus or minus 16% of the actual $\dot{V}O_{2max}$ and is considered suitable for mass testing.[54]

There are additional step tests described in the literature. The Harvard Step Test is for young men, who step 30 times per minute for 5 minutes on a 20-in. bench. A description of the test is given by Brouha.[55] There is also the Astrand–Rhyming nomogram, which may be used to predict $\dot{V}O_{2max}$ from postexercise heart rate and body weight during bench stepping. The subject steps at a rate of 22.5 steps per minute for 5 minutes. The bench height is 33 cm for women and 40 cm for men. The postexercise heart rate is obtained by counting the number of beats between 15 and 30 seconds immediately after exercise (then multiplying by 4).[56]

Box 3.1

Stepping Ergometry and MET-Energy Calculations

Each MET is equal to 3.5 ml of oxygen per kilogram of body weight per minute (3.5 ml · kg^{-1} · min^{-1}). Total oxygen uptake can thus be determined by multiplying the MET value by 3.5 ml · kg^{-1} · min^{-1}. The equations are based on submaximal, steady-state exercise; thus, caution should be taken in extrapolating to $\dot{V}O_{2max}$ (data may overpredict $\dot{V}O_{2max}$ by 1 to 2 METs).

The equation for stepping ergometry is

$$\dot{V}O_2 \text{ ml} \cdot \text{kg} \cdot \text{min} = 0.2\,(\text{stepping rate}) + (1.33 \times 1.8)\,(\text{step height}) \times (\text{stepping rate}) + 3.5$$

where stepping rate is in steps · min^{-1}, and step height is in meters (1 inch = 0.0254 m). For example, if a participant steps at 20 steps · min^{-1} on an 8-inch step (0.2032 m), then $\dot{V}O_2$ is

$$\dot{V}O_2 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = (0.2 \times 20) + (1.33 \times 1.8 \times 0.2032 \text{ m} \times 20) \times 3.5$$
$$= 17.23 \text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$$

or 4.9 METs

Because 1 MET = 1 kcal · kg^{-1} · hour^{-1}, energy expenditure in kcal · min^{-1} can be determined by multiplying the MET value by the body weight of the person in kilograms, and then dividing by 60 minutes per hour. For example, for a person weighing 65 kg,

$$5 \text{ METs} = \text{kcal} \cdot \text{kg}^{-1} \cdot \text{hour}^{-1}$$
$$= 5 \text{ kcal} \cdot \text{kg}^{-1} \cdot \text{hour}^{-1} \times 65 \text{ kg} \cdot \text{hour}^{-1}$$
$$= 325 \text{ kcal} \cdot \text{hour}^{-1}$$

or 5.4 kcal · min^{-1}

ACSM Bench-Stepping Equation

The American College of Sports Medicine has published an equation for estimating the energy expenditure for stepping in terms of METs[1,18] (see Box 3.1). To use this and other ACSM metabolic equations, two units must be understood: METs and kcal · min^{-1}. As explained earlier, 1 MET is equal to 3.5 ml · kg^{-1} · min^{-1} or the oxygen consumption during rest. One MET is also equal to 1 kcal · kg^{-1} · hour^{-1}. Thus the energy expenditure in kcal · min^{-1} can be determined by multiplying the MET value of the exercise by the body weight of the person tested in kilograms and then dividing by 60 (minutes per hour). (See Box 3.1. See also Physical Fitness Activity 3.1 at the end of this chapter.)

Treadmill Submaximal Laboratory Tests

Submaximal testing is conducted not only on steps but also with the treadmill. Submaximal testing on treadmills can use a cutoff point based on a predetermined heart rate—for example, 85% of the predicted heart rate range.

There are limitations, however, when using the test heart rate as a single measure of fitness. Heart rate does not always correlate closely with $\dot{V}O_2$ and is often affected by emotional state, environmental noise, stress, age, and previous meal and beverage intake. For these reasons several submaximal treadmill tests have been developed using multiple regression techniques to estimate $\dot{V}O_{2max}$ from measured factors.[57–63] One submaximal treadmill test was developed and cross-validated on males and females spanning a wide range of age and fitness levels.[57] In this test a brisk walking pace, ranging from 2.0 to 4.5 mph and eliciting a heart rate within 50–70% of age-predicted maximum, should be established during a 4-minute warm-up at 0% grade. This should be followed by a second 4-minute stage in which the speed remains the same, but the treadmill is raised to a 5% grade. The ending heart rate should be measured and used in the following equation to estimate $\dot{V}O_{2max}$:

$$\begin{aligned}\dot{V}O_{2max} &= 15.1 + (21.8 \times \text{speed}) \\ &\quad - (0.327 \times \text{heart rate}) - (0.263 \times \text{speed} \times \text{age}) \\ &\quad + (0.00504 \times \text{heart rate} \times \text{age}) + (5.98 \times \text{gender})\end{aligned}$$

[speed is treadmill speed in mph; gender = 0 for females, 1 for males]

For example, if a 45-year-old male walks at 3.0 mph up a 5% grade at a heart rate of 145 bpm, his $\dot{V}O_{2max}$ would be estimated as

$$\begin{aligned}\dot{V}O_{2max} &= 15.1 + (21.8 \times 3\text{ mph}) \\ &\quad - (0.327 \times 145\text{ bpm}) - (0.263 \times 3\text{ mph} \times 45\text{ yr}) \\ &\quad + (0.00504 \times 145\text{ bpm} \times 45\text{ yr}) + (5.98 \times 1) \\ &= 36.4\text{ ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}\end{aligned}$$

This equation is fairly valid; 68% of the time, values are within ± 4.85 ml · kg − 1 · min^{-1} of actual $\dot{V}O_{2max}$.[57]

Cycle Ergometer Submaximal Laboratory Tests

Before discussing submaximal cycle ergometer tests, a comparison of the advantages and disadvantages of treadmills versus bicycles is helpful (see Box 3.2). The most commonly used submaximal cycle ergometer tests include the multistage physical work capacity test developed by Sjostrand[64] and a single-stage test by Astrand and Rhyming.[56] Both tests assume that because heart rate and $\dot{V}O_2$ are linearly related over a broad range, the submaximal heart rate at a certain workload can predict $\dot{V}O_{2max}$. The YMCA has adopted these tests for use in its nationwide testing program.[53]

Box 3.2

Treadmills Versus Cycle Ergometers

In general both treadmills and cycle ergometers have their place in exercise testing facilities.

Advantages of Treadmills

1. Walking, jogging, and running are the most natural forms of locomotion. Most Americans are unaccustomed to bicycling (the treadmill was invented in the United States, the cycle ergometer in Europe).
2. In general, subjects reach higher $\dot{V}O_{2max}$ values during treadmill tests than they do with the cycle. $\dot{V}O_{2max}$ is usually 5–25% lower with cycle tests than with treadmill tests, depending on the participant's conditioning and leg strength. Only elite cyclists can achieve $\dot{V}O_{2max}$ values on cycles that equal treadmill values.

Disadvantages of Treadmills

1. Treadmills are more expensive than most cycle ergometers.
2. The treadmill is less portable than the cycle, requires more space, is heavy, and makes more noise.
3. The power (workload) of the treadmill cannot be measured directly in kg · m · min^{-1} or watts, so it must be calculated.
4. The workload on the treadmill depends on body weight. In longitudinal studies with body weight changes, the workload changes. The body weight has a much smaller effect on cycle ergometer performance.
5. The danger of a fall is greater while running on a treadmill than while cycling on the cycle ergometer.
6. Measurement of heart rate and blood pressure is more difficult when a person is exercising on a treadmill than when on a cycle.

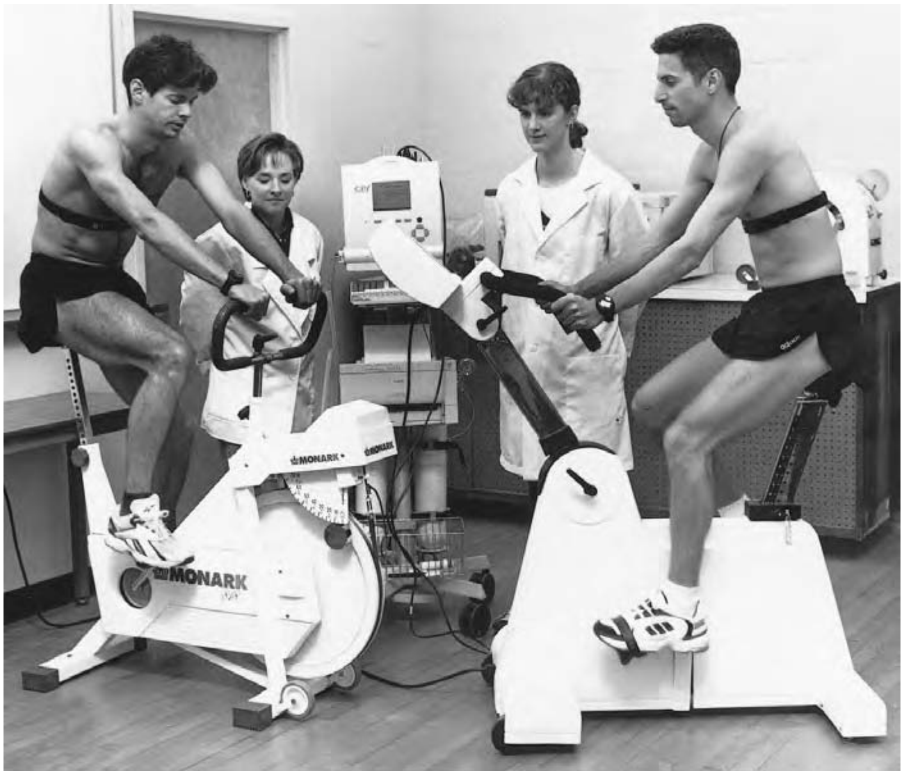
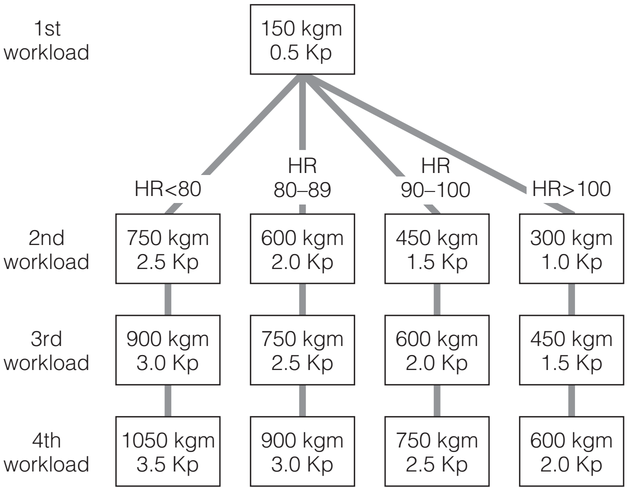


Figure 3.12 Mechanically braked cycle ergometers such as the Monark model pictured here have a front flywheel braked by a belt running around the rim attached to a weighted pendulum. The workload is adjusted by tightening or loosening the brake belt. The pedaling rate has to be maintained by the exerciser in time to a metronome. Good mechanically braked models cost between $750 and $1,000. The electronically braked ergometer uses an electromagnetic braking force to adjust the workload. The resistance is variable in relation to the pedaling rate, so that a constant work output in watts is maintained. However, electronically braked ergometers cost over $2,500.

A Description of Cycle Ergometers

A few facts on cycle ergometers include the following:[53]

- There are two major types of bicycle ergometers—mechanically braked and electronically braked (see Figure 3.12). The mechanically braked cycle ergometers are very accurate in workload adjustment and are not as expensive as the electronic versions. The mechanically braked cycle ergometers have a front flywheel braked by a belt running around the rim, attached to a weighted pendulum. The workload is adjusted by tightening or loosening the brake belt. The pedaling rate has to be maintained by the person being tested, in time to a metronome. The electronically braked ergometers use an electromagnetic braking force to adjust the workload (the resistance is variable in relation to the pedaling rate, so that a constant work output in watts is maintained). (*Note:* Because of the high expense of the electronically braked ergometer, the rest of this discussion focuses on mechanically braked cycle ergometers.)
- The mechanically braked cycle ergometer should be accurate, easily calibrated, have constant torque, and have a range of 0–2,100 $kg \cdot m \cdot min^{-1}$. Several ergometers meet these specifications.
- The calibration of the cycle should always be checked before testing. If using the Monark, be sure the red line on the pendulum weight is reading 0 on the workload scale. An adjusting wing nut easily corrects malalignments. The calibration of the cycle itself is done precisely at the factory, and unless the adjusting screw on the pendulum weight has been tampered with, there is seldom a need for recalibration. The calibration can be checked by hanging a known 2- or 4-kg weight on the part of the strap that moves the pendulum weight. The pendulum weight should read exactly 2 or 4 kg. If the numbers don't agree, the adjusting screw on the pendulum weight should be adjusted.
- The seat height of the ergometer should be set to the leg length of the rider. With the pedal in its lowest position if the heel of the foot is put onto the pedal, the leg should be straight. When the ball of the foot is put onto the pedal (as should be done during cycling), a slight bend of the leg at the knee should be apparent.
- The workload on the Monark or other mechanically braked bicycles is usually expressed in *kilogram-meters per minute* ($kg \cdot m \cdot min^{-1}$) or in *watts* (1 watt = 6 $kg \cdot m \cdot min^{-1}$). The equation $W = F \times D$ (W = work in $kg \cdot m \cdot min^{-1}$; F = force or resistance in kilograms; D = distance traveled by the flywheel rim per pedal revolution) applies to the Monark cycle ergometers. On a Monark, the flywheel travels 6 m per pedal revolution. If the resistance is set with



Directions:
1. Set the first workload at 150 kgm (0.5 Kp).
2. If the HR in the third minute is
   - less than (<) 80, set the second load at 750 kgm (2.5 Kp);
   - 80 to 89, set the second load at 600 kgm (2.0 Kp);
   - 90 to 100, set the second load at 450 kgm (1.5 Kp);
   - greater than (>) 100, set the second load at 300 kgm (1.0 Kp).
3. Set the third and fourth (if required) loads according to the loads in the columns below the second loads.

Figure 3.13 Guide to setting workloads for males on the YMCA's submaximal cycle ergometer test.
Source: Reprinted and adapted with permission of the YMCA of the USA, 101 N. Wacker Drive, Chicago, IL 60606.

the front handwheel knob (which sets the weighted pendulum at 1 kilopond [kp] or 1 kg, 2 kp, etc.), the workload is easily figured out. If, for example, the cycling rate is 50 revolutions per minute (rpm) with the weighted pendulum set at 2 kg, then the workload is

$$\begin{aligned} \text{Work} &= 2\ \text{kg} \times 6\ \text{m} \cdot \text{rpm}^{-1} \times 50\ \text{rpm} \\ &= 600\ \text{kg} \cdot \text{m} \cdot \text{min}^{-1}\ (100\ \text{watts}) \end{aligned}$$

The YMCA Submaximal Cycle Test

Following is a step-by-step approach in conducting the YMCA's popular submaximal cycle ergometer test:[53]

- For the YMCA test set the metronome at 100 bpm, for a rate of 50 rpm (one beat for each foot down). Let the person being tested get used to the cadence, warming up for about 3 to 5 minutes.
- Next, set the workload, using Figure 3.13. The initial workload is set at 150 kg · m · min^{-1}.

  The person cycles at the first workload for 3 minutes, then stops, with the heart rate counted immediately, using either a stethoscope for 10 seconds (and then multiplying by 6) or a heart rate monitor. If there is doubt as to the accuracy of the heart rate, let the subject cycle another minute at the same workload and try again. The objective is to get a steady-state heart rate at this particular workload.
- Check Figure 3.13 to decide on the next workload setting. Workloads are adjusted on the basis of heart rate response.
- Regularly check the workload setting on the cycle ergometer during each workload period. As the friction belt gets hot, the workload creeps upward, so continual readjustment during the early stages is necessary.
- Again check the pulse after 3 or 4 minutes of cycling at the new workload. Determine the steady state pulse rate, and check Figure 3.13 to determine the third and final workload. (*Note:* If the first workload produced a heart rate greater than 110 bpm, the third workload is not necessary.)
- Throughout the test, watch for exertional intolerance or other signs of undue fatigue or unusual response. Explain to the participant that the rating of perceived exertion should be between 3 and 5 on the Borg scale[65] (see Figure 3.14).
- The objective of the YMCA submaximal bicycle test is to obtain two heart rates between 110 and 150 bpm. There is a linear relationship between heart rate and workload between these two rates for most people. When the heart rate is less than 110, many external stimuli can affect the rate (talking, laughter, nervousness). Once the heart rate climbs between 110 and 150, external stimuli should no longer affect the rate and there is a linear relationship. If the heart rate climbs above 150, the relationship becomes curvilinear. So the objective of this test is to obtain two heart rates between 110 and 150 bpm (steady state) at two different workloads to establish linearity between heart rate and workload for the person being tested.
- To establish the line, two points are needed. It is important that the heart rates taken be true steady-state values. To ensure this, it is better to let participants cycle beyond 3 minutes, especially during the second workload (the heart rate takes longer to plateau when the workload is harder).
- Once the test is completed, the two steady-state heart rates should be plotted against the respective

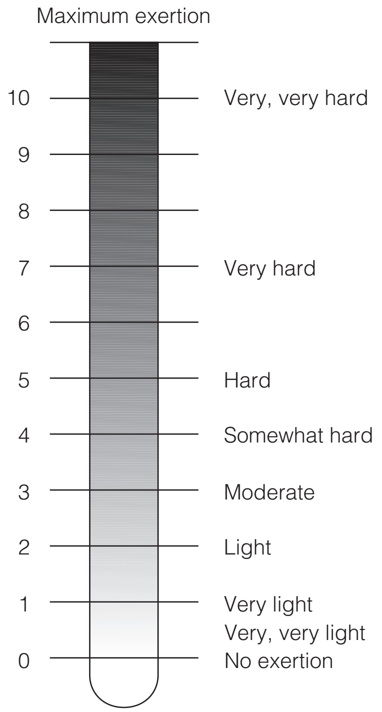


Figure 3.14 Borg scale rating of perceived exertion. During exercise heart rates of 110–115, exercise for most people will feel "3—Moderate" to "5—Hard." If the exercise feels harder than this, the workload should be reassessed. Source: Noble B, Borg GAV, Jacobs I, Ceci R, Kaiser P. A category ratio perceived exertion scale: Relationship to blood and muscle lactates and heart rate. *Med Sci Sports Exerc* 15:523–528, 1983.

workload in Figure 3.15. A straight line is drawn through the two points and extended to that participant's predicted maximal heart rate (220 – age). The point at which the diagonal line intersects the horizontal predicted maximal heart rate line represents the maximal working capacity for that participant. A perpendicular line should be dropped from this point to the baseline where the maximal physical workload capacity can be read in $kg \cdot m \cdot min^{-1}$.

- The maximal physical workload capacity in $kg \cdot m \cdot min^{-1}$ can then be used to predict a person's maximum oxygen uptake. These values are listed at the bottom of the graph. Use the norms in Appendix A (Tables 23 and 24) for interpretation. Remember that these results are predictions or estimates, not direct measurements, and are thus open to error (but usually within 15% of the actual value).

Cycling Equations

The ACSM has developed a formula to estimate the MET cost of leg and arm ergometry.[1] Box 3.3 describes the use of the formulas.

An equation has also been developed for estimating $\dot{V}O_2$ during outdoor bicycling on a level surface.[66]

$$\dot{V}O_2 (L \cdot min^{-1}) = -4.5 + (0.17 \times \text{rider, kmh}) + (0.052 \times \text{wind, kmh}) + (0.022 \times \text{weight, kg})$$

For example, if a 70-kg bicyclist is cycling at 30 kmh (kilometers per hour) with no headwind in his face, his oxygen consumption would be

$$\dot{V}O_2 = -4.5 + (0.17 \times 30) + (0.052 \times 0) + (0.022 \times 70) = 2.14\ L \cdot min^{-1}$$

$$\text{or} \quad 30.6\ ml \cdot kg^{-1} \cdot min^{-1} [(2.14/70) \times 1{,}000]$$

Drafting (riding closely behind another cyclist) reduces the oxygen consumption by 18–39% depending on speed and the formation and number of riders being drafted.[66]

MAXIMAL LABORATORY TESTS

The graded exercise test (GXT) to exhaustion, with ECG monitoring, is considered the best substitute for the gold-standard test (direct $\dot{V}O_{2max}$ determination). This diagnostic functional capacity test is mandatory for all people in the high-risk category who want to start an exercise program.[1]

The maximal graded exercise test (usually done with a treadmill or cycle ergometer) with ECG serves several purposes:[1,67]

- To diagnose overt or latent heart disease
- To evaluate cardiorespiratory functional capacity (heart and lung endurance)
- To evaluate responses to conditioning or cardiac-rehabilitation programs
- To increase individual motivation for entering and adhering to exercise programs

Maximal Graded Exercise Treadmill Test Protocols

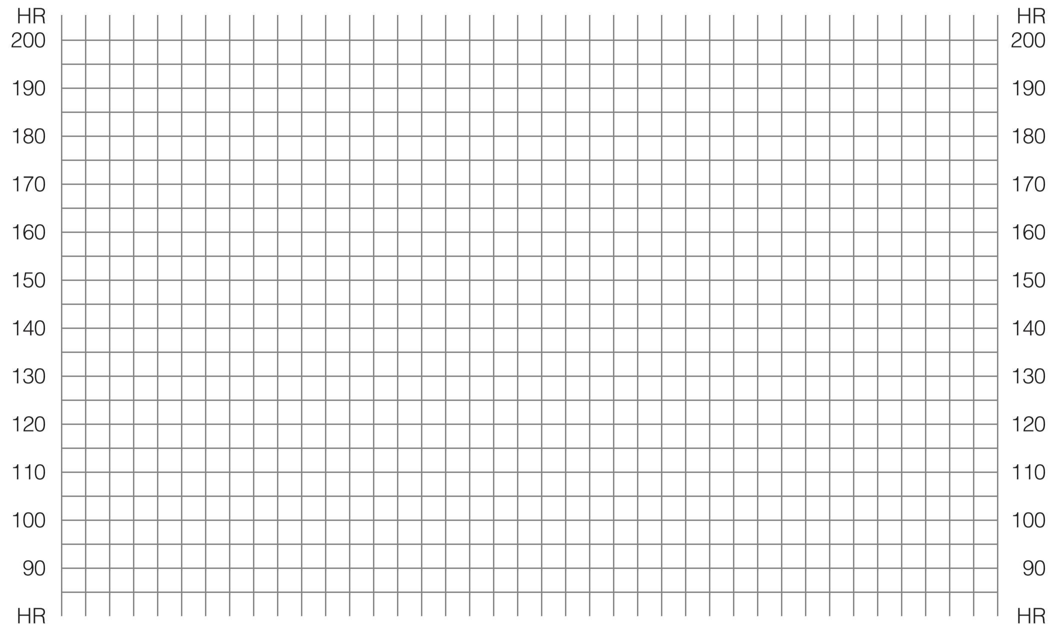
When deciding on a test modality, the treadmill should be considered for most individuals because it tends to produce the best test outcomes. For example, among one group of triathletes, $\dot{V}O_{2max}$ from tethered swimming or cycle ergometry was 13–18% and 3–6% lower, respectively, than values obtained from treadmill running.[68]

Figures 3.16 and 3.17 describe the most commonly used maximal treadmill protocols.[69–71] There are many other protocols, many of which have been developed for cardiac patients or athletes.[71] For example, in the Naughton protocol high-risk patients first go through a 4-minute warm-up, Name ____________ Age ______ Weight ______ Lb ______ Kg Seat Height ____________ Predicted Max HR ____________

	Date	1st Workload HR Used	2nd Workload HR Used	Max Workload	Max O_2 (L/min)	Max O_2 (mL/kg)
TEST 1						
TEST 2						
TEST 3						

Directions

1. Plot the HR of the 2 workloads versus the work (kgm/min).
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value.
3. Draw a line through both points and extend to the max HR line for age.
4. Drop a line from this point to the baseline and read the predicted max workload and O_2 uptake.



Workload (kgm)	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100
Max O_2 Uptake (L/m)	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	5.0
KCal Used (kcal/m)	3.0	4.5	6.0	7.5	9.0	10.5	12.0	14.0	16.0	17.5	19.0	21.0	23.0	25.0
Approx MET Level (for 132 lb)	3.3	4.7	6.0	7.3	8.7	10.0	11.3	12.7	14.0	15.3	16.7	18.0	19.3	20.7
Approx MET Level (for 176 lb)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0

Figure 3.15 Graph for determining $\dot{V}O_{2max}$ from submaximal heart rates obtained during the YMCA's submaximal cycle test. Source: Reprinted and adapted with permission of the YMCA of the USA, 101 N. Wacker Drive, Chicago, IL 60606.

Box 3.3

Estimated Oxygen Demand Formula for Leg and Arm Ergometry[9]

The ACSM formula for estimating oxygen demands for leg ergometer exercise is

$$\dot{V}O_2\ \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = \frac{\text{kg} \cdot \text{m} \cdot \text{min}^{-1} \times 1.8}{\text{kg}} + 7$$

For example, if a 70-kg man cycles at a work rate of 900 kg · m · min^{-1}, the $\dot{V}O_2$ in ml · kg^{-1} · min^{-1} = [900 kg · m · min^{-1} × 1.8)/kg + 7 = 30.14 ml · kg^{-1} · min^{-1} or 8.6 METs.

The ACSM formula for estimating oxygen demands for arm erogometry is

$$\dot{V}O_2\ \text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} = \frac{\text{kg} \cdot \text{m} \cdot \text{min}^{-1} \times 3}{\text{kg}} + 3.5$$

For example if a 70-kg man performs arm ergometry at 450 kg · m · min^{-1}, then

$\dot{V}O_2$ m · kg^{-1} · m^{-1} = (450 kg · m · min^{-1} × 3)/(70) + 3.5 = 22.8 ml · kg^{-1} · m^{-1}
or 6.5 METs

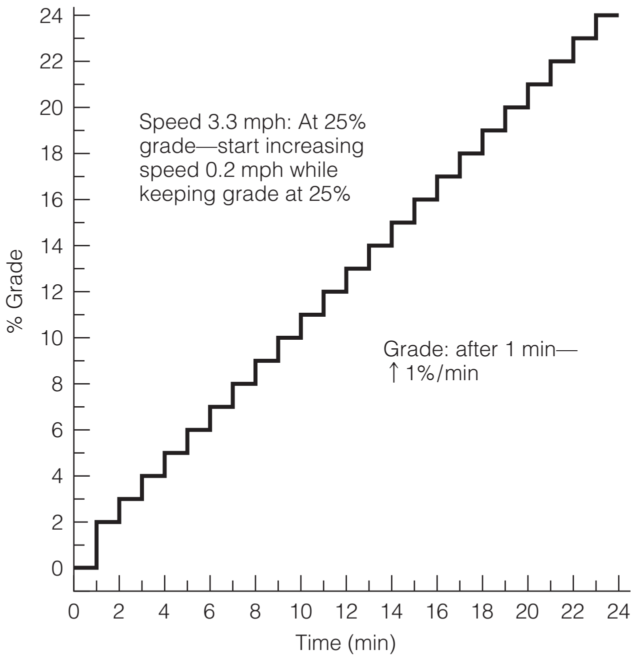


Figure 3.17 The Balke maximal graded exercise test protocol. Source: Balke B, Ware RW. An experimental study of "physical fitness" of Air Force personnel. *U.S. Armed Forces Medical Journal* 10(6):675–688, 1959.

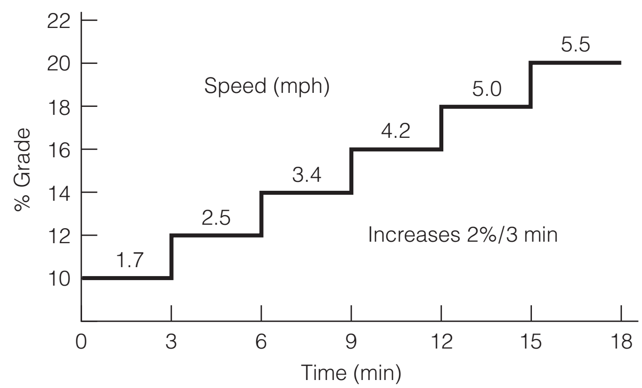


Figure 3.16 The Bruce maximal graded exercise test protocol. Source: Bruce RA, Kusumi F, Hosmer D. Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. *Am Heart J* 85:546–562, 1973.

with the speed then set at 2 mph and the grade increased 3.5% every 2 minutes until maximal effort is reached.[72] In the Costill and Fox protocol for the athlete, following a 10-minute warm-up, the speed is set at 8.9 mph, with the grade increasing 2% every 2 minutes until exhaustion.[73] Of the treadmill protocols, the Bruce (Figure 3.16) is by far the most popular, followed by the Balke (Figure 3.17). The Bruce has relatively large, abrupt increases in workload every 3 minutes (8.5 ml · kg^{-1} · min^{-1} each stage), and some have criticized the test for this. Nonetheless, excellent maximal data can be obtained and because the test is so widely used, there is an abundance of comparative data. (See Appendix A, Table 23.)

The main criticism of the Balke test is its duration (nearly twice as long as the Bruce). In testing large numbers of people, the length of time needed for the Balke makes its use prohibitive. Ken Cooper uses the Balke protocol at the Aerobics Center in Dallas because he feels the Balke allows for a more gradual warm-up and is therefore safer.[32] The Balke is basically an uphill walking test, whereas the Bruce starts out as an uphill walking test and then in stage 4 becomes an uphill running test.

In general, $\dot{V}O_{2max}$ can be estimated accurately from performance time on the treadmill (see Figure 3.18). Maximal treadmill tests using performance time show very high correlations with laboratory-determined $\dot{V}O_{2max}$.[71] Thus, actual measurement of $\dot{V}O_{2max}$ is not always necessary if the person is taken to a "true max," which means

- The person is allowed to practice one time before the maximal test to become "habituated" to the treadmill.
- Testers give verbal support to urge on the subject until exhaustion is reached.
- When the subject is "maxed out," there is no additional increase in heart rate despite an increase

Figure 3.18 $\dot{V}O_{2max}$ can be estimated accurately from performance time on the treadmill if the subject is taken to a "true max" and does *not* hold onto the treadmill bar.

in workload, signs of exertional intolerance (fatigue staggering, inability to keep up with the workload, facial pallor), and a maximal rating of perceived exertion is given (Figure 3.14).

- During the test, the subject is not allowed to hold onto the treadmill bar, except for the tips of two fingers, to maintain balance when needed.[74]

To ensure valid and reliable $\dot{V}O_{2max}$ values, the testing protocol should be very specific to the type of exercise the person is accustomed to. The laboratory environment should be 20–238°C, 50% humidity, and if follow-up testing is conducted, tests should be repeated at the same time of the day, using the exact same procedures.[75] Practical procedures for administering a maximal graded exercise treadmill test include the following:

- Pretest

  Ensure that all equipment is in good working order (and calibrated) and that supplies are in place.

  Review the medical/health questionnaire, have the participant read and sign the consent form, and ensure appropriate physician supervision.

  For high-risk subjects, obtain a 12-lead resting ECG in supine and exercise postures (otherwise, attach a heart rate monitor for heart rate measurement).

  Obtain blood pressure measurements in the supine and exercise postures.

  Review the treadmill test procedures and have the participant practice walking on the treadmill (and ensure that he or she can exercise without hanging onto the bar).

- Exercise

  Take heart rate/ECG measurements during the last 15 seconds of every stage and at peak exercise (educate participants to give a warning prior to grabbing the bar when they feel they no longer can continue).

  Take blood pressure measurement during the last minute of each stage (if systolic blood pressure does not change or decreases between stages, verify immediately).

  Take the rating of perceived exertion (RPE) at the end of each stage. Observe and record symptoms reported by the participant.

  Ensure that stage changes are made on time, with the treadmill adjusted to the exact speed and grade.

  Urge the participant to exercise as long as possible (and ensure safety by putting a hand behind the participant's back). When the subject is maxed out, note the time exactly, obtain the maximum heart rate and blood pressure, and slow down the treadmill to stage 1.

- Posttest

  Obtain heart rate/ECG and blood pressure measurements every 1–2 minutes for at least 5 minutes to allow any exercise induced changes to return to baseline.

  Continue to record symptoms reported by the participant.

Treadmill Equations for Predicting $\dot{V}O_{2max}$

When the participant is allowed to exercise to maximal capacity in this way, $\dot{V}O_{2max}$ can be estimated very precisely. Appendix A (Table 23) contains a table that accurately estimates $\dot{V}O_{2max}$ based on length of time until exhaustion with the Bruce or Balke protocol.[76] Appendix A (Tables 24 and 25) also contains norms for classifying $\dot{V}O_{2max}$.

Formulas have been developed for predicting $\dot{V}O_{2max}$ from maximal treadmill tests.[3,70,77,78] These are summarized in Table 3.8. The critical measurement is time to exhaustion with subjects not holding onto the bar or being aided in any way.

TABLE 3.8 Equations for Estimating $\dot{V}O_{2max}$ from Maximal Treadmill Tests

Protocol	Equation
Bruce[78]	$\dot{V}O_{2max}$ (ml · kg^{-1} · min^{-1}) = 14.76 − (1.379 × time) + (0.451 × time^2) − (0.012 × time^3)
Balke[77]	$\dot{V}O_{2max}$ (ml · kg^{-1} · min^{-1}) = 11.12 + (1.51 × time)

Box 3.4

ACSM Energy Requirements Formulas*

The American College of Sports Medicine formulas for these data are as follows:

Walking

$\dot{V}O_2$ ml · kg^{-1} · min^{-1}
= speed m · min^{-1}
× 0.1 ml · kg^{-1} · min^{-1}/m · min^{-1}
+ 3.5 ml · kg^{-1} · min^{-1}

Example: For a walking speed of 80 m · min^{-1} (3 mph):

$\dot{V}O_2$ = 80 m · min^{-1} × 0.1 ml · kg^{-1} · min^{-1}/m · min^{-1}
+ 3.5 ml · kg^{-1} · min^{-1}
= 11.5 ml · kg^{-1} · min^{-1} (METs = 11.5/3.5 = 3.3)

Graded Walking

Use the preceding equation plus:

$\dot{V}O_2$ ml · kg^{-1} · min^{-1}
= percent grade × speed m · min^{-1}
× 1.8 ml · kg · min^{-1}/m · min^{-1}

Example: If a person walks at 80 m · min^{-1} up a 13% grade, then $\dot{V}O_2$ is equal to 11.5 ml · kg^{-1} · min^{-1} (see above) plus:

0.13 × 80 m · min^{-1} × 1.8 ml · kg · min^{-1}/m · min^{-1} = 18.72
$\dot{V}O_2$ = 11.5 + 18.72 = 30.22 ml · kg^{-1} · min^{-1} (8.64 METs)

Jogging and Running (speeds over 5 mph)

$\dot{V}O_2$ ml · kg^{-1} · min^{-1}
= speed m · min^{-1}
× 0.2 ml · kg^{-1} · min^{-1}/m · min^{-1}
+ 3.5 ml · kg^{-1} · min^{-1}

Example: For a running speed of 200 m · min^{-1} (7.5 mph):

$\dot{V}O_2$ ml · kg^{-1} · min^{-1}
= 200 m · min^{-1} × 0.2 ml · kg^{-1} · min^{-1}/m · min^{-1}
+ 3.5 ml · kg^{-1} · min^{-1}
= 43.5 (METs = 43.5/3.5 = 12.4)

Note: For speeds in units of kmh, the MET requirement is approximately equal to the speed (10 kmh = 10 METs; 16 kmh = 16 METs).

Inclined Running

Use the equation for running, plus:

On treadmill: $\dot{V}O_2$ ml · kg^{-1} · min^{-1}
= speed in m · min^{-1} × percent grade
× 0.9 ml · kg · min^{-1}/m · min^{-1}

*1 mph = 26.8 m · min^{-1} = 1.6 km · hour^{-1}.

Maximal Treadmill Test for College Students

A maximal treadmill graded exercise test for college students has been developed by researchers at Arizona State University, which (a) allows the participant to select a comfortable walking-jogging speed, (b) is time-efficient, and (c) is relatively accurate in estimating $\dot{V}O_{2max}$.[78] The test protocol is as follows:

- *Stage 1*. Participant walks up a 5% grade at a self-selected, brisk pace for 3 minutes.
- *Stage 2*. Participant has the option to either continue walking briskly on a 5% grade, or self-select a comfortable jogging pace on a 0% grade for 3 minutes. The first two stages are considered a warm-up.
- *Stages 3 to maximum*. Starting at 0% grade, increase treadmill grade by 1.5% each minute while keeping the speed constant until participants are unable to continue despite verbal encouragement. Note ending speed in miles per hour (mph) and the final treadmill percent grade that the participant is able to sustain for close to 1 minute.

$\dot{V}O_{2max}$ in ml · kg^{-1} · min^{-1} is estimated from this formula.[79]

$\dot{V}O_{2max}$ ml · kg^{-1} · min^{-1}
= 4.702 − (0.0924 × kg) + (6.191 × mph)
+ (1.311 × % grade) + (2.674 × gender)

For gender, males are given 1, females 0. For example, if a 70-kg male chooses a jogging speed of 5.4 mph, and is maxed out after the treadmill grade reaches 10%, the estimated $\dot{V}O_{2max}$ is

4.702 − (0.0924 × 70) + (6.191 × 5.4)
+ (1.311 × 10) + (2.674 × 1)
= 47.4 ml · kg^{-1} · min^{-1}

The standard error of estimate is 2.1ml · kg^{-1} · min^{-1}.

ACSM Equations for Estimating $\dot{V}O_2$ for Walking and Running

The ACSM has developed steady-state $\dot{V}O_2$ formulas for running outdoors and on the treadmill, and also for walking (see Box 3.4).[1] The formula for graded treadmill exercise has been validated with a large number of people and

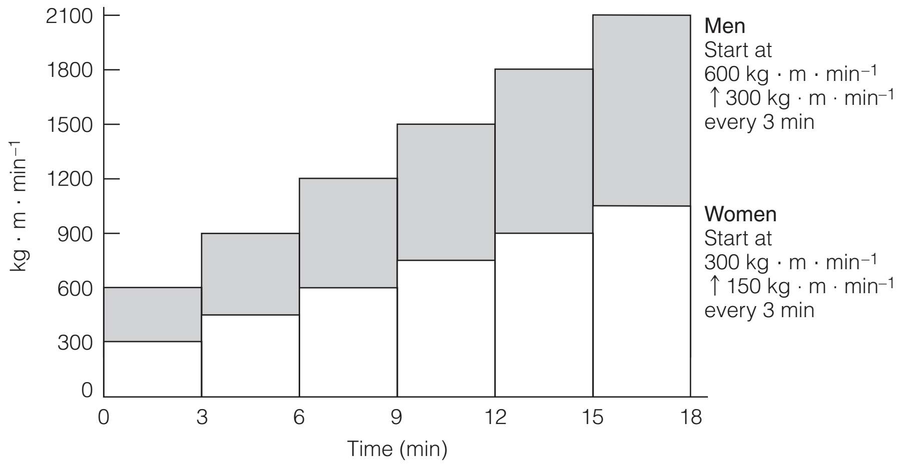


Figure 3.19 The Astrand maximal graded cycle exercise test protocol. The metronome should be set at 100, with a cycling rate of 50 rpm (one foot down with each click of the metronome). With the pedaling speed at 50 rpm, 300 kg · m/min is achieved with the cycle ergometer belt tension set at 1 kg, 600 kg · m/min at 21 kg, 900 kg · m/min at 3 kg, etc. Source: Astrand PO. *Work Tests with the Bicycle Ergometer*. Varberg, Sweden: AB Cykelfabriken Monark, 1965.

found to be accurate for adults.[1] Once again, these data are *steady-state* values, which means that if they are used to predict $\dot{V}O_{2max}$ data 2–4 minutes from the end point should be used. (*Note:* 1 mph = 26.8 m · min^{-1} = 1.6 kmh.)

Maximal Graded Exercise Cycle Test Protocols

There are two recommended maximal graded exercise cycle test protocols: the Astrand and the Storer–Davis.[80,81]

The Astrand Maximal Cycle Protocol

For the Astrand maximal cycle test, the initial workload is 300 kg · m · min^{-1} (50 watts) (1 kp at 50 rpm) for women, and 600 kg · m · min^{-1} (100 watts) (2 kp at 50 rpm) for men[80] (see Figure 3.19). After 2 minutes at this initial workload the workload is increased every 2 to 3 minutes in increments of 150 kg · m · min^{-1} (= 25 watts, or ½ kp) for women, and 300 kg · m · min^{-1} (50 watts, or 1 kp) for men. The test is continued until the participant is exhausted or can no longer maintain the pedaling frequency of 50 rpm. A metronome should be used, with the tester carefully ensuring that the proper cadence is maintained.

The $\dot{V}O_{2max}$ for most people (except for elite cyclists) will be lower when derived from the maximal cycle test than when derived from the Bruce's treadmill protocol.

Caution should be used with estimating $\dot{V}O_{2max}$ from the ACSM cycle formula. The ACSM cycle formula assumes that a steady state has been achieved, and for the normal population, it has been shown that $\dot{V}O_2$ often plateaus 1 to 3 minutes before the test is completed (if the participant is taken to a true max). Steady-state $\dot{V}O_2$ tables will thus overpredict $\dot{V}O_{2max}$, unless steady-state values 2 to 4 minutes from the end point are used. In addition, the ACSM formulas may not be accurate for workloads over 200 watts. For people with high fitness levels, direct measurement of $\dot{V}O_{2max}$ is necessary.

The Storer–Davis Maximal Cycle Protocol

The Storer–Davis equation was developed to make maximal cycle ergometer testing more practical and accurate and to provide a valid method for estimating $\dot{V}O_{2max}$. This equation was developed after testing 115 males and 116 females ages 20 to 70.[81] After a 4-minute warm-up at 0 watts, the workload is increased by 15 watts/min, with a recommended rate of 60 rpm. On a mechanically braked ergometer, the kp setting should be increased ¼ kp each minute (see Figure 3.20).

The equation uses the final workload in watts:

Males

$$\dot{V}O_{2max}\ (\text{ml} \cdot \text{min}^{-1}) = (10.51 \times \text{watts}) + (6.35 \times \text{kg}) - (10.49 \times \text{age}) + 519.3\ \text{ml} \cdot \text{min}^{-1}$$

Females

$$\dot{V}O_{2max}\ (\text{ml} \cdot \text{min}^{-1}) = (9.39 \times \text{watts}) + (7.7 \times \text{kg}) - (5.88 \times \text{age}) + 136.7\ \text{ml} \cdot \text{min}^{-1}$$

For males, the correlation with measured oxygen consumption is very high (r = .94). The standard error of estimate (SEE) is low for both males (±212 ml · min^{-1}) and females (±145 ml · min^{-1}) (r = .93). This equation has been validated for use with adolescents.[82]

The Wingate Anaerobic Test

The maximal treadmill and cycle protocols described thus far test cardiorespiratory capacity. A different type of test has been developed to test maximal anaerobic power. *Anaerobic power* is the ability to exercise for a short time at high power levels and is important for various sports where sprinting and power movements are common (e.g., football).

The Wingate Anaerobic Test (WAnT) was developed during the 1970s at the Department of Research and Sport Medicine of the Wingate Institute for Physical Education and Sport in Israel.[83,84] The impetus for the development of the WAnT was the lack of interest in anaerobic performance as a component of fitness, and the scarcity of appropriate easily administered laboratory tests. Various other tests

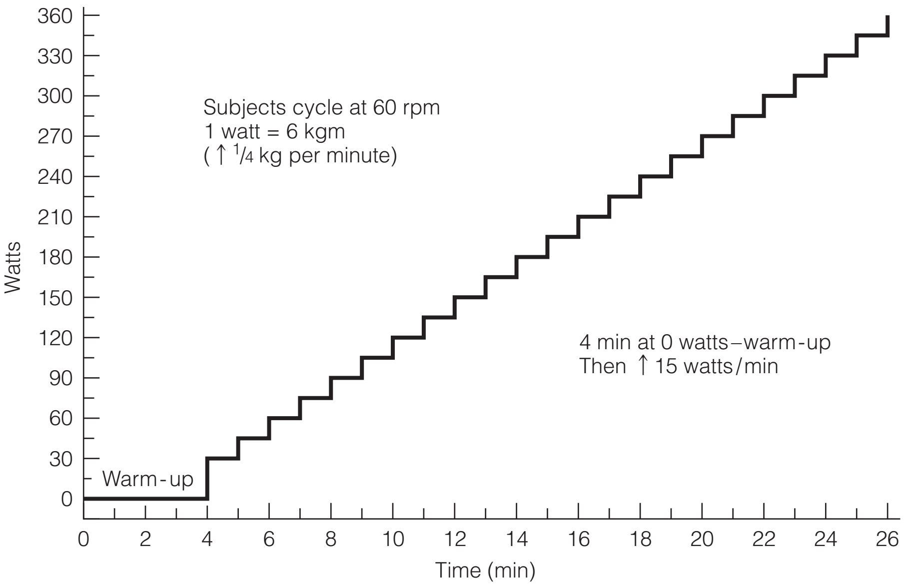


Figure 3.20 The Storer–Davis maximal cycle protocol. In the protocol, subjects cycle for 4 minutes at 0 watts to warm up. The workload is then increased 15 watts per minute, at a recommended rate of 60 rpm. On a mechanically braked ergometer, the setting should be increased ¼ kg each minute. Source: Storer TW, Davis JA, Caiozzo VJ. Accurate prediction of $\dot{V}O_{2max}$ in cycle ergometry. *Med Sci Sports Exerc* 22:704–712, 1990.

for anaerobic power and capacity have been promoted at various times, including the vertical jump, the Margaria step–running test, high-velocity treadmill running, and leg extensor force, but none of them have achieved the prominence and acceptance of the WAnT.

The WAnT requires pedaling or arm cranking on a cycle ergometer for 30 seconds at maximal speed against a constant force (with 5 minutes of both warm-up and cool-down recommended).[83,84] Power in watts is determined by counting pedal revolutions (watts = kp × rpm) or by using computerized equipment (Figure 3.21).[85]

Three indices are measured: (1) peak power (the highest mechanical power in watts elicited during the test, usually within the first 5 seconds); (2) mean power (the average power sustained throughout the 30-second period); (3) rate of fatigue (peak power minus the lowest power, divided by the peak power).

A predetermined force is used to ensure that a supramaximal effort is given. As a general guideline, with the Monark ergometer, a force of 0.090 kp/kg body weight should be used with adult nonathletes and of 0.100 kp/kg with adult athletes. The Monark cycle ergometer, however, is limited to athletes weighing less than 95 kg unless it is mechanically adapted. The use of toe stirrups increases performance by 5–12%. Some tentative norms have been developed[83] (see Table 3.9).

Figure 3.21 The Wingate Anaerobic Test requires pedaling for 30 seconds at maximal speed against a constant force. Verbal encouragement is recommended throughout the test.

When to Terminate the Maximal GXT-ECG Test

As emphasized in Chapter 2, maximal exercise testing, with precautions, is a relatively safe procedure.[1] The risk of death in clinical exercise laboratories is less than 0.01%, and the risk of acute heart attack during or immediately after an exercise test is ≤0.04%.[1] The risk of a complication requiring hospitalization is ≤0.2%.[1] The death rate is even lower in preventive medicine clinics, suggesting that the rate of complications during exercise testing is higher in coronary-prone individuals. Some individuals should not take a maximal GXT (see Table 2.1 in Chapter 2).

To safely conduct a maximal GXT-ECG test, various criteria should be carefully adhered to, and emergency drugs and equipment, along with an attending physician, should be available.[1]

In a maximum graded exercise stress test, the exercise usually continues until the participant voluntarily terminates the test because of exhaustion. Occasionally, for safety reasons, the test may have to be terminated prior

TABLE 3.9 Young Adult (Ages 18–25) Norms for the Wingate Anaerobic Test

	Males		Females	
Classification	Peak Power (watts/kg)	Mean Power (watts/kg)	Peak Power (watts/kg)	Mean Power (watts/kg)
Very poor	5.4–6.8	5.1–6.0	6.3–7.3	4.3–4.9
Poor	6.8–7.5	6.0–6.4	7.3–7.8	4.9–5.2
Below average	7.5–8.2	6.4–6.9	7.8–8.3	5.2–5.5
Average	8.2–8.8	6.9–7.3	8.3–8.8	5.5–5.8
Good	8.8–9.5	7.3–7.7	8.8–9.3	5.8–6.1
Very good	9.5–10.2	7.7–8.2	9.3–9.8	6.1–6.4
Excellent	10.2–11.6	8.2–9.0	9.8–10.8	6.4–7.0
Elite sprinters/jumpers	11.0–12.2	8.5–9.5		
Elite rowers	11.2–12.2	9.9–10.9		

Source: Data from Inbar O, Bar-Or O, Skinner JS. *The Wingate Anaerobic Test*. Champaign, IL: Human Kinetics, 1996.

to the point of maximal exercise. General indications for test termination—those that do not rely on physician involvement or ECG monitoring—are listed below. General indications for stopping an exercise test in low-risk adults include:[1]

- Onset of angina or angina-like pains (severe constricting pain in the chest, often radiating from the center of the chest to a shoulder [usually left] and down the arm, due to lack of blood flow and oxygen to the heart muscle usually because of coronary heart disease)
- Significant drop (>10 mm Hg) in systolic blood pressure from baseline despite an increase in workload
- Excessive rise in blood pressure (systolic blood pressure rises above 250 mm Hg, or the diastolic blood pressure rises above 115 mm Hg)
- Signs of poor perfusion: light-headedness, confusion, ataxia, pallor, cyanosis, nausea, or cold and clammy skin
- Failure of heart rate to increase with increased exercise intensity
- Noticeable change in heart rhythm
- Subject requests to stop
- Physical or verbal manifestations of severe fatigue
- Failure of the testing equipment
- Shortness of breath, wheezing, leg cramps, or claudication

Emergency Procedures

The ACSM advises the following:[1]

- All personnel involved with exercise testing and supervision should be trained in basic cardiopulmonary resuscitation (CPR) and preferably advanced cardiac life support (ACLS).
- There should be at least one, and preferably two, licensed and trained ACLS personnel and a physician immediately available at all times when maximal sign- or symptom-limited exercise testing is performed.
- Telephone numbers should be posted clearly.
- Regular drills should be conducted for all personnel.
  - A specific person or persons should be assigned to the regular maintenance of the emergency equipment and to the regular surveillance of all pharmacologic substances.
  - Records should be kept documenting the function of emergency equipment such as defibrillator, AED, oxygen supply, and suction. In addition, expiration dates for pharmacologic agents and other supportive supplies should be kept.
  - Hospital emergency departments and other sources of support should be advised as to the exercise testing lab location as well as the usual times of operation.

Personnel

It is advised that ACSM-certified personnel administer the graded exercise test (see Chapter 2). When low-risk, young adult participants are being tested, a physician need not be in attendance (but a qualified physician should be the overall director of any testing program and should be consulted concerning protocols and emergency procedures). When testing people classified as high risk, the test should be physician supervised.[1]

SPORTS MEDICINE INSIGHT

Administering the Electrocardiogram

Learning to interpret the electrocardiogram (ECG) takes special training under the guidance of experienced health professionals. Nevertheless, many experts feel that health and fitness leaders should be familiar with basic ECG principles. In addition, treadmill or cycle ergometer operators are expected to be able to know when abnormal ECG patterns appear on the oscilloscope (and to call the attending physician, or if necessary terminate the test). The following description should be reviewed with an instructor familiar with ECG interpretation.

THE ECG

The ECG presents a visible record of the heart's electrical activity, by means of a stylus that traces the activity on a continuously moving strip of special heat-sensitive paper.[86] All heartbeats appear as a similar pattern, equally spaced, and consist of three major units (see Figure 3.22):

- *P wave* (transmission of electrical impulse through the atria)
- *QRS complex* (impulse through the ventricles)
- *T wave* (electrical recovery or repolarization of the ventricles)

Heart cells are charged or *polarized* in the resting state (negative ions inside the cell, positive outside), but when electrically stimulated, they depolarize (positive ions go inside the heart cell, negative ions go outside) and contract. Thus, when the heart is stimulated, a wave of depolarization passes through the heart (an advancing wave of positive charges within the cells). As the positive wave of depolarization within the heart cells moves toward a positive skin electrode, there is a positive upward deflection recorded on the ECG.

The P wave (atrial wave) begins in the *sinoatrial* (*SA*) node (the normal physiological pacemaker) located near the top of the atrium. The impulse reaches the *atrioventricular* (*AV*) node located in the superior aspect of the ventricles. There is a 1⁄10-second pause, allowing blood to enter the ventricles from the contracting atria (see Figure 3.23).

The QRS complex (ventricular wave) begins in the AV node. After the 1⁄10-second pause, the AV node is stimulated, initiating an electrical impulse that starts down the AV bundle, called the *bundle of HIS* into the *bundle branches* and finally into the *Purkinje fibers*. The neuromuscular conduction system of the ventricles is composed of specialized nervous material that transmits the electrical impulse from the AV node into the ventricular heart cells.

The ECG is recorded on ruled paper. The smallest divisions are 1-mm squares. On the horizontal line (see Figure 3.24), 1 small block represents 0.04 second (1 large block of 5 small blocks is 0.20 second). On the vertical axis, 1 small block represents 1⁄10 of a millivolt (mV) (10 small blocks vertically or 2 large blocks is 1 mV).

The standard ECG is composed of 12 separate leads:

Limb leads: Lead 1, Lead 2, Lead 3

Augmented unipolar leads: aVR, aVL, aVF

Chest leads: V_1,V_2,V_3,V_4,V_5,V_6

An *ECG lead* is a pair of electrodes placed on the body and connected to an ECG recorder. An axis is an imaginary

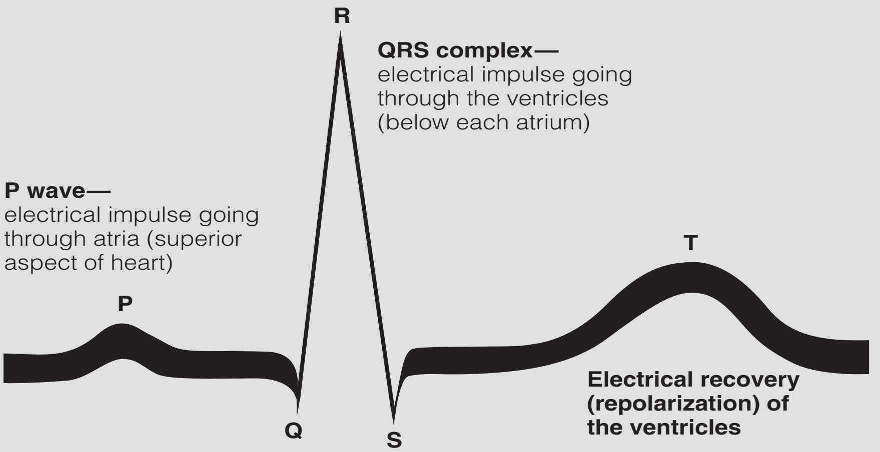


Figure 3.22 Normal single heartbeat. All heartbeats consist of three major units, the P wave, the QRS complex, and the T wave, which represent the transmission of electrical impulses through the heart.

(continued)

SPORTS MEDICINE INSIGHT *(continued)*

Administering the Electrocardiogram

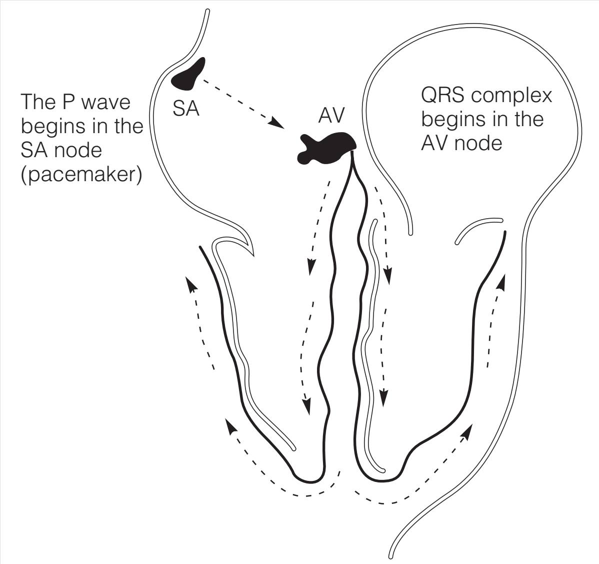


Figure 3.23 Normal electrical pathway. The P wave (atrial wave) begins in the SA node (normal physiological pacemaker) located near the top of the atrium. The QRS complex (ventricular wave) begins in the AV node.

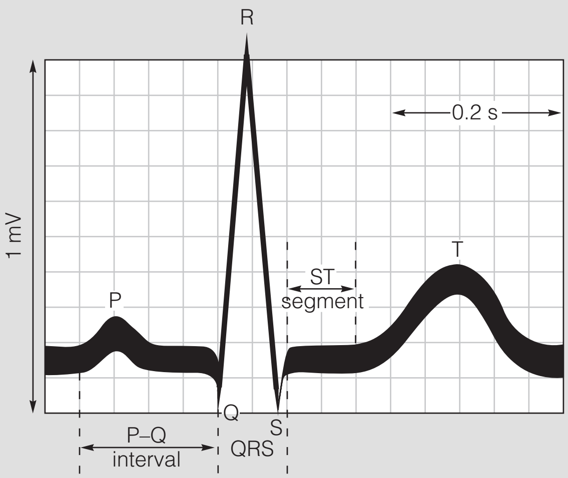


Figure 3.24 On the horizontal line, one small block represents 0.04 second or 1 mm. One large block of five small blocks is 0.20 second. On the vertical axis, one small block represents 1⁄10 millivolt (mV). Ten small blocks vertically or two large blocks is 1 mV.

line connecting the two electrodes. The electrodes for the three limb leads are placed on the right arm, left arm, and left leg. The ground electrode is placed on the right leg. This is electronically equivalent to placing the electrodes at the two shoulders and the symphysis pubis. From these three electrodes (plus the ground), the ECG recorder can make certain electrodes positive and others negative to produce six leads (1, 2, 3, aVR, aVL, aVF) (see Figure 3.25).

It is not the purpose of this book to give details on how to interpret the ECG. The exercise technician can administer the resting 12-lead ECG, but a qualified physician (especially cardiologists and internists) should interpret the results.[67] The resting 12-lead ECG should be administered to high-risk patients before the treadmill ECG to help screen out those with various contraindications to exercise.

EXERCISE TEST ELECTRODE PLACEMENT

The diagnostic GXT should be performed with a multiple-lead electrocardiographic system. The best possible GXT-ECG test is one in which all 12 leads are monitored. The *Mason-Likar* 12-lead exercise ECG system should be used, in which the six precordial electrodes are placed in their usual positions: the right and left arm electrodes are placed on the shoulders at the distal ends of the clavicles; and the right and left leg electrodes are positioned at the base of the torso, just medial to the anterior iliac crests[1,87] (see Figure 3.25).

However, the majority of abnormal ECG responses to exercise can be picked up by lead V_5 alone. When only V_5 is monitored, the CM5 electrode placement system is generally used, in which the second electrode (the negative) is placed on the top third of the sternum (RA electrode), and the third electrode (the ground) is placed on the right side of the chest in the V_5 position (RL electrode).[1,87] The V_5 electrode (LA) is put in its normal position.

All leads should be continuously monitored by oscilloscope and recordings taken at the end of each minute of exercise or when significant ECG changes or abnormalities are noted on the screen. During recovery, this should continue every 1 to 2 minutes for the 8-minute postexercise test.

During the early part of the recovery period, the participant should exercise at low intensity (2 mph, 0% grade on the treadmill). The ECG and blood pressure should be recorded every 1 to 2 minutes for at least 8 minutes of recovery (or longer if there are abnormalities). The participant should not be allowed to stand still or sit still immediately following the exercise test. After approximately 2 minutes of cool-down, the subject can sit down and continue to move her or his feet for several more minutes. Disposable electrodes (available for about 25 cents each) stick on the body very well despite the accumulation of sweat, and they conduct the electrical

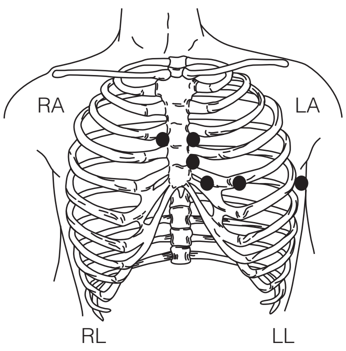
(continued)

SPORTS MEDICINE INSIGHT *(continued)*

Administering the Electrocardiogram

Standard or bipolar limb leads	*Electrodes connected*	*Marketing code*
Lead 1	LA & RA	·
Lead 2	LL & RA	··
Lead 3	LL & LA	···
Augmented unipolar limb leads		
aVR	RA & (LA-LL)	—
aVL	LA & (RA-LL)	— —
aVF	LL (RA-LA)	— — —
Chest or precordial leads		
V	C & (LA-RA-LL)	(see data on right)

Recommended positions for multiple chest leads
(Line art illustration of chest positions)



V_1	Fourth intercostal space at right margin of sternum	— ·
V_2	Fourth intercostal space at left margin of sternum	— ··
V_3	Midway between position 2 and position 4	— ···
V_4	Fifth intercostal space at junction of left midclavicular line	— ····
V_5	At horizontal level of position 4 at left anterior axillary line	— ·····
V_6	At horizontal level of position 4 at left midaxillary line	— ······

Figure 3.25 Ten electrode positions form 12 leads for the routine electrocardiogram. Electrodes should be placed in the exact anatomical position noted so that the physician can compare the ECG with appropriate standards.

impulses from the body to the ECG with little or no movement-artifact interference. Proper skin preparation is essential for the best ECG recordings. The resistance of the skin should be lowered by first cleansing thoroughly with an alcohol saturated gauze pad and then removing the superficial layer of the skin by rubbing vigorously. Shaving of the skin is not necessary.

BASIC PRINCIPLES IN ARRHYTHMIA DETERMINATION

An *arrhythmia* is any disturbance of rate, rhythm, or conduction of electrical impulses in the heart. The following criteria should be systematically analyzed for each ECG strip (while watching the oscilloscope), until the ability to pick out abnormal ECGs becomes automatic.

1. *R to R intervals.* Evenly spaced (maximum allowable difference between R waves is 3 small squares)
2. *P waves.*
   - a. Within the 3 × 3 small square box
   - b. Positive
   - c. Same consistent, rounded shape
3. *P-R interval.* Three to 5 small squares (0.12 to 0.20 second)
4. *P to QRS ratio.* Always 1:1 ratio
5. *QRS duration.* Less than 2½ small squares (0.10 second)

The exercise technician should be (a) able to monitor the screen and pick out any abnormal PQRST wave complex, and (b) alert to call the supervising physician for an interpretation. However, the exercise technician does not necessarily need to know how to interpret abnormal ECGs during exercise. (One of the most common ECG abnormalities during the exercise test is the premature ventricular contraction [PVC].) (See Figure 3.26 for examples of PVCs.)

One of the major purposes in giving a treadmill ECG stress test is to load the heart muscle beyond normal demands to see whether any obstruction to blood flow in the coronary arteries can be picked up on the ECG.[1] During the maximal exercise test coronary blood flow increases fivefold. If the coronary blood vessel is restricted approximately two thirds, the ST segment of the PQRST wave complex may be depressed.

ST segment depression is determined if all the following criteria are present (see Figure 3.26 for examples):

- 1 mm or more depressed (below baseline)
- At least 0.08 second (2 small squares) in length
- Flat or downsloping
- Three or more consecutive complexes

(continued)

SPORTS MEDICINE INSIGHT *(continued)*

Administering the Electrocardiogram

When ST segment depression is recorded, this is a "positive" test for coronary heart disease (CHD). When ST segment depression is not present, the test is called "negative."

The supervising physician should know that the specificity, sensitivity, and diagnostic accuracy of the test can vary considerably according to the prevalence of CHD in the population being tested (Bayes theorem) and according to criteria used.[1,87] Ischemic chest pain induced by the exercise test is strongly predictive of CHD and is even more predictive with ST segment depression.[1,87] Severity of CHD is also related to the time of appearance of ST segment depression, with changes occurring early translating to a poor prognosis and increased risk of multivessel disease. The probability and severity of CHD are also directly related to the amount of ST segment depression and the downslope.

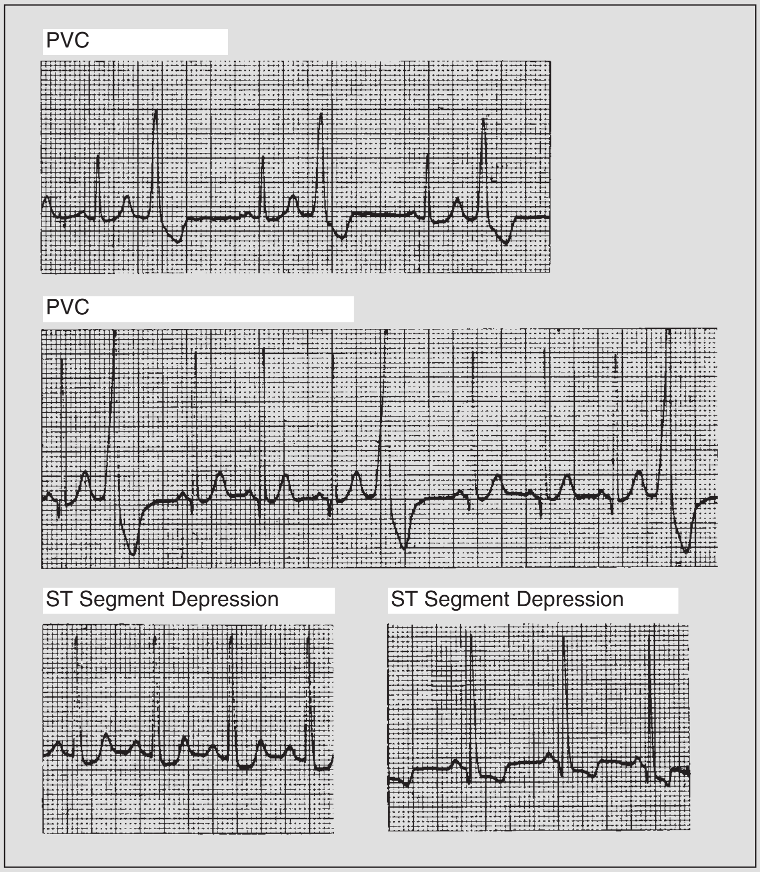


Figure 3.26 One of the most common arrhythmias is the premature ventricular contraction (PVC). ST segment depression may occur when coronary blood vessels are partially restricted, decreasing blood flow during exercise.

SUMMARY

1. While the direct measurement of $\dot{V}O_{2max}$ is the best estimate of heart and lung endurance, for various practical reasons, other tests have been developed as substitutes. These include field tests (mainly running tests), step tests (YMCA 3-minute step test, Canadian Home Fitness Step Test), submaximal laboratory tests (YMCA submaximal cycle test), and maximal laboratory tests (both cycle and treadmill).
2. This chapter provided a detailed description of these tests. Maximal treadmill testing with ECG is explained in detail because of its great value in diagnosing overt or latent heart disease, evaluating cardiorespiratory functional capacity, evaluating responses to conditioning or cardiac rehabilitation programs, and increasing individual motivation for entering and adhering to exercise programs.
3. Resting and exercise blood pressure and heart rate determination are reviewed. The diagnosis of adult hypertension is confirmed when the average of two or more measurements on at least two separate visits are 140/90 mm Hg or higher.

4. Principles for taking blood pressure measurements are listed. At rest, diastolic blood pressure equals the disappearance of the pulse sound (fifth Korotkoff sound).
5. Heart rate can be determined through several methods including the use of heart rate rulers, auscultation with a stethoscope, and heart rate monitors.
6. A number of performance tests, such as maximal endurance runs on a track, have been devised for testing large groups in field situations. Equations for predicting $\dot{V}O_{2max}$ from one's ability to run various distances at maximal speed have been developed. A 1-mi walk test has been developed to more safely test adults.
7. Both maximal and submaximal step tests have been developed for predicting $\dot{V}O_{2max}$. Of these, the Canadian Aerobic Fitness Test and the YMCA's 3-minute step test have been most widely used.
8. The American College of Sports Medicine has developed equations for predicting oxygen consumption during bench stepping, cycling, walking, and running. Two important terms are used by the ACSM in its equations and calculations—METs and kcal $\cdot$ min^{-1}. One MET is equal to 3.5 ml $\cdot$ kg^{-1} $\cdot$ min^{-1}, or the oxygen consumption during rest. One MET is also equal to 1 kcal $\cdot$ kg^{-1} $\cdot$ hour^{-1}.
9. Both treadmill and cycle ergometers are used in testing cardiorespiratory fitness. In the United States, most facilities use treadmills for exercise testing because walking, jogging, and running are more familiar to Americans, who generally are unaccustomed to cycling. In addition, most people reach higher $\dot{V}O_{2max}$ values during treadmill tests than they do with the cycle.
10. A complete description of cycle ergometers is presented. The workload on the Monark or other mechanically braked cycles is usually expressed in kilogram-meters per minute (kg $\cdot$ m $\cdot$ min^{-1}) or in watts (1 watt = 6 kg $\cdot$ m $\cdot$ min^{-1}). Work = kg setting $\times$ 6 m $\cdot$ rpm^{-1} $\times$ rpm = kg $\cdot$ m $\cdot$ min^{-1}.
11. One of the best submaximal cycle protocols is the one used by the YMCA in its testing program. The objective of the YMCA submaximal cycle test is to obtain two heart rates between 110 and 150 bpm and then extrapolate these to an estimated maximal oxygen consumption.
12. The most commonly used maximal treadmill protocols are the Bruce and the Balke. $\dot{V}O_{2max}$ can be estimated accurately from performance time to exhaustion during these protocols.
13. There are two recommended maximal graded exercise cycle test protocols: the Astrand and the Storer–Davis.
14. The maximal treadmill and cycle protocols described herein test maximal cardiorespiratory capacity. A different type of test, the Wingate Anaerobic Test (WAnT), has been developed to test maximal anaerobic power. The WAnT requires pedaling or arm cranking on a cycle ergometer for 30 seconds at maximal speed against a constant force.
15. The Sports Medicine Insight reviewed basic principles for administering electrocardiograms.

Review Questions

1. ***One MET represents ____.***

   A. resting oxygen consumption
   B. oxygen consumption during running
   C. oxygen consumption during walking
   D. maximal oxygen consumption

2. ***Hypertension is diagnosed for adults when the average of two or more systolic measurements are ____ mm Hg or higher and/or the diastolic blood pressure measurements on at least two separate visits is ____ mm Hg or higher.***

   A. 110/60 **B.** 140/90
   C. 120/80 **D.** 160/100
   E. 180/110

3. ***The pressure in the artery when the heart is resting is called the ____.***

   A. systolic pressure
   B. diastolic pressure

4. ***$\dot{V}O_{2max}$ is defined as the greatest rate at which oxygen can be consumed during maximal exercise conditions and is usually expressed in terms of ____.***

   A. ml $\cdot$ kg^{-1} min^{-1} **B.** mg $\cdot$ min^{-1}
   C. ml $\cdot$ kg^{-1} **D.** g $\cdot$ kg^{-1}
   E. None of these

5. ***During a graded exercise test on a treadmill, the systolic blood pressure in healthy participants ____.***

   A. increases **B.** stays the same **C.** decreases

6. ***Resting oxygen consumption is ____ ml $\cdot$ kg^{-1} min^{-1} in the average human.***

   A. 11.5 **B.** 3.5 **C.** 50 **D.** 245 **E.** 75

7. ***Which fitness test uses a 1-minute recovery heart rate to determine fitness classification?***

   A. Canadian Aerobic Fitness Test
   B. YMCA 3-minute step test

C. 1.5-mile run test
D. Bruce treadmill test

8. ***Which maximal treadmill test protocol has a larger workload increase per stage?***

A. Bruce B. Balke

9. ***A diastolic blood pressure of 84 mm Hg is classified as ____.***

A. normal B. prehypertension
C. optimal D. stage 1 hypertension
E. stage 2 hypertension

10. ***If the blood pressure is less than 145/95 mm Hg, it should be rechecked within ____.***

A. 2 months B. 6 months
C. 1 year D. 2 years

11. ***During exercise testing, the ____ Korotkoff sound should be used for systolic blood pressure.***

A. second B. third
C. first D. fifth
E. fourth

12. ***If 50 mm separate 4 R waves, the heart rate is ____.***

A. 100 B. 120 C. 150 D. 200 E. 250

13. ***Which submaximal test uses two 8-in. steps?***

A. Canadian Aerobic Fitness Test
B. YMCA 3-minute step test
C. Katch and McArdle step test

14. ***On a cycle ergometer such as the Monark, 10 watts equal ____ kg · m · min***$^{-1}$.

A. 10 B. 20 C. 30 D. 40 E. 60

15. ***On a cycle ergometer such as the Monark, if a client cycles at 60 rpm at a setting of 2 kp, the workload is ____ kg · m · min***$^{-1}$.

A. 120 B. 2,000 C. 30 D. 520 E. 720

16. ***The Wingate test measures ____.***

A. aerobic power B. muscular endurance
C. anaerobic power

17. ***Which one of the following is*** **not** ***a criterion for exercise test termination during those that do not rely on physician involvement or ECG monitoring?***

A. Subject asks to stop
B. Significant drop in systolic BP
C. Diastolic BP that rises above 90 mm Hg
D. Onset of angina
E. Signs of poor perfusion, including light-headedness, confusion, ataxia, cyanosis

18. ***If a 60-kg man runs 9 mph for 45 minutes, how many kilocalories will he expend?***

A. 750 B. 857 C. 1,142 D. 665 E. 443

19. ***If a 70-kg man is expending 10 METs during exercise, how many kilocalories per minute is this?***

A. 11.7 B. 4.8 C. 8.8 D. 6.2 E. 13.3

20. ***If a 60-kg woman is cycling at a work rate of 900 kg · m · min***$^{-1}$***, the energy expenditure in METs is ____.***

A. 9.7 B. 16.2 C. 7.9 D. 15.3 E. 11.4

21. ***If a person walks at 3.5 mph, what is the energy expenditure in METs?***

A. 2.3 B. 3.7 C. 5.3 D. 3.0 E. 6.9

22. ***If a 50-kg man is expending 10 METs during exercise, how many kilocalories per hour is this?***

A. 500 B. 600
C. 650 D. 750
E. None of these

23. ***Which one of the following is*** **not** ***a criterion used to determine whether an individual's true*** $\dot{V}O_{2max}$ ***has been achieved?***

A. Oxygen consumption plateaus during the last minutes of a graded exercise test.
B. Respiratory exchange ratio increases to 1.0 or higher.
C. Subject's heart rate increases to within 10 beats of the age-predicted maximum.
D. Blood lactate levels rise above 8 mmol/l.

24. ***The 1-mi walk equation does not use which one of the following measurements or factors?***

A. Ending heart rate B. Total walk time
C. Body weight D. Gender
E. Body mass index

25. ***The Wingate anaerobic test requires pedaling on a cycle ergometer for ____ seconds.***

A. 30 B. 60 C. 10 D. 5 E. 120

Answers

1. A	**5.** A	**9.** B	**13.** A	**17.** C	**21.** B	**24.** E
2. B	**6.** B	**10.** A	**14.** E	**18.** D	**22.** A	**25.** A
3. B	**7.** B	**11.** C	**15.** E	**19.** A	**23.** B	
4. A	**8.** A	**12.** B	**16.** C	**20.** A		

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PHYSICAL FITNESS ACTIVITY 3.1

Practical Use of the ACSM Equations

The American College of Sports Medicine equations presented in this chapter are highly useful for health and fitness instructors. However, the use of these equations can be initially confusing to some students. It is highly recommended that prospective instructors practice using the equations many times over, applying them to varying situations to gain a full understanding of them. In the ACSM Health/Fitness Instructor Certification program, the ACSM equations are an integral part of the process.

Here are some sample questions to help you learn how to use the equations. Correct answers are noted with an asterisk (*). Consult your instructor to help clarify use of the equations. However, all the information you need to solve these problems is in this chapter.

1. If a person is cycling at 60 rpm with the bicycle ergometer set at 2 kp, the workload in watts is
   - **a.** 200
   - **b.** *120
   - **c.** 150
   - **d.** 180
   - **e.** None of the above
2. If a 60-kg man runs 9 mph for 45 minutes, how many kilocalories will he expend?
   - **a.** 750
   - **b.** 857
   - **c.** 1,142
   - **d.** *665
   - **e.** 443
3. If a 100-kg man is expending 5 METs during exercise, how many kcal/min is this?
   - **a.** 7.5
   - **b.** 4.8
   - **c.** 5.8
   - **d.** 6.2
   - **e.** *8.3
4. If a 60-kg woman is cycling at a work rate of 600 $kg \cdot m \cdot min^{-1}$, the energy expenditure in METs is
   - **a.** *7.1
   - **b.** 6.2
   - **c.** 8.0
   - **d.** 5.3
   - **e.** 4.0
5. If a person walks at 5.0 mph, what is the energy expenditure in METs?
   - **a.** 2.3
   - **b.** *4.8
   - **c.** 5.3
   - **d.** 3.0
   - **e.** 6.9

6. If the person in question 5 is a male weighing 70 kg, how many kilocalories would he burn if he walked for 30 minutes?
   a. 100
   b. 284
   c. 154
   d. *168
   e. 220
7. The oxygen cost of running on the level at 300 m/min would be about
   a. 6 METs
   b. 8 METs
   c. 10.5 METs
   d. 12.5 METs
   e. *18.1 METs
8. If a person is cycling at 50 rpm with the cycle ergometer set at 4 kp, the workload in $kg \cdot m \cdot min^{-1}$ is
   a. 200
   b. *1,200
   c. 1,500
   d. 2,200
   e. None of the above
9. If a 50-kg man is expending 10 METs during exercise, how many kilocalories per hour is this?
   a. *500
   b. 600
   c. 650
   d. 750
   e. None of the above
10. If a 72-kg man is cycling at a work rate of $kg \cdot m \cdot min^{-1}$, the energy expenditure in $ml \cdot kg^{-1} \cdot min^{-1}$ is
    a. 15
    b. *22
    c. 34
    d. 48
    e. None of the above
11. If an 80-kg person walks at 2.0 mph, how many kilocalories will be expended after 2 hours?
    a. *405
    b. 502
    c. 609
    d. 650
    e. None of the above
12. The oxygen cost in $ml \cdot kg^{-1} \cdot min^{-1}$ of running on the level at 8.0 mph would be
    a. 34.2
    b. *46.4
    c. 53.9
    d. 56.7
    e. 65.0

Questions 13 to 18 apply to Mr. Smith's graded exercise test on a cycle ergometer (3-minute stages, 80 rpm). This was conducted without a physician present because Mr. Smith is an athlete training for national competition, is 22 years old, weighs 65 kg, and is apparently healthy.

Stage	Work Rate (watts)	Heart Rate	Blood Pressure	RPE
1	50	100	125/70	2
2	100	135	140/72	3
3	150	150	150/70	4
4	200	164	160/73	5
5	250	178	172/70	6
6	300	190	185/73	8
7	350	200	190/72	9
8	400	205	195/75	10

13. The final workload in kilogram-meters per minute is approximately
- **a.** 1,200
- **b.** *2,400
- **c.** 1,500
- **d.** 3,500
- **e.** None of the above

14. What was the final approximate "kg" setting (if the test was conducted on a Monark mechanically braked cycle)?
- **a** *5.0
- **b.** 3.5
- **c.** 4.4
- **d.** 6.4
- **e.** None of the above

15. What was the energy expenditure in METs during stage 7 (assume he reached close to a steady state)?
- **a.** 15.6
- **b.** 17.4
- **c.** *18.6
- **d.** 20.2
- **e.** None of the above

16. What is his energy expenditure in kcal · min^{-1} during stage 5?
- **a.** *15.0
- **b.** 10.4
- **c.** 11.5
- **d.** 8.6
- **e.** None of the above

17. What is his energy expenditure in METs during stage 3?

a. 5.4
b. *9.1
c. 9.5
d. 10.8
e. 12.4

18. What is his energy expenditure in L · min during stage 6?

a. *3.70
b. 4.23
c. 5.67
d. 5.80
e. None of the above

PHYSICAL FITNESS ACTIVITY 3.2

Cardiorespiratory Endurance Testing

In this chapter, detailed information is given for several tests of cardiorespiratory endurance ($\dot{V}O_{2max}$), including the following:

- 1-mi run
- YMCA 3-minute step test
- Canadian Aerobic Fitness Test
- YMCA submaximal cycle test
- Storer–Davis maximal cycle test
- Bruce maximal treadmill test

Under the supervision of your instructor or a local fitness center director, using the directions outlined in the chapter and the norms outlined in Appendix A, take each of these six tests and fill in the cardiorespiratory test worksheet. Be sure to follow the precautions outlined in this chapter. If you are not categorized as "low risk" using the ACSM guidelines, these tests should not be taken unless under the direct supervision of a physician (see Chapter 2).

After taking these tests, answer the following questions.

1. Did the estimated $\dot{V}O_{2max}$ vary widely for the six different tests? (Define "widely" as more than 25% from the Bruce treadmill maximal test result.)

a. Yes

b. No

2. If you answered "yes" on question 1, list at least five reasons as to why you feel $\dot{V}O_{2max}$ varied so widely.

a. ____

b. ____

c. ____

d. ____

e. ____

Assessment of Cardiorespiratory Endurance Testing

Test	Your Score	Classification
1-mi run		
YMCA 3-minute step test		
Canadian Aerobic Fitness Test		
YMCA submaximal cycle test		
Storer–Davis maximal cycle test		
Bruce maximal treadmill test		

Note: Record all scores in ml · kg^{-1} · min^{-1}, except for the YMCA 3-minute step test. Use $\dot{V}O_{2max}$ norms from Appendix A for classification. For the 1-mi run, use the estimating equation from Table 3.4. For the YMCA 3-minute step test, record 60-second recovery pulse, and then use norms in Appendix A (Table 22). For the Canadian Aerobic Fitness Test, use the aerobic fitness score described in the text. For the YMCA submaximal cycle test, use Figure 3.15. For the Storer–Davis maximal cycle test, use equations from text. For the Bruce maximal treadmill, use the equation described in Table 3.8.

PHYSICAL FITNESS ACTIVITY 3.3

Measurement of Your Resting Heart Rate

As emphasized in the text, a low resting heart rate usually indicates a heart conditioned by regular aerobic exercise. Some people have a low resting heart rate due to various genetic factors, but they can still lower their resting heart rates through exercise training.

Many factors can increase the resting heart rate to levels that are higher than normal (see chapter discussion). To rule out these factors, the resting heart rate is best measured a few minutes after awakening when seated on the edge of the bed. In this Physical Fitness Activity, you will take your resting heart rate, using the artery in your wrist or neck, three mornings in a row after getting out of bed. Put three fingers at the base of your thumb on the bottom of your wrist to count the heartbeats for 1 full minute using the radial artery, or three fingers on either side of your voice box on the neck (carotid artery). Do not press too hard.

Record these values in the blanks below, average them, and then using Table 21 in Appendix A, classify your resting heart rate from the YMCA norms.

Resting Heart Rate Measurements:

First morning: ____________________ bpm

Second morning: ____________________ bpm

Third morning: ____________________ bpm

Average resting heart rate: ____________________ bpm

Classification
(from Table 21, Appendix A): ____________________

PHYSICAL FITNESS ACTIVITY 3.4

Measurement of Your Resting Blood Pressure

Follow the procedures summarized in the text. Sit quietly for at least 5 minutes before having your blood pressure measured. Be totally relaxed. The same factors that raise the resting heart rate can elevate the blood pressure (stress and anxiety, food in the stomach, a full bladder, pain, extreme hot or cold, tobacco use, caffeine, and certain kinds of medications). Ideally, two measurements should be taken on two separate days. If this is not practical, have your blood pressure measured twice during the class session, and then average. Use Table 3.1 to classify your blood pressure.

Resting Blood Pressure Measurements:

First reading: ____________________ mm Hg

Second reading: ____________________ mm Hg

Average resting Blood pressure: ____________________ mm Hg

Classification

(from Table 3.1): ____________________

PHYSICAL FITNESS ACTIVITY 3.5

Estimation of $\dot{V}O_{2max}$ Using an Equation

Low levels of cardiorespiratory fitness have been linked to most of the leading causes of death, including heart disease, stroke, cancer, and diabetes. Direct measurement of cardiorespiratory fitness or $\dot{V}O_{2max}$ is expensive and requires trained technicians and medical supervision. There has been much interest in developing simple methods of estimating $\dot{V}O_{2max}$, especially for large groups of people. One method that is gaining widespread acceptance is the use of an estimating equation that factors in several personal characteristics including age, gender, height, weight, and physical activity habits.

Use the equation below to estimate your $\dot{V}O_{2max}$. You will need a calculator. Calculate your body mass index (BMI) from Figure 4.11. It should be emphasized that this equation provides a "ballpark" estimate of your $\dot{V}O_{2max}$, and that other methods, especially running and walking tests, are preferred. Once you estimate your $\dot{V}O_{2max}$, use Table 24 in Appendix A to obtain your classification.

Equation for Estimating $\dot{V}O_{2max}$

$\dot{V}O_{2max}$ ml · kg^{-1} · min^{-1} = ______________ ______________
Classification (Table 24, Appendix A)

56.363 − (________ × 0.381)
age

− (__________ × 0.754)
body mass index

+ (________________ × 1.921)
physical activity rating, 0 to 7*

+ 10.987 (if you are a male) or 0 (if you are a female)

Example: Calculate $\dot{V}O_{2max}$ in ml · kg^{-1} · min^{-1} for a 20-year-old female college student who is 5 ft, 5 in. tall (65 in.), weighs 130 lb, and swims laps 45 minutes each week.

$\dot{V}O_{2max}$ ml · kg^{-1} · min^{-1} = 42.0 Average
Classification (Table 24, Appendix A)

56.363 − (20 × 0.381)
age

− (21.7 × 0.754)
body mass index

+ (5 × 1.921)
physical activity rating, 0 to 7*

+ 0 (female)

*Pick a physical activity rating that best fits your typical habits:

I. Does not participate regularly in programmed recreation sport or physical activity.
- **0 points:** Avoids walking or exertion (e.g., always uses elevator, drives whenever possible instead of walking)
- **1 point:** Walks for pleasure, routinely uses stairs, occasionally exercises sufficiently to cause heavy breathing or perspiration.

II. Participates regularly in recreation or work requiring modest physical activity, such as golf, horseback riding, calisthenics, gymnastics, table tennis, bowling, weight lifting, or yard work.
- **2 points:** 10 to 60 minutes per week.
- **3 points:** Over 1 hour per week.

III. Participates regularly in heavy physical exercise (such as running or jogging, swimming, cycling, rowing, skipping rope, running in place) or engages in vigorous aerobic-type activity (such as tennis, basketball, or handball).
- **4 points:** Runs less than 1 mi per week or spends less than 30 minutes per week in comparable physical activity.
- **5 points:** Runs 1 to 5 mi per week or spends 30 to 60 minutes per week in comparable physical activity.
- **6 points:** Runs 5 to 10 mi per week or spends 1 to 3 hours per week in comparable physical activity.
- **7 points:** Runs over 10 mi per week or spends over 3 hours per week in comparable physical activity.

PHYSICAL FITNESS ACTIVITY 3.6

The 1-Mile Walk Test

To take the test, walk a mile around a track or measured course as fast as possible, measure the total walking time, and then take the heart rate just after finishing.
This equation is recommended for college students:

$\dot{V}O_{2max}$ $ml \cdot kg^{-1} \cdot min^{-1} = 88.768 + (8.892 \times$ ________________________)
(gender with M = 1, F = 0)

$- (0.0957 \times$ ______________)
(weight in lb)

$- (1.4537 \times$ ______________)
(walk time in minutes in decimal format)

$- (0.1194 \times$ ______________)
(ending exercise heart rate)

For example, a college female weighing 128 lb and able to walk 1 mi in 13 minutes with an ending heart rate of 133 bpm would have this estimated $\dot{V}O_{2max}$: $88.768 + (8.892 \times 0) - (0.0957 \times 128) - (1.4537 \times 13.0) - (0.1194 \times 133) = 41.7\ ml \cdot kg^{-1} \cdot min^{-1}$.

One-mi walking time:	________________________	minutes
Ending heart rate:	________________________	bpm
Fitness rating		
(from Table 24, Appendix A):	________________________	

PHYSICAL FITNESS ACTIVITY 3.7

A Step Test for College Students

As explained in the text, in this step test, the heart rate is taken for 15 seconds after stepping up and down on a 16.25-in. bench for 3 minutes at a rate of 24 steps per minute for men and 22 for women, and is then applied to the equations listed below to determine $\dot{V}O_{2max}$. Overweight individuals and those with medical problems or leg injuries should not take this test.

1. The step test requires a stopwatch, metronome, and stepping bench (16.25 in. high, typical of most gymnasium bleachers). The metronome should be set at 96 bpm for men and 88 bpm for women. Practice stepping to a four-step cadence (up with the right foot, up with the left foot, down with the right foot, down with the left foot) to ensure 24 complete step-ups per minute for men and 22 step-ups per minute for women.
2. Begin the test and perform the step-ups for exactly 3 minutes.
3. After stepping, remain standing, wait 5 seconds, and then count the heart rate at the wrist or neck for 15 seconds.
4. Convert the 15-second pulse count into beats per minute by multiplying by 4.
5. Use these equations and to estimate $\dot{V}O_{2max}$, and Table 24, Appendix A to classify your fitness status.

MALES: Predicted $\dot{V}O_{2max}$ = 111.33 − (0.42 × heart rate in bpm)

FEMALES: Predicted $\dot{V}O_{2max}$ = 65.81 − (0.1847 × heart rate in bpm)

15-second pulse count after stepping:	____________________ beats
Convert heart rate to beats per minute:	____________________ bpm
Estimated $\dot{V}O_{2max}$ from equations:	____________________ $ml \cdot kg^{-1} \cdot min^{-1}$
$\dot{V}O_{2max}$ classification	
(from Table 24, Appendix A):	____________________