Seventh Edition

Advanced Fitness Assessment and Exercise Prescription

Cardiorespiratory Fitness Assessment and Prescription

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Preface

One of the most important components of physical fitness is cardiorespiratory endurance. Cardiorespiratory endurance is the ability to perform dynamic exercise involving large muscle groups at moderate-to-high intensity for prolonged periods. Every physical fitness evaluation should include an assessment of cardiorespiratory function during both rest and exercise.

Once you have assessed an individual's cardiorespiratory fitness status, you are responsible for planning an aerobic exercise program to develop and maintain the cardiorespiratory endurance of that program participant—a program that will meet the individual's needs and interests, taking into account age, gender, physical fitness level, and exercise habits.

In designing the exercise prescription, keep in mind that some people engage in aerobic exercise to improve their health status or reduce their disease risk, while others are primarily interested in enhancing their physical fitness levels. Given that the quantity of exercise needed to promote health is less than that needed to develop and maintain higher levels of physical fitness, you must adjust the exercise prescription according to your client's primary goal.

Chapter 4 presents guidelines for graded exercise testing, as well as maximal and submaximal exercise test protocols and procedures. Although many of the graded exercise test (GXT) protocols presented were developed years ago, these classic protocols are still widely used in research and clinical settings. In addition, each of these protocols meets the ACSM guidelines for graded exercise tests. The chapter also addresses graded exercise testing for children and older adults and includes a discussion of cardiorespiratory field tests.

Chapter 5 provides guidelines for writing individualized exercise prescriptions that promote health status as well as develop and maintain cardiorespiratory fitness. It compares various training methods and aerobic exercise modes, and presents examples of individualized exercise programs.

These chapters and the accompanying appendix are full excerpts from *Advanced Fitness Assessment and Exercise Prescription, Seventh Edition*. The book's full glossary and reference list are also provided at the end of the e-book.

CHAPTER 4

Assessing Cardiorespiratory Fitness

KEY QUESTIONS

- How is cardiorespiratory fitness ($\dot{V}O_2max$) assessed?
- What is a graded exercise test?
- How is $\dot{V}O_2max$ estimated from a graded exercise test and field test data?
- Should all clients be given a maximal graded exercise test? What factors should I consider in determining whether to give my client a maximal or submaximal exercise test?
- How accurate are submaximal exercise tests and field tests in assessing cardiorespiratory fitness?
- What exercise modes are suitable for graded exercise testing?
- What are the standardized testing procedures for graded exercise testing?
- What are the criteria for terminating a graded exercise test?
- Is it safe to give children and older adults a graded exercise test?

One of the most important components of physical fitness is cardiorespiratory endurance. **Cardiorespiratory endurance** is the ability to perform dynamic exercise involving large muscle groups at moderate-to-high intensity for prolonged periods (American College of Sports Medicine [ACSM] 2014). Every physical fitness evaluation should include an assessment of cardiorespiratory function during both rest and exercise.

This chapter presents guidelines for graded exercise testing, as well as maximal and submaximal exercise test protocols and procedures. Although many of the **graded exercise test (GXT)** protocols presented in this chapter were developed years ago, these classic protocols are still widely used in research and clinical settings. In addition, each of these protocols meets the ACSM (2014) guidelines for graded exercise tests. The chapter also addresses graded exercise testing for children and older adults and includes a discussion of cardiorespiratory field tests. All of the test protocols included in this chapter are summarized in appendix B.1, "Summary of Graded Exercise Test and Cardiorespiratory Field Test Protocols."

DEFINITION OF TERMS

Exercise physiologists consider directly measured **maximum oxygen uptake ($\dot{V}O_2max$)** the most valid measure of functional capacity of the cardiorespiratory system. The **$\dot{V}O_2max$**, or rate of oxygen uptake during maximal exercise, reflects the capacity of the heart, lungs, and blood to deliver oxygen to the working muscles during dynamic exercise involving large muscle mass. The $\dot{V}O_2max$ is widely accepted as the criterion measure of cardiorespiratory fitness.

Traditionally, a plateau in oxygen consumption despite an increase in workload is the criterion used to determine the attainment of a true $\dot{V}O_2max$ during a maximum exercise tolerance test. Over the last decade, however, evidence suggests that the incidence of a $\dot{V}O_2$ plateau during incremental exercise testing is highly variable, ranging from 16% to 94% (Day et al. 2003; Magnan et al. 2013; Mier, Alexander, and Mageean 2012; Rossiter, Kowalchuk, and Whipp 2006; Yoon, Kravitz, and Robergs 2007). In fact, studies have established that a "plateau phenomenon" is not a prerequisite for identifying a true $\dot{V}O_2max$ in the majority of individuals (Noakes 2008). According to Magnan and colleagues (2013), the incidence of a plateau for inactive people is related to body mass index (BMI), waist-to-hip ratio, sense of self-efficacy, gender, and method for determining the plateau. Highly fit college-aged adults may also fail to demonstrate a plateau with treadmill running (Mier, Alexander, and Mageean 2012).

Ramp-type protocols elicit a peak rather than a maximum rate of oxygen consumption. **$\dot{V}O_2$peak** is the highest rate of oxygen consumption measured during the exercise test, regardless of whether or not a $\dot{V}O_2$ plateau is reached. $\dot{V}O_2$ peak may be higher than, lower than, or equal to $\dot{V}O_2max$. For many individuals who do not reach an actual $\dot{V}O_2$ plateau, the $\dot{V}O_2$peak attained during a maximum-effort incremental test to the limit of tolerance is a valid index of $\dot{V}O_2max$ (Day et al. 2003; Hawkins et al. 2007; Howley 2007).

Maximal and submaximal $\dot{V}O_2$ are expressed in absolute or relative terms. **Absolute $\dot{V}O_2$** is measured in liters per minute (L·min^{-1}) or milliliters per minute (ml·min^{-1}) and provides a measure of energy cost for non-weight-bearing activities such as leg or arm cycle ergometry. Absolute $\dot{V}O_2$ is directly related to body size; thus, men typically have a larger absolute $\dot{V}O_2max$ than women.

Because absolute $\dot{V}O_2$ depends on body size, $\dot{V}O_2$ is typically expressed relative to body weight, that is, in ml·kg^{-1}·min^{-1}. **Relative $\dot{V}O_2max$** is used to classify an individual's cardiorespiratory (CR) fitness level or to compare fitness levels of individuals differing in body size. Relative $\dot{V}O_2$ can also be used to estimate the energy cost of weight-bearing activities such as walking, running, and stair climbing. However, although the relationship between absolute $\dot{V}O_2max$ and body mass is strong ($r = 0.86$), it is not perfect ($r = 1.00$). Therefore, when $\dot{V}O_2max$ is expressed simply as a linear function of body mass, CR fitness levels of heavier (>75.4 kg) and lighter (<67.7 kg) individuals may be under- or overclassified, respectively (Heil 1997). Some experts propose scaling exercise capacity (i.e., $\dot{V}O_2$, 6 min walk test distance) to an exponential function of body mass (Buresh and Berg 2002; Dourado and McBurnie 2012; Heil 1997). Dourado and McBurnie (2012) recommended using body mass exponents of 0.11 and 0.37 to compare timed walking distance of middle-aged and older adults, respectively. Heil (1997) suggested using a body mass exponent of 0.67 to compare $\dot{V}O_2$ of individuals of similar height, age, and training status and an exponent of 0.75 to compare heterogeneous groups (e.g., older vs. younger or trained vs. sedentary individuals). A current limitation of this exponential approach is that the norms used to classify CR fitness levels were established for relative $\dot{V}O_2max$ values expressed as ml·min^{-1}·kg^{-1} and not as ml·min^{-1}·kg$^{0.67 \text{ or } 0.75}$. Carrick-Ranson and colleagues (2012) suggested that scaling relative to fat-free mass (FFM), the most metabolically active tissue, is more appropriate than is allometric scaling.

Expressing $\dot{V}O_2$ relative to the individual's FFM (see chapter 8), that is, as ml·kgFFM^{-1}·min^{-1}, provides you with an estimate of cardiorespiratory endurance that is independent of changes in body weight. For example, your client's improvement in relative $\dot{V}O_2max$ following a 16 wk aerobic exercise program may reflect both improved capacity of the cardiorespiratory system (increase in absolute $\dot{V}O_2max$) and weight loss (increase in relative $\dot{V}O_2$ expressed as ml·kg^{-1}·min^{-1} due to a decrease in body weight). Thus, expressing $\dot{V}O_2max$ relative to FFM, instead of body weight, reflects the oxygen consumption of the tissues most active during exercise and physical activity.

The rate of oxygen consumption can also be expressed as a gross $\dot{V}O_2$ or net $\dot{V}O_2$. **Gross $\dot{V}O_2$** is the total rate of oxygen consumption and reflects the caloric costs of both rest and exercise (gross $\dot{V}O_2$ = resting $\dot{V}O_2$ + exercise $\dot{V}O_2$). On the other hand, **net $\dot{V}O_2$** represents the rate of oxygen consumption in excess of the resting $\dot{V}O_2$ and is used to describe the caloric cost of the exercise. Both gross and net $\dot{V}O_2$ can be expressed in either absolute (e.g., L·min^{-1}) or relative (ml·kg^{-1}·min^{-1}) terms. Unless specified as a net $\dot{V}O_2$, the $\dot{V}O_2$ values reported throughout this book refer to gross $\dot{V}O_2$.

GRADED EXERCISE TESTING: GUIDELINES AND PROCEDURES

Exercise scientists and physicians use exercise tests to evaluate functional cardiorespiratory capacity ($\dot{V}O_2$max) objectively. The $\dot{V}O_2$max, determined from graded maximal or submaximal exercise tests, is used to classify the cardiorespiratory fitness level of your client (see table 4.1). You can use baseline and follow-up data to evaluate the progress of exercise program participants and to set realistic goals for your clients. You can use the heart rate (HR) and oxygen uptake data obtained during the graded exercise test to make accurate, precise exercise prescriptions.

As discussed in chapter 2, before the start of a vigorous (>60% $\dot{V}O_2$max or >6 METs [metabolic equivalents]) exercise program, ACSM (2014) recommends a graded **maximal exercise test** for high-risk individuals with one or more signs or symptoms of cardiovascular, pulmonary, renal, and metabolic disease and for high-risk individuals with known cardiovascular, pulmonary, renal, or metabolic disease.

However, you may use **submaximal exercise tests** or maximal exercise tests for low-risk individuals as well as clients with moderate risk if they are starting either a moderate (40–60% $\dot{V}O_2$max or 3–6 METs) or vigorous (≥60% $\dot{V}O_2$max or >6 METs) exercise program (ACSM 2014). For medical conditions that constitute absolute and relative contraindications to exercise testing, see chapter 2.

GENERAL GUIDELINES FOR EXERCISE TESTING

You may use a maximal or submaximal graded exercise test (GXT) to assess the cardiorespiratory fitness of the individual. The selection of a maximal or submaximal GXT depends on

- your client's risk stratification (low risk, moderate risk, or high risk),
- your reasons for administering the test (physical fitness testing or clinical testing), and
- the availability of appropriate equipment and qualified personnel.

In clinical and research settings, $\dot{V}O_2$max is typically measured directly, which requires expensive equipment and experienced personnel. Although $\dot{V}O_2$max can be predicted from maximal exercise intensity with a fair degree of accuracy, submaximal tests also provide a reasonable estimate of your client's cardiorespiratory fitness level. They are less costly, time-consuming, and risky. Submaximal exercise testing, however, is considered less sensitive as a diagnostic tool for coronary heart disease (CHD).

Table 4.1 Cardiorespiratory Fitness Classifications: $\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$)

Age (yr)	Poor	Fair	Good	Excellent	Superior
WOMEN					
20-29	≤35	36-38	40-43	44-48	49+
30-39	≤33	34-36	37-41	42-46	47+
40-49	≤32	33-35	36-38	39-44	45+
50-59	≤28	29-31	32-35	36-40	41+
60-69	≤26	27-28	29-32	33-36	37+
70-79	≤25	26-27	28-29	30-36	37+
MEN					
20-29	≤41	42-45	46-49	51-55	56+
30-39	≤40	41-43	44-47	48-53	54+
40-49	≤37	38-41	42-45	46-52	53+
50-59	≤34	35-38	39-42	43-48	49+
60-69	≤31	32-34	35-38	39-44	45+
70-79	≤28	29-31	32-35	36-42	43+

Data from Cooper Institute for Aerobics Research 2005.

In either case, the exercise test should be a multistage graded test. This means that the individual exercises at gradually increasing submaximal workloads. Many commonly used exercise test protocols require that each workload be performed for 3 min. The GXT measures maximum functional capacity ($\dot{V}O_2max$) when the oxygen uptake plateaus and does not increase by more than 150 ml·min^{-1} with a further increase in workload. However, given that many individuals do not attain a $\dot{V}O_2$ plateau, other criteria may be used to indicate the attainment of a true $\dot{V}O_2max$:

- Failure of the HR to increase with increases in exercise intensity
- Venous lactate concentration exceeding 8 mmol·L^{-1}
- **Respiratory exchange ratio (RER)** greater than 1.15
- **Rating of perceived exertion (RPE)** greater than 17 using the original Borg scale (6-20)

If the test is terminated before the person reaches a plateau in $\dot{V}O_2$ and an RER greater than 1.15, the GXT is a measure of $\dot{V}O_2peak$ rather than $\dot{V}O_2max$. Children, older adults, sedentary individuals, and clients with known disease are more likely than other groups to attain a $\dot{V}O_2peak$ rather than a $\dot{V}O_2max$. For CHD screening and classification purposes, bringing a person to at least 85% of the age-predicted maximal HR is desirable because some electrocardiogram (ECG) abnormalities do not appear until the HR reaches this level of intensity.

Evidence suggests that maximal exercise tests are no more dangerous than submaximal tests provided that you carefully follow guidelines for exercise tolerance testing and monitor the physiological responses of the exercise participant continuously. Shephard (1977) predicted one fatality every 10 to 20 yrs for a population of 5 million middle-aged Canadians who undergo maximal exercise testing. For high-risk patients, he estimated one fibrillation per 5,000 submaximal exercise tests and one fibrillation per 3,000 maximal exercise tests. Likewise, eight nonfatal and no fatal events were identified in a retrospective study of 5060 symptom-limited exercise tests (adverse event rate of 0.16%) performed on clients with various underlying high-risk cardiac diagnoses (Skalski, Allison, and Miller 2012). For clinical testing, the risk of an exercise test being fatal is no greater than 0.4 to 0.5 per 10,000 tests (Atterhog, Jonsson, and Samuelsson 1979; Goodman, Thomas, and Burr 2011; Rochmis and Blackburn 1971; Skalski, Allison, and Miller 2012), although the risk of myocardial infarction has been estimated to be 4 per 10,000 tests (Thompson 1993). The ACSM (2014) identified the overall risk of exercise testing in a mixed population as six cardiac events (e.g., myocardial infarction, death, and dysrhythmias) per 10,000 tests. Based on a review of studies including clients with and without CVD, Goodman and colleagues (2011) identified the average risk of an adverse event during exercise testing as being less than 2.9 nonfatal and 0.3 fatal events per 10,000 tests. The risk for apparently healthy individuals (without known disease) is very low, with no complications occurring in 380,000 exercise tests done on young individuals (Levine, Zuckerman, and Cole 1998). Similarly, there were no complications reported in the 700,000-plus exercise tests performed on "sports-persons" and athletes in the studies reviewed by Goodman and colleagues (2011). As a result, Goodman and colleagues recommend that the risks of maximal exertion exercise testing reflect a fatal-event incidence of 0.2 to 0.8 per 10,000 tests and a nonfatal-event incidence of 1.4 per 100,000 tests.

GENERAL PROCEDURES FOR CARDIORESPIRATORY FITNESS TESTING

At least 1 day before the exercise test, you should give your client pretest instructions (see chapter 3). Prior to graded exercise testing, the client should read and sign the informed consent and complete the PAR-Q; see appendix A.1, "Physical Activity Readiness Questionnaire (PAR-Q)." Step-by-step instructions, as recommended by ACSM (2014), are listed in "Procedures for Administering a Graded Exercise Test."

Pretest, exercise, and recovery HRs can be measured using the palpation or auscultation technique (see chapter 2) if a HR monitor or ECG recorder is unavailable. Because of extraneous noise and vibration during exercise, it may be difficult to obtain accurate measurements of BP, especially when

Procedures for Administering a Graded Exercise Test

- Measure the client's resting HR and blood pressure (BP) in the exercise posture (see chapter 2 for these procedures).
- Begin the GXT with a 2 to 3 min warm-up to familiarize clients with the exercise equipment and prepare them for the first stage of the exercise test.
- During the test, monitor HR, BP, and ratings of perceived exertion (RPEs) at regular intervals. Measure HR at least two times during each stage, near the end of the second and third minutes of each stage. A steady-state HR (two HR measurements within ±5 bpm) should be reached for each stage of the test. Do not increase the workload until a steady-state HR is reached.
- Blood pressure should be measured during the last minute of each stage of the test and repeated if a hypotensive or hypertensive response is observed.
- Rating of perceived exertion should be assessed near the end of the last minute of each exercise stage using either the Borg or OMNI scales.
- Throughout the exercise test, continuously monitor the client's physical appearance and symptoms.
- Discontinue the GXT when the test termination criteria are reached (e.g., 70% HRR or 85% HR_{max}), if the client requests stopping the test, or if any of the indications for stopping an exercise test are apparent (see "General Indications for Termination of a Graded Exercise Test in Low-Risk Adults").
- Have the client cool down by exercising at a low work rate that does not exceed the intensity of the first stage of the exercise test (e.g., walking on the treadmill at 2 mph [53.6 m·min^{-1}] and 0% grade, or cycling on the cycle ergometer at 50 to 60 revolutions per minute [rpm] and zero resistance). Active recovery reduces the risk of hypotension from venous pooling in the extremities.
- During recovery, continue measuring postexercise HR and BP for at least 5 min. If an abnormal response occurs, extend the recovery period. The HR and BP during active recovery should be stable but may be higher than pre-exercise levels. Continue monitoring the client's physical appearance during recovery.
- If your client has signs of discomfort or if an emergency occurs, use a passive cool-down with the client in a sitting or supine position.

your client is running on the treadmill. To become proficient at taking exercise BP, you need to practice as much as possible.

For years, the Borg scales have been used to obtain ratings of perceived exertion (RPE) during exercise testing. The original scale (6–20) and the revised scale (0–10) allow clients to rate their degree of exertion subjectively during exercise and are highly related to exercise HRs and $\dot{V}O_2$. Both RPE scales take into account the linear rise in HR and $\dot{V}O_2$ during exercise. The revised scale also reflects nonlinear changes in blood lactate and ventilation during exercise. Ratings of 6 on the original scale and 0 on the revised scale correspond to no exertion at all; ratings of 10 on the revised scale and 19 on the original scale usually correspond with the maximal level of exercise (Borg 1998). Moderate-intensity exercise is rated between 12 and 14 on the original scale and rated 5 or 6 on the revised scale. Ratings of perceived exertion are useful in determining the endpoints of the GXT, particularly for patients who are taking beta-blockers or other medications that may alter the HR response to exercise. You can teach your clients how to use the RPE scales to monitor relative intensities during aerobic exercise programs.

Alternatively, you may use OMNI scales to obtain your client's RPE for various modes of exercise testing. The OMNI scales can be used to measure RPE for the overall body, the limbs, and the chest. These scales were originally developed for children and adolescents using a picture system to illustrate intensity (0 = extremely easy to 10 = extremely hard) of effort during exercise. Later the scales were modified for use with adults engaging in cycle ergometer, treadmill, stepping, elliptical, and resistance exercises. As part of the validation testing for the cycling, stepping, elliptical, and treadmill ergometry scales, the OMNI RPE values were correlated with HR and $\dot{V}O_2$ data. Concurrent validity coefficients ranged from 0.82 to 0.95 for HR and OMNI RPE; likewise, the validity coefficients ranged between 0.88 and 0.96 for $\dot{V}O_2$ and OMNI RPE (Guidetti et al. 2011; Krause et al. 2012; Mays et al. 2010; Robertson 2004). For resistance exercise, RPE values from the OMNI scale were correlated with weight lifted, yielding validity coefficients ranging from 0.72 to 0.91 (Robertson 2004; Robertson et al. 2005). Appendix B.4 contains sample instructions, procedures, and OMNI pictorial scales for boys, girls, and adults engaging in cycling, treadmill walking or running, stepping, and resistance exercise. Like the Borg scales, the OMNI scales can be used by your clients to monitor intensity of their workouts during aerobic and resistance exercise training. For a detailed discussion of how to use these scales, refer to the work of Guidetti (2011), Robertson (2004), Krause (2012), and Mays (2010). Table 4.2 summarizes the verbal cues corresponding to the numerical values of the OMNI RPE scales.

Table 4.2 Verbal Cues for OMNI RPE Scales

Adults	Children
Extremely easy = 0	Not tired at all = 0
Easy = 2	A little tired = 2
Somewhat easy = 4	Getting more tired = 4
Somewhat hard = 6	Tired = 6
Hard = 8	Really tired = 8
Extremely hard = 10	Very, very tired = 10

TEST TERMINATION

In a maximal or submaximal GXT, the exercise usually continues until the client voluntarily terminates the test or a predetermined endpoint is reached. As an exercise technician, however, you must be acutely aware of all indicators for stopping a test. If you notice any of the following signs or symptoms, you should stop the exercise test prior to the client's reaching $\dot{V}O_2$max (for a maximal GXT) or the predetermined endpoint (for a submaximal GXT).

GENERAL INDICATIONS FOR TERMINATION OF A GRADED EXERCISE TEST IN LOW-RISK ADULTS[a]

1. Onset of angina or angina-like symptoms
2. Drop in systolic BP of >10 mmHg from baseline BP despite an increase in workload
3. Excessive rise in BP: systolic pressure >250 mmHg or diastolic pressure >115 mmHg
4. Shortness of breath, wheezing, leg cramps, or claudication
5. Signs of poor perfusion (e.g., ataxia, dizziness, pallor, cyanosis, cold or clammy skin, or nausea)
6. Failure of HR to rise with increased exercise intensity
7. Noticeable change in heart rhythm
8. Client's request to stop
9. Physical or verbal manifestations of severe fatigue
10. Failure of the testing equipment

[a]For definitions of specific terms, refer to the glossary.

Adapted from Gibbons et al. 2002.

MAXIMAL EXERCISE TEST PROTOCOLS

Many maximal exercise test protocols have been devised to assess cardiorespiratory capacity. As the exercise technician, you must be able to select an exercise mode and test protocol that are suitable for your clients given their age, gender, and health and fitness status. Commonly used modes of exercise are treadmill walking or running and stationary cycling. Arm ergometry is useful for persons with paraplegia and clients who have limited use of the lower extremities. Also, combined leg and arm ergometry and total body recumbent stepper exercise tests may be suitable alternatives to treadmill testing for assessing the cardiorespiratory fitness of older persons with balance deficits, gait impairments, and decreased coordination (Billinger, Loudon, and Gajewski 2008; Loudon et al. 1998). Bench stepping is not highly recommended but could be useful in field situations when large groups need to be tested.

General Principles of Exercise Testing[a]

Video 4.1
Video 4.2

1. Typically, you will use either a treadmill or stationary cycle ergometer for graded exercise testing. All equipment should be calibrated before use (see online videos on calibrating treadmills and cycle ergometers).
2. Begin the GXT with a 2 to 3 min warm-up to orient clients to the equipment and prepare them for the first stage of the GXT.
3. The initial exercise intensity should be considerably lower than the anticipated maximal capacity.
4. Exercise intensity should be increased gradually throughout the stages of the test. Work increments may be 2 METs or greater for apparently healthy individuals and as small as 0.5 MET for patients with disease.
5. Closely observe contraindications for testing and indications for stopping the exercise test. When in any doubt about the safety or benefits of testing, do not perform the test at that time.
6. Monitor the HR at least two times, but preferably each minute, during each stage of the GXT. Heart rate measurements should be taken near the end of each minute. If the HR does not reach steady state (two HRs within ±5 or 6 bpm), extend the work stage an additional minute or until the HR stabilizes.
7. Measure BP and RPE once during each stage of the GXT, in the later portion of the stage.
8. Continually monitor client appearance and symptoms.
9. For submaximal GXTs, terminate the test when the client's HR reaches 70% HRR (heart rate reserve) or 85% HR_{max} (maximal heart rate), unless the protocol specifies a different termination criterion. Also, stop the test immediately if there is an emergency situation, if the client fails to conform to the exercise protocol, or if the client experiences signs of discomfort.
10. The test should include a cool-down period of at least 5 min, or longer if abnormal HR and BP responses are observed. During recovery, HR and BP should be monitored each minute. For active recovery, the workload should be no more than that used during the first stage of the GXT. A passive recovery is used in emergency situations and when clients experience signs of discomfort and cannot perform an active cool-down.
11. Exercise tolerance in METs should be estimated for the treadmill or ergometer protocol used, or directly assessed if oxygen uptake is measured during the GXT.
12. The testing area should be quiet and private. The room temperature should be 21° to 23° C (70–72° F) or less and the humidity 60% or less if possible.

[a] Physician supervision is recommended for sub-maximal and maximal exercise tests of high-risk clients.

Whichever mode of exercise you choose, be sure to adhere to the principles explained in "General Principles of Exercise Testing."

The exercise test may be continuous or discontinuous. A continuous test is performed with no rest between work increments. **Continuous exercise tests** can vary in the duration of each exercise stage and the magnitude of the increment in exercise intensity between stages. The ACSM (2014) recommends total test duration between 8 and 12 min to increase the probability of individuals reaching $\dot{V}O_2$max. However, Midgley and colleagues (2008) challenged this recommendation based on an extensive review of studies dealing with this topic. They concluded that duration of cycle ergometer tests should be between 7 and 26 min and that treadmill tests should be between 5 and 26 min to yield a valid determination of $\dot{V}O_2$max. This recommendation assumes that an adequate warm-up precedes the shorter-duration tests and that the treadmill grade does not exceed 15% during the protocol. For most continuous exercise test protocols, the exercise intensity is increased gradually (2 to 3 METs for low-risk individuals) throughout the test, and the duration of each stage is usually 2 or 3 min, allowing most individuals to reach a steady-state $\dot{V}O_2$

during each stage. Across the stages of this type of GXT, the workload may increase linearly or nonlinearly. Each increment in workload is dictated by the specific protocol and does not vary among individuals. Although this type of GXT is widely used in research and clinical settings, it may not be optimal for assessing the functional capacity of all individuals, especially those with low exercise tolerance. Continuous graded exercise tests may also limit the ability of very fit individuals to satisfy some of the criteria commonly associated with attaining $\dot{V}O_2$max (Mier, Alexander, and Mageean 2012).

Today, continuous ramp-type tests are gaining popularity and are widely used because they can be individualized for the client's estimated exercise tolerance. For example, increments in work rate during a ramp protocol are much higher for endurance-trained athletes than for sedentary individuals (e.g., 30 W·min^{-1} vs. 10 W·min^{-1}). Also, each exercise stage for ramp protocols is much shorter (e.g., 20 sec) than that of the traditional continuous GXT protocols (2–3 min). **Ramp protocols** provide continuous and frequent increments in work rate throughout the test so that the $\dot{V}O_2$ increases linearly; they are designed to bring individuals to their limit of exercise tolerance in approximately 10 min. In a study comparing four ramp protocol durations (5, 8, 12, and 16 min) during incremental cycling exercise, Yoon and colleagues (2007) reported that the optimal protocol duration to elicit $\dot{V}O_2$max of healthy, moderately to highly trained men and women is between 8 and 10 min.

Because of the frequent (e.g., every 10 or 20 sec) increases in work rate with ramp protocols, $\dot{V}O_2$ plateaus are rarely observed. However, as previously mentioned, the $\dot{V}O_2$peak from ramp-type protocols appears to be a valid index of $\dot{V}O_2$max even without a plateau in $\dot{V}O_2$ (Day et al. 2003). This ramp approach potentially improves the prediction of $\dot{V}O_2$max given that $\dot{V}O_2$ increases linearly across work rates. Ramp protocols allow some individuals to reach a higher exercise tolerance compared to traditional GXT protocols. However, there are disadvantages. To design an individualized ramp protocol, the maximum work rate for each client must be predetermined or accurately estimated from training records or questionnaires so that you can select a work rate that allow clients to reach their peak exercise tolerance in approximately 10 min. Also, ramp protocols increase work rate frequently (e.g., 25–30 stages in a 10 min test), requiring more expensive electromagnetically braked cycle ergometers and programmable treadmills that make rapid and smooth transitions between the stages of the exercise test. Lastly, inexperienced technicians may have difficulty measuring exercise BP during each minute of the ramp protocol.

For **discontinuous exercise tests**, the client rests 5 to 10 min between workloads. The workload is progressively increased until the client reaches maximum exercise tolerance (exhaustion). Typically, each stage of the discontinuous protocol lasts 5 or 6 min, allowing $\dot{V}O_2$ to reach a steady state. On average, discontinuous tests take five times longer to administer than do continuous tests. Similar $\dot{V}O_2$max values are attained using discontinuous and continuous (increasing workload every 2–3 min) protocols (Maksud and Coutts 1971); therefore, continuous tests are preferable in most research and clinical settings.

McArdle, Katch, and Pechar (1973) compared the $\dot{V}O_2$max scores as measured by six commonly used continuous and discontinuous treadmill and cycle ergometer tests. They noted that the $\dot{V}O_2$max scores for the cycle ergometer tests were approximately 6% to 11% lower than for the treadmill tests. Many subjects identified local discomfort and fatigue in the thigh muscles as the major factors limiting further work on both the continuous and discontinuous cycle ergometer tests. For the treadmill tests, subjects indicated windedness and general fatigue as the limiting factors and complained of localized fatigue and discomfort in the calf muscles and lower back.

TREADMILL MAXIMAL EXERCISE TESTS

Video 4.3

Generally, the treadmill is the preferred exercise test modality in the United States (Balady et al. 2010). For treadmill maximal exercise tests, the exercise is performed on a motor-driven treadmill with variable speed and incline (see figure 4.1). Speed varies up to 25 mph (40 km·hr^{-1}), and the incline is measured in units of elevation per 100 horizontal units and is expressed as a percentage. The workload on the treadmill is raised through increases in the speed or incline or both. Workload is usually expressed in miles per hour and percent grade.

FIGURE 4.1 Treadmill.

It is difficult and expensive to measure oxygen consumption during exercise. Therefore, ACSM (2014) has developed equations (table 4.3) to estimate the metabolic cost of exercise ($\dot{V}O_2$). These equations provide a valid estimate of $\dot{V}O_2$ for steady-state exercise only. When used to estimate the maximum rate of energy expenditure ($\dot{V}O_2max$), the measured $\dot{V}O_2$ will be less than the estimated $\dot{V}O_2$ if steady state is not reached. Also, because maximal exercise involves both aerobic and anaerobic components, the $\dot{V}O_2max$ will be overestimated since the contribution of the anaerobic component is not known.

Before using any of the ACSM metabolic equations to estimate $\dot{V}O_2$, make certain that all units of measure match those in the equation (see "Converting Units of Measure").

The ACSM metabolic equations in table 4.3 are useful in clinical settings for estimating the total rate of energy expenditure (gross $\dot{V}O_2$) during steady-state treadmill walking or running. The total energy expenditure, in ml·kg^{-1}·min^{-1}, is a function of three components: *speed, grade,* and *resting energy expenditures.* For treadmill walking, the oxygen cost of raising one's body mass against gravity (vertical work) is approximately 1.8 ml·kg^{-1}·m^{-1}, and 0.1 ml·kg^{-1}·m^{-1} of oxygen is needed to move the body horizontally. For treadmill running, the oxygen cost for vertical work is one-half that for treadmill walking (0.9 ml·kg^{-1}·m^{-1}), whereas the energy expenditure for running on the treadmill (0.2 ml·kg^{-1}·m^{-1}) is twice that for walking. See "ACSM Walking Equation" for an example of how to take these three factors into account when figuring $\dot{V}O_2$.

The $\dot{V}O_2$ estimated from the ACSM walking equation (see table 4.3) is reasonably accurate for walking speeds between 50 and 100 m·min^{-1} (1.9–3.7 mph). However, since the equation is more accurate for walking up a grade than on the level, $\dot{V}O_2$ may be underestimated as much as 20% during walking

Converting Units of Measure

- Convert body mass (M) in pounds to kilograms (1 kg = 2.2 lb). For example, 170 lb / 2.2 = 77.3 kg.
- Convert treadmill speed (S) in miles per hour to meters per minute (1 mph = 26.8 m·min^{-1}). For example, 5.0 mph × 26.8 = 134.0 m·min^{-1}.
- Convert treadmill grade (G) from percent to decimal form by dividing by 100. For example, 12% / 100 = 0.12.
- Convert METs to ml·kg^{-1}·min^{-1} by multiplying (1 MET = 3.5 ml·kg^{-1}·min^{-1}). For example, 6 METs × 3.5 = 21.0 ml·kg^{-1}·min^{-1}.
- Convert kgm·min^{-1} to watts (W) (1 W = 6 kgm·min^{-1}) by dividing. For example, 900 kgm·min^{-1} / 6 = 150 W.
- Convert step height in inches to meters (1 in. = 0.0254 m) by multiplying. For example, 8 in. × 0.0254 = 0.2032 m.

Table 4.3 Metabolic Equations for Estimating Gross $\dot{V}O_2$ (ACSM 2013)

Exercise mode gross $\dot{V}O_2$ (ml·kg–1·min–1)	Resting $\dot{V}O_2$ (ml·kg–1·min–1)	Comments
Walking $\dot{V}O_2 = S^a \times 0.1 + S \times G^b \times 1.8$	+3.5	1. For speeds of 50–100 m·min^{-1} (1.9–3.7 mph) 2. 0.1 ml·kg^{-1}·m^{-1} = O_2 cost of walking horizontally 3. 1.8 ml·kg^{-1}·m^{-1} = O_2 cost of walking on incline (% grade of treadmill)
Running $\dot{V}O_2 = S^a \times 0.2 + S \times G^b \times 0.9$	+3.5	1. For speeds >134 m·min^{-1} (>5.0 mph) 2. If truly jogging (not walking), this equation can also be used for speeds of 80–134 m·min^{-1} (3–5 mph) 3. 0.2 ml·kg^{-1}·m^{-1} = O_2 cost of running horizontally 4. 0.9 ml·kg^{-1}·m^{-1} = O_2 cost of running on incline (% grade of treadmill)
Leg ergometry $\dot{V}O_2 = W^c / M^d \times 1.8 + 3.5$	+3.5	1. For work rates between 50 and 200 W (300–1200 kgm·min^{-1}) 2. kgm·min^{-1} = kg × m·rev^{-1} × rev·min^{-1} 3. Monark and Bodyguard = 6 m·rev^{-1}; Tunturi = 3 m·rev^{-1} 4. 1.8 ml·kg^{-1}·min^{-1} = O_2 cost of cycling against external load (resistance) 5. 3.5 ml·kg^{-1}·min^{-1} = O_2 cost of cycling with zero load
Arm ergometry $\dot{V}O_2 = W^c / M^d \times 3.0$ + none	+3.5	1. For work rates between 25 and 125 W (150–750 kgm·min^{-1}) 2. kgm·min^{-1} = kg × m·rev^{-1} × rev·min^{-1} 3. 3.0 ml·kg^{-1}·min^{-1} = O_2 cost of cycling against external load (resistance) 4. None = due to small mass of arm musculature, no special term for unloaded (zero load) cycling needed
Stepping $\dot{V}O_2 = F^e \times 0.2 + F \times ht^f \times 1.8 \times 1.33$	+3.5	1. Appropriate for stepping rates between 12 and 30 steps·min^{-1} and step heights between 0.04 m (1.6 in.) and 0.40 m (15.7 in.) 2. 0.2 ml·kg^{-1}·m^{-1} = O_2 cost of moving horizontally 3. 1.8 ml·kg^{-1}·m^{-1} = O_2 cost of stepping up (bench height) 4. 1.33 includes positive component of stepping up (1.0) + negative component of stepping down (0.33)

[a]S = speed of treadmill in m·min^{-1}; 1 mph = 26.8 m·min^{-1}.

[b]G = grade (% incline) of treadmill in decimal form (e.g., 10% = 0.10).

[c]W = work rate in kgm·min^{-1}; 1 Watt = 6 kgm·min^{-1}.

[d]M = body mass in kilograms; 1 kg = 2.2 lb.

[e]F = frequency of stepping in steps per minute.

[f]ht = bench height in meters; 1 in. = 0.0254 m.

on the level (ACSM 2014). For the ACSM running or jogging equations, the $\dot{V}O_2$ estimates are relatively accurate for speeds exceeding 134 m·min^{-1} (5 mph) and speeds as low as 80 m·min^{-1} (3 mph) provided that the client is jogging and not walking (ACSM 2014). When HRs fall between 110 bpm and 85% of age-predicted maximum HR, the ACSM running equation provides a reasonably good (*SEE* [standard error of estimate] = 4.2 to 4.35 ml·kg^{-1}·min^{-1}) estimation of maximal aerobic capacity (Marsh 2012).

Figure 4.2 illustrates commonly used treadmill exercise test protocols. These protocols conform to the general guidelines for maximal exercise testing. Some of the protocols are designed for a specific population, such as well-conditioned athletes or high-risk cardiac patients. The exercise intensity for each stage of the various treadmill test protocols can be expressed in METs. The MET estimations for each stage of some commonly used treadmill protocols are listed in table 4.4.

Population-specific and generalized equations have been developed to estimate $\dot{V}O_2$max from exercise time for some treadmill protocols (see table 4.5). It is important for exercise technicians to keep in mind that the initial workload in some of the protocols designed for highly trained athletes is too intense (exceeding 2–3.5 METs) for the average individual. The Balke and Bruce protocols are

ACSM Walking Equation

To calculate the gross $\dot{V}O_2$ for a 70 kg (154 lb) subject who is walking on the treadmill at a speed of 3.5 mph and a grade of 10%, follow these steps:

$$\dot{V}O_2 = \text{speed} + (\text{grade} \times \text{speed}) + \text{resting } \dot{V}O_2 \ (\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1})$$

$$= [\text{speed } (\text{m}\cdot\text{min}^{-1}) \times 0.1] + [\text{grade (decimal)} \times \text{speed } (\text{m}\cdot\text{min}^{-1}) \times 1.8] + 3.5$$

1. Convert the speed in mph to $\text{m}\cdot\text{min}^{-1}$; 1 mph $= 26.8\ \text{m}\cdot\text{min}^{-1}$.

$$3.5 \text{ mph} \times 26.8 = 93.8\ \text{m}\cdot\text{min}^{-1}$$

2. Calculate the speed component (S).

$$S = \text{speed } (\text{m}\cdot\text{min}^{-1}) \times 0.1$$
$$= 93.8\ \text{m}\cdot\text{min}^{-1} \times 0.1$$
$$= 9.38\ \text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$

3. Calculate the grade × speed component (G × S). Convert % grade into a decimal by dividing by 100.

$$G \times S = \text{grade (decimal)} \times \text{speed} \times 1.8$$
$$= 0.10 \times (93.8\ \text{m}\cdot\text{min}^{-1}) \times 1.8$$
$$= 16.88\ \text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$

4. Calculate the total gross $\dot{V}O_2$ in $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ by adding the speed, grade × speed, and resting $\dot{V}O_2$ (R).

$$\dot{V}O_2 = S + (S \times G) + R$$
$$= (9.38 + 16.88 + 3.5)\ \text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$
$$= 29.76\ \text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$$

well suited for low-risk individuals, and the Bruce protocol is easily adapted for high-risk individuals using an initial workload of 1.7 mph at 0% to 5% grade.

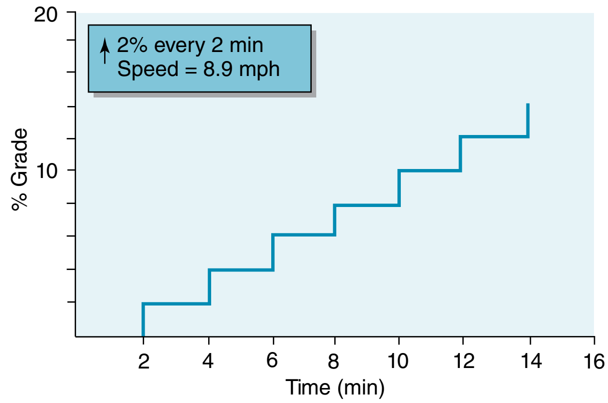
Balke Treadmill Protocol

To administer the Balke and Ware (1959) exercise test protocol (see figure 4.2), set the treadmill speed at 3.4 mph (91.1 $\text{m}\cdot\text{min}^{-1}$) and the initial grade of the treadmill at 0% during the first minute of exercise. Maintain a constant speed on the treadmill throughout the entire exercise test. At the start of the second minute of exercise, increase the grade to 2%. Thereafter, at the beginning of every additional minute of exercise, increase the grade by only 1%.

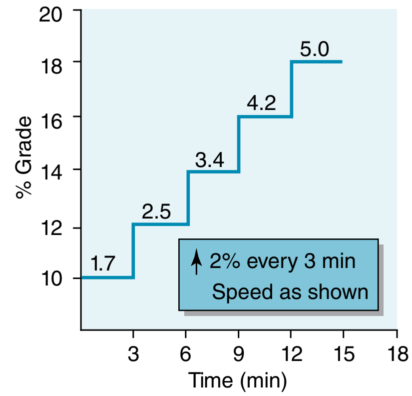
Use the prediction equation for the Balke protocol in table 4.5 to estimate your client's $\dot{V}O_2$max from exercise time. Alternatively, you can use a nomogram (see figure 4.3) developed for the Balke treadmill protocol to calculate the $\dot{V}O_2$max of your client. To use this nomogram, locate the time corresponding to the last complete minute of exercise during the protocol along the vertical axis labeled "Balke time," and draw a horizontal line from the time axis to the oxygen uptake axis. Be certain to plot the exercise time of women and men in the appropriate column when using this nomogram.

Bruce Treadmill Protocol

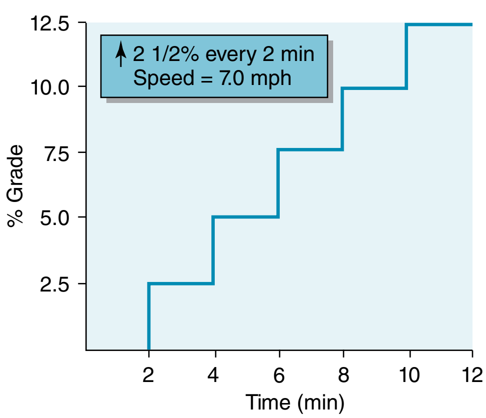
The Bruce, Kusumi, and Hosmer (1973) exercise test is a multistaged treadmill protocol (see figure 4.3). The protocol increases the workload by changing both the treadmill speed and percent grade. During the first stage (minutes 1–3) of the test, the normal individual walks at a 1.7 mph pace at 10% grade. At the start of the second stage (minutes 4–6), increase the grade by 2% and the speed to 2.5 mph (67 $\text{m}\cdot\text{min}^{-1}$). In each subsequent stage of the test, increase the grade by 2% and the speed by either 0.8 or 0.9 mph (21.4 or 24.1 $\text{m}\cdot\text{min}^{-1}$) until the client is exhausted. Prediction equations for this protocol have been developed to estimate the $\dot{V}O_2$max of active and sedentary women and men, cardiac patients, and people who are elderly (see table 4.5). As an alternative, you may use the nomogram (see figure 4.4) developed for the Bruce protocol. Plot the client's exercise time for this protocol along the vertical axis labeled "Bruce time," and draw a horizontal line from the time axis to the oxygen uptake. Again, be certain to use the appropriate column for men and women.



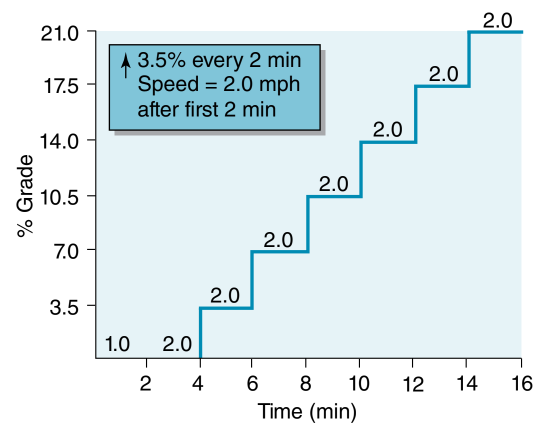
Costill and Fox (1969)
For: highly trained
Warm-up: 10-min walk or run
Initial workload: 8.9 mph, 0%, 2 min



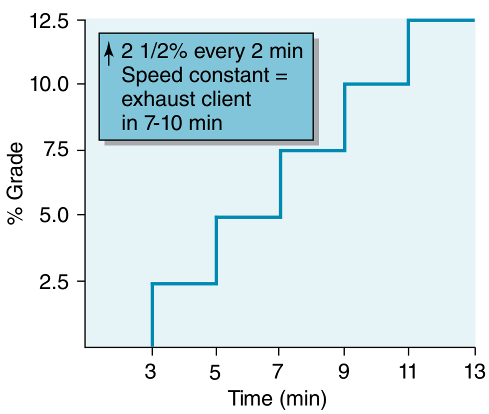
Bruce et al. (1973)
For: normal and high risk
Initial workload: 1.7 mph, 10%, 3 min = normal
1.7 mph, 0-5%, 3 min = high risk



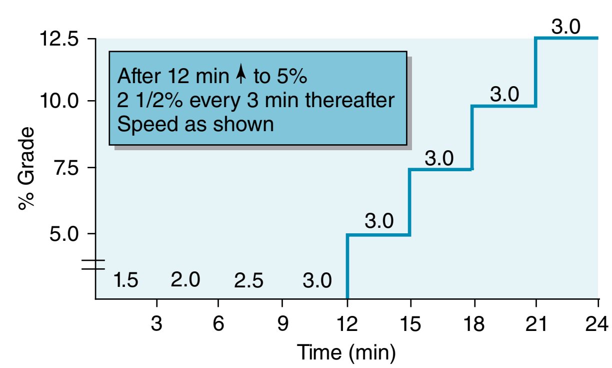
Maksud and Coutts (1971)
For: highly trained
Warm-up: 10-min walking, 3.5 mph, 0%
Initial workload: 7 mph, 0%, 2 min



Naughton et al. (1964)
For: cardiac and high risk
Initial workload: 1.0 mph, 0%, 2 min



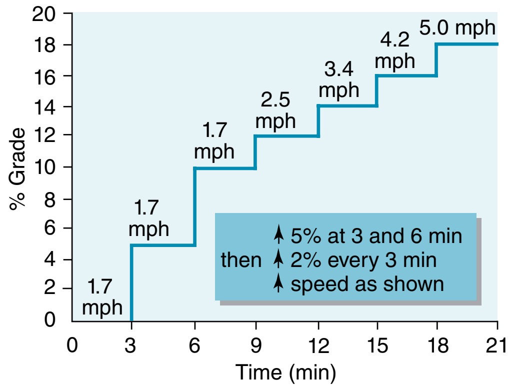
Modified Åstrand (Pollock et al. 1978)
For: highly trained
Warm-up: 5-min walk or jog
Initial workload: 5-8 mph, 0%, 3 min



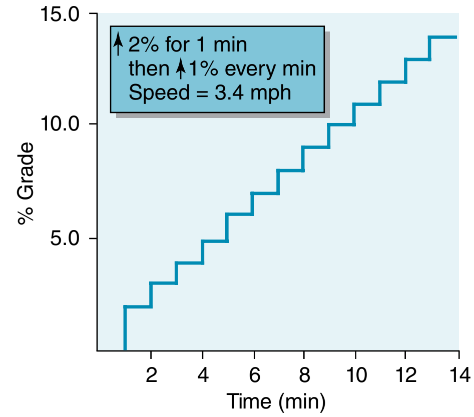
Wilson et al. (1978)
For: cardiac and high risk
Initial workload: 1.5 mph, 0%, 3 min

(continued)

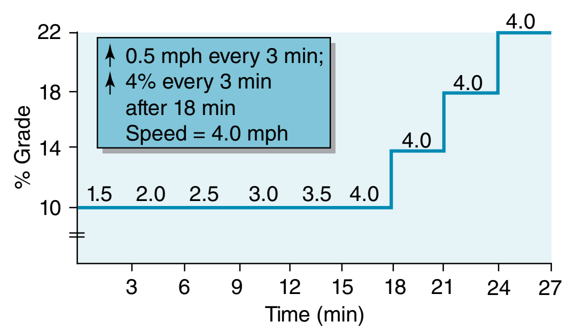
FIGURE 4.2 Treadmill exercise test protocols.



Modified Bruce (Lerman et al. 1976)
For: normal and high risk
Initial workload: 1.7 mph, 0%, 3 min



Balke and Ware (1959)
For: normal risk
Initial workload: 3.4 mph, 0%, 1 min



Kattus (1968)
For: cardiac and high risk
Initial workload: 1.5 mph, 10%, 3 min

FIGURE 4.2 *(continued)*

Table 4.4 MET Estimations for Each Stage of Commonly Used Treadmill Protocols

Stage[a]	Bruce	Modified Bruce[b]	Balke	Naughton
1	4.6	2.3	3.6	1.8
2	7.0	3.5	4.5	3.5
3	10.2	4.6	5.0	4.5
4	12.1	7.0	5.5	5.4
5	14.9	10.2	5.9	6.4
6	17.0	12.1	6.4	7.4
7	19.3	14.9	6.9	8.3

[a]Percent grade and speed for each stage are illustrated in figure 4.2.

[b]Stage 1 = 0% grade, 1.7 mph; Stage 2 = 5% grade, 1.7 mph.

Table 4.5 Population-Specific and Generalized Equations for Treadmill Protocols

Protocol	Population	Reference	Equation
Balke	Active and sedentary men	Pollock et al. (1976)	$\dot{V}O_2max$ = 1.444(time) + 14.99 r = 0.92, SEE = 2.50 (ml·kg^{-1}·min^{-1})
	Active and sedentary women[a]	Pollock et al. (1982)	$\dot{V}O_2max$ = 1.38(time) + 5.22 r = 0.94, SEE = 2.20 (ml·kg^{-1}·min^{-1})
Bruce[b]	Active and sedentary men	Foster et al. (1984)	$\dot{V}O_2max$ = 14.76 – 1.379(time) + 0.451(time^2) – 0.012(time^3) r = 0.98, SEE = 3.35 (ml·kg^{-1}·min^{-1})
	Active and sedentary women	Pollock et al. (1982)	$\dot{V}O_2max$ = 4.38(time) – 3.90 r = 0.91, SEE = 2.7 (ml·kg^{-1}·min^{-1})
	Cardiac patients and elderly persons[c]	McConnell and Clark (1987)	$\dot{V}O_2max$ = 2.282(time) + 8.545 r = 0.82, SEE = 4.9 (ml·kg^{-1}·min^{-1})
Naughton	Male cardiac patients	Foster et al. (1983)	$\dot{V}O_2max$ = 1.61(time) + 3.60 r = 0.97, SEE = 2.60 (ml·kg^{-1}·min^{-1})

[a]For women, the Balke protocol was modified: speed 3.0 mph; initial workload 0% grade for 3 min, increasing 2.5% every 3 min thereafter.

[b]For use with the standard Bruce protocol; cannot be used with modified Bruce protocol.

[c]This equation is used only for treadmill walking while holding the handrails.

SEE = standard error of estimate.

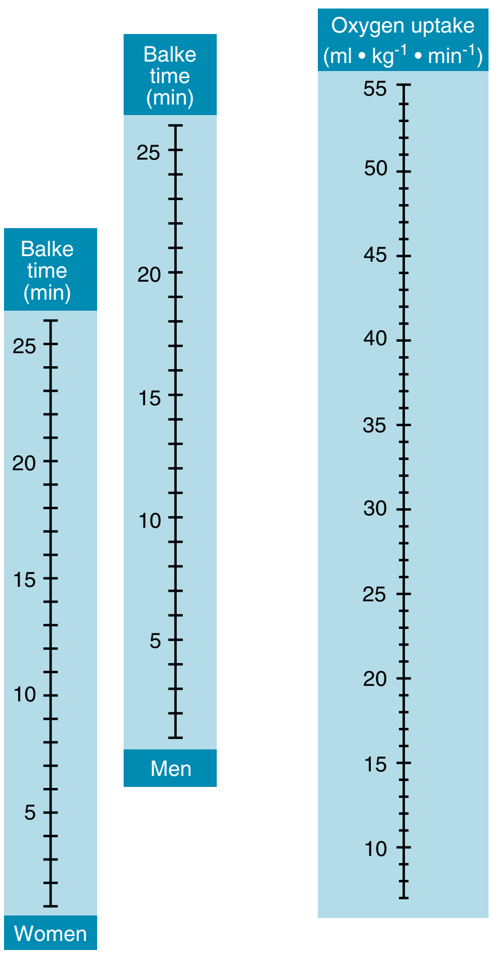


FIGURE 4.3 Nomogram for Balke graded exercise test.

Reprinted, by permission, from N. Ng, 1995, *METCALC* (Champaign, IL: Human Kinetics), 30.

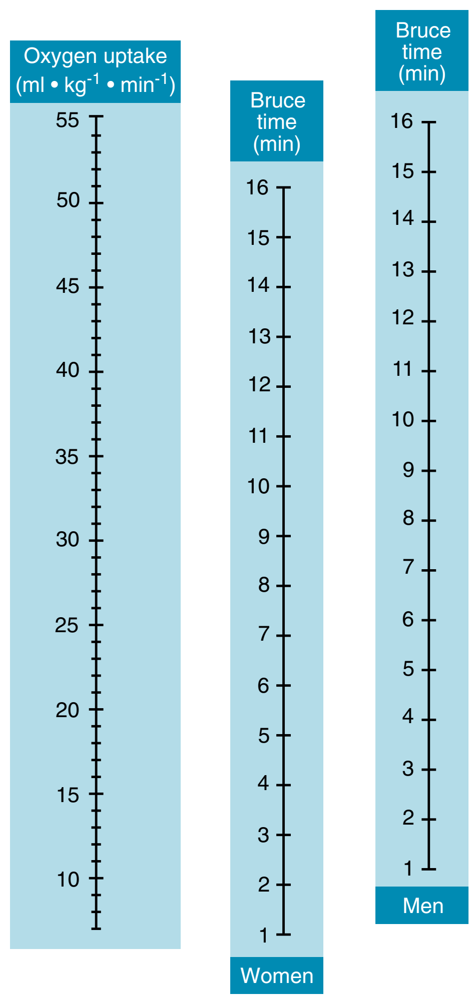


FIGURE 4.4 Nomogram for standard Bruce graded exercise test.

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Modified Bruce Protocol

The modified Bruce protocol (see figure 4.2) is more suitable than the Bruce protocol for high-risk and elderly individuals. However, with the exception of the first two stages, this protocol is similar to the standard Bruce protocol. Stage 1 starts at 0% grade and a 1.7 mph walking pace. For stage 2, the % grade is increased to 5%. McInnis and Balady (1994) compared physiological responses to the standard and modified Bruce protocols in patients with CHD and reported similar HR and BP responses at matched exercise stages despite the additional 6 min of low-intensity exercise performed using the modified Bruce protocol.

Note that the prediction equations for the Bruce protocol (see table 4.5) can be used for only the standard, not the modified, Bruce protocol. To estimate $\dot{V}O_2$ for the modified Bruce protocol, use the ACSM metabolic equation for walking (see table 4.3).

Treadmill Ramp Protocols

Kaminsky and Whaley (1998) developed a standardized ramp protocol (i.e., BSU/Bruce ramp protocol) for assessing the functional cardiorespiratory capacity of symptomatic, sedentary, and apparently healthy individuals. For this protocol, the treadmill speed increases gradually (in 0.1–0.4 mph, or 2.68–10.72 m·min^{-1}, increments) every minute. The minimum speed is 1.0 mph (26.8 m·min^{-1}); the maximum speed is 5.8 mph (155 m·min^{-1}). The treadmill grade also increases gradually (by 0–5%) every minute. The minimum grade is 0%; the maximum grade is 20%. Every 3 min during this ramp protocol, the work rates (i.e., speed and grade) equal those of the traditional Bruce protocol (see table 4.6). For example, during the sixth minute of exercise, the treadmill speed (2.5 mph, or 53.6 m·min^{-1}) and grade (12%) are the same, allowing comparisons between the two types of protocols. The ramp approach has the advantage of avoiding large, unequal increments in workload. Also, it results in uniform increases in hemodynamic and physiological responses to incremental exercise and more accurately estimates exercise capacity and ventilatory threshold.

Porszasz and colleagues (2003) devised a ramp protocol that increases work rate linearly so that the individual walking on a treadmill reaches exhaustion in approximately 10 min. To linearly increase work rate over time, it is necessary to couple linear increases in walking speed with curvilinear increases in treadmill grade. Because this protocol starts with slow walking (i.e., 0.5–1.0 mph, or 13.4–26.8 m·min^{-1}), it is suitable for individuals with low-exercise tolerance as well as for sedentary individuals with a range of exercise tolerances. As with all types of ramp protocols, this protocol is individualized. The peak work rate, a comfortable range of walking speeds, and the increments in treadmill incline or grade are determined for each client.

This protocol compares favorably to cycle ergometer ramp protocols that increase work rate linearly so that maximum exercise tolerance is reached in ~10 min. The slope of the relationship between $\dot{V}O_2$ and work rate, however, is consistently steeper on the treadmill than on the cycle ergometer (Porszasz

Table 4.6 Comparison of Work Rates for the Standard Bruce Protocol and the Bruce Ramp Protocol

	SPEED IN MPH[b]		GRADE (%)	
Minute[a]	**SB**	**BR**	**SB**	**BR**
1	1.7	1.0	10	0
2	1.7	1.3	10	5
3	***1.7***	***1.7***	***10***	***10***
4	2.5	2.1	12	10
5	2.5	2.3	12	11
6	***2.5***	***2.5***	***12***	***12***
7	3.4	2.8	14	12
8	3.4	3.1	14	13
9	***3.4***	***3.4***	***14***	***14***
10	4.2	3.8	16	14
11	4.2	4.1	16	15
12	***4.2***	***4.2***	***16***	***16***
13	5.0	4.5	18	16
14	5.0	4.8	18	17
15	***5.0***	***5.0***	***18***	***18***
16	5.5	5.3	20	18
17	5.5	5.6	20	19
18	5.5	5.8	20	20

SB = standard Bruce protocol; BR = Bruce ramp protocol.

[a]Boldfaced italics identify the times during the two protocols when the work rates are equivalent.

[b]To convert mph to m·min^{-1}, multiply by 26.8.

et al. 2003). This steeper slope reflects additional use of the limbs (i.e., swinging the arms and legs) and frictional force as treadmill speed increases. For each individual, the time course for the grade increments needed to elicit a linear increase in work rate can be calculated with a prediction equation based on the client's body weight, desired initial and final walking speeds, initial grade, and estimated peak work rate (see Porszasz et al. 2003). These individual variables, along with the prediction equation for increasing grade, can be programmed into the computer of a contemporary treadmill. Thus, each individualized ramp protocol is controlled by the computer so that the frequent increases in speed and grade are smooth and rapid.

Video 4.4

CYCLE ERGOMETER MAXIMAL EXERCISE TESTS

The cycle ergometer is a widely used instrument for assessing cardiorespiratory fitness and is the preferred modality for exercise tests conducted on individuals with conditions affecting their ability to safely walk or jog on a treadmill (Balady et al. 2010). On a friction-type cycle ergometer (see figure 4.5), resistance is applied against the flywheel using a belt and weighted pendulums. The hand wheel adjusts the workload by tightening or loosening the brake belt. The workload on the cycle ergometer is raised through increases in the resistance on the flywheel. The power output is usually expressed in kilogram-meters per minute (kgm·min^{-1}) or watts (1 W = 6 kgm·min^{-1}) and is easily measured using the equation:

$$\text{power} = \text{force} \times \text{distance} / \text{time}$$

where force equals the resistance or tension setting on the ergometer (kilograms) and distance is the distance traveled by the flywheel rim for each revolution of the pedal times number of revolutions per minute. On the Monark and Bodyguard cycle ergometers, the flywheel travels 6 m per pedal revolution. Therefore, if a resistance of 2 kg is applied and the pedaling rate is 60 rpm, then

$$\text{power} = 2\text{ kg} \times 6\text{ m} \times 60\text{ rpm} = 720\text{ kgm·min}^{-1}\text{ or } 120\text{ W.}$$

FIGURE 4.5 Cycle ergometer (mechanically braked).

To calculate the distance traveled by the flywheel of cycle ergometers with varying-sized flywheels, measure the circumference (in meters) of the resistance track on the flywheel and multiply the circumference by the number of flywheel revolutions during one complete revolution (360°) of the pedal (Gledhill and Jamnik 1995).

When you are standardizing the work performed on a friction-type cycle ergometer, the client should maintain a constant pedaling rate. Some cycle ergometers have a speedometer that displays the individual's pedaling rate. Check this dial frequently to make certain that your client is maintaining a constant pedaling frequency throughout the test. If a speedometer is not available, use a metronome to establish your client's pedaling cadence. Controlling the pedaling rate on an electrically braked cycle ergometer (figure 4.6) is unnecessary. An electromagnetic braking force adjusts the resistance for slower or faster pedaling rates, thereby keeping the

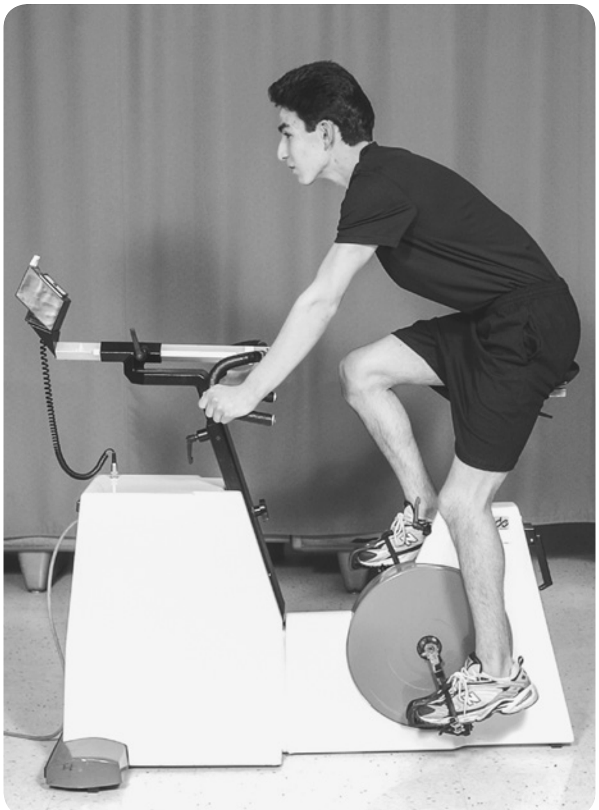


FIGURE 4.6 Cycle ergometer (electrically braked).

power output constant. This type of cycle ergometer, however, is difficult to calibrate.

Most cycle ergometer test protocols for untrained cyclists use a pedaling rate of 50 or 60 rpm, and power outputs are increased by 150 to 300 kgm·min^{-1} (25–50 W) in each stage of the test. However, you can use higher pedaling rates (≥80 rpm) for trained cyclists. A pedaling rate of 60 rpm produces the highest $\dot{V}O_2$max when compared with rates of 50, 70, or 80 rpm (Hermansen and Saltin 1969). Figure 4.7 illustrates some widely used discontinuous and continuous maximal exercise test protocols for the cycle ergometer. Guidelines for use of cycle ergometers are presented in "Testing With Cycle Ergometers."

To calculate the energy expenditure for cycle ergometer exercise, use the ACSM equations provided in table 4.3. The total energy expenditure or gross $\dot{V}O_2$, in ml·kg^{-1}·min^{-1}, is a function of the oxygen cost of pedaling against resistance (power output in watts), the oxygen cost of unloaded cycling (approximately 3.5 ml·kg^{-1}·min^{-1} at 50–60 rpm with zero resistance), and the resting oxygen consumption. The cost of cycling against an external load or resistance is approximately 1.8 ml·kg^{-1}·m^{-1}. For a sample calculation, see "ACSM Leg Ergometry Equation."

Keep in mind that the leg and arm ergometry equations are accurate in estimating $\dot{V}O_2$ only if the client attains a steady state during the maximal GXT. If, for example, the client is able to complete only 1 min of exercise during the last stage of the maximal test protocol, the power output from the previous stage (in which the client reached steady state) should be used to estimate $\dot{V}O_2$max rather than the power output corresponding to the last stage.

Testing With Cycle Ergometers

The following guidelines are suggested for the use of cycle ergometers:

1. Calibrate the cycle ergometer often by hanging known weights from the belt of the flywheel and reading the dial on the hand wheel.
2. Always release the tension on the belt between tests.
3. Establish pedaling frequency before setting the workload.
4. Check the load setting frequently during the test because it may change as the belt warms up.
5. Set the metronome so that one revolution is completed for every two beats (e.g., set the metronome at 120 for a test requiring a pedaling frequency of 60 rpm).
6. Adjust the height of the seat so the knee is slightly flexed (about 25°) at maximal leg extension with the ball of the foot on the pedal.
7. Have the client assume an upright, seated posture with hands properly positioned on the handlebars.

ACSM Leg Ergometry Equation

To calculate the energy expenditure of a 62 kg (136 lb) woman cycling at a work rate or power output of 360 kgm·min^{-1}, follow these steps:

1. Calculate the energy cost of cycling at the specified power output.

$$\dot{V}O_2 = \text{work rate}^{a}\ (W) / \text{body mass}\ (M) \times 1.8$$
$$= 360\ \text{kgm·min}^{-1} / 62\ \text{kg} \times 1.8$$
$$= 10.45\ \text{ml·kg}^{-1}\text{·min}^{-1}$$

2. Add the estimated cost of cycling at zero load (i.e., 3.5 ml·kg^{-1}·min^{-1}).

$$\dot{V}O_2 = 10.45\ \text{ml·kg}^{-1}\text{·min}^{-1} + 3.5\ \text{ml·kg}^{-1}\text{·min}^{-1}$$
$$= 13.95\ \text{ml·kg}^{-1}\text{·min}^{-1}$$

3. Add the estimated resting energy expenditure (3.5 ml·kg^{-1}·min^{-1}).

$$\dot{V}O_2 = 13.95\ \text{ml·kg}^{-1}\text{·min}^{-1} + 3.5\ \text{ml·kg}^{-1}\text{·min}^{-1}$$
$$= 17.45\ \text{ml·kg}^{-1}\text{·min}^{-1}$$

[a]Work rate is in kgm·min^{-1}.

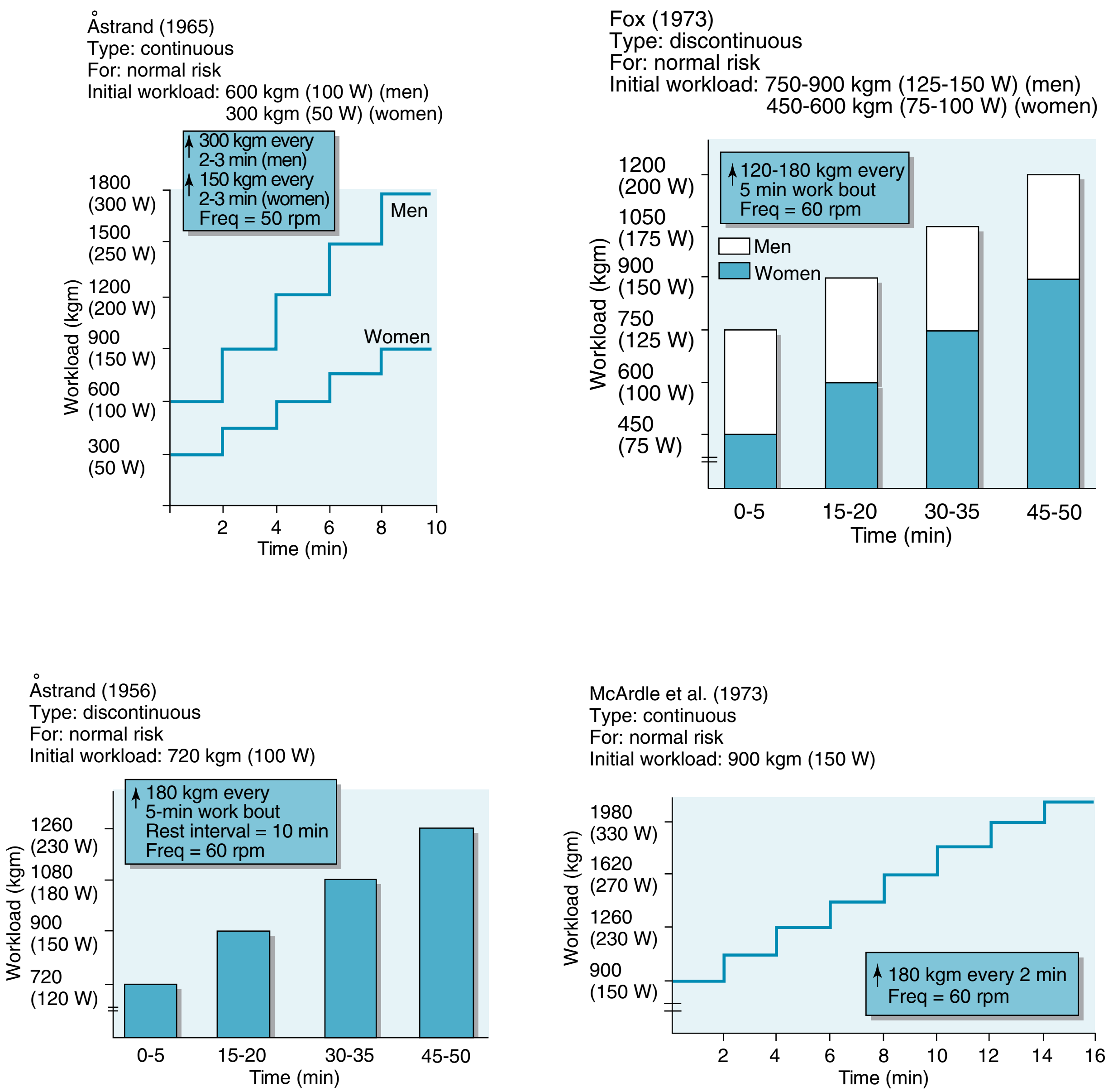


FIGURE 4.7 Cycle ergometer exercise test protocols.

Åstrand Cycle Ergometer Maximal Test Protocol

For the Åstrand (1965) continuous test protocol (see figure 4.7), the initial power output is 300 kgm·min^{-1} (50 W) for women and 600 kgm·min^{-1} (100 W) for men. Because the pedaling rate is 50 rpm, the resistance is 1 kg for women (1 kg × 6 m × 50 rpm = 300 kgm·min^{-1}) and 2 kg for men (2 kg × 6 m × 50 rpm = 600 kgm·min^{-1}). Have your client exercise at this initial workload for 2 min. Then increase the power output every 2 to 3 min in increments of 150 kgm·min^{-1} (25 W) and 300 kgm·min^{-1} (50 W) for women and men, respectively. Continue the test until the client is exhausted or can no longer maintain the pedaling rate of 50 rpm. Use the ACSM metabolic equation for leg ergometry to estimate $\dot{V}O_2$ from your client's power output during the last steady-state stage of the GXT.

Fox Cycle Ergometer Maximal Test Protocol

The Fox (1973) protocol is a discontinuous test consisting of a series of 5 min exercise bouts with 10 min rest intervals. The starting workload is between 750 and 900 kgm·min^{-1} (125–150 W) for men and 450 and 600 kgm·min^{-1} (75–100 W) for women. The progressive increments in work depend on the client's HR response and usually are between 120 and 180 kgm·min^{-1} (20–30 W). The client exercises until exhausted or until no longer able to pedal for at least 3 min at a power output that is 60 to 90 kgm·min^{-1} (10–15 W) higher than the previous workload. You can use the metabolic equations to convert the power output from the last steady-state stage of this protocol to $\dot{V}O_2$max.

BENCH STEPPING MAXIMAL EXERCISE TESTS

The least desirable mode of exercise for maximum exercise testing is bench stepping. During bench stepping, the individual is performing both positive (up phase) and negative (down phase) work. Approximately one-quarter to one-third less energy is expended during negative work (Morehouse 1972). This factor, coupled with adjusting the step height and stepping rate for differences in body weight, makes standardization of the work extremely difficult.

General Procedures

Most step test protocols increase the intensity of the work by gradually increasing the height of the bench or stepping rate. The work (W) performed can be calculated using the equation W = F × D, where F is body weight in kilograms and D is bench height times number of steps per minute. For example, a 50 kg (110 lb) woman stepping at a rate of 22 steps·min^{-1} on a 30 cm (0.30 m) bench is performing 330 kgm·min^{-1} of work (50 kg × 0.30 m × 22 steps·min^{-1}).

The following equations can be used to adjust the step height and stepping rate for differences in body weight to achieve a given work rate (Morehouse 1972):

$$\text{step height (cm)} = \text{work (kgcm·min}^{-1}) \,/\, \text{body weight (kg)} \times \text{stepping rate}$$

$$\text{stepping rate (steps·min}^{-1}) = \text{work (kgcm·min}^{-1}) \,/\, \text{body weight (kg)} \times \text{step height (cm)}$$

For example, if you devise a graded step test protocol that requires a client weighing 60 kg (132 lb) to exercise at a work rate of 300 kgm·min^{-1}, and the stepping rate is set at 18 steps·min^{-1}, you need to determine the step height that corresponds to the work rate:

$$\begin{aligned}\text{step height} &= 300 \text{ kgm·min}^{-1} / (60 \text{ kg} \times 18 \text{ steps·min}^{-1})\\ &= 0.28 \text{ m, or } 28 \text{ cm}\end{aligned}$$

Alternatively, you may choose to keep the step height constant and vary the stepping cadence for each stage of the GXT. For example, if the step height is set at 30 cm (0.30 m), and the protocol requires that a client weighing 60 kg (132 lb) exercise at a work rate of 450 kgm·min^{-1}, you need to calculate the corresponding stepping rate for this client:

$$\begin{aligned}\text{stepping rate} &= 450 \text{ kgm·min}^{-1} / (60 \text{ kg} \times 0.30 \text{ m})\\ &= 25 \text{ steps·min}^{-1}\end{aligned}$$

You can calculate the energy expenditure in METs using the ACSM metabolic equation for stepping exercise (see table 4.3). The total gross

$\dot{V}O_2$ is a function of step frequency, step height, and the resting energy expenditure. The oxygen cost of the horizontal movement is approximately 0.2 $ml \cdot kg^{-1} \cdot m^{-1}$ for each four-count stepping cycle. The oxygen demand for stepping up is 1.8 $ml \cdot kg^{-1} \cdot m^{-1}$; approximately one-third more must be added (i.e., constant of 1.33 in equation) to account for the oxygen cost of stepping down. For an example of such calculations, see "ACSM Stepping Equation."

Nagle, Balke, and Naughton Maximal Step Test Protocol

Nagle, Balke, and Naughton (1965) devised a graded step test for assessing work capacity. Have your client step at a rate of 30 $steps \cdot min^{-1}$ on an automatically adjustable bench (2–50 cm). Set the initial bench height at 2 cm and increase the height 2 cm every minute of exercise. Use a metronome to establish the stepping cadence (four beats per stepping cycle). To establish a cadence of 30 $steps \cdot min^{-1}$, set the metronome at 120 (30 × 4). Terminate the test when the subject is fatigued or can no longer maintain the stepping cadence. Use the ACSM metabolic equation for stepping exercise to calculate the energy expenditure ($\dot{V}O_2max$) corresponding to the step height and stepping cadence during the last work stage of this protocol.

RECUMBENT STEPPER MAXIMAL EXERCISE TEST

Billinger and colleagues (2008) developed a maximum exercise test using a total body recumbent stepper (NuStep TRS 4000). This device has 10 settings ranging from 50 to 290 watts (W). The protocol begins with a 2 min warm-up at load setting 1 (50 W). Immediately following the warm-up, the initial workload is set to 4 (75 W), and the resistance is increased progressively until the participant reaches test termination criteria. A constant cadence (115 $steps \cdot min^{-1}$) is used throughout the exercise protocol. Compared to treadmill testing (Bruce protocol), the recumbent stepper test elicited a lower HR_{max} (181 vs. 188 bpm) and $\dot{V}O_2$ (3.13 vs. 3.67 $L \cdot min^{-1}$) on average. These differences are expected given the seated posture during the recumbent stepper exercise test.

ACSM Stepping Equation

To calculate the energy expenditure for bench stepping using a 16 in. (about 40 cm) step height at a cadence of 24 $steps \cdot min^{-1}$, use the following procedure:

$$\dot{V}O_2 \text{ in } ml \cdot kg^{-1} \cdot min^{-1} = [\text{frequency (F) in } steps \cdot min^{-1} \times 0.2] + (\text{step height in } m \cdot step^{-1} \times \text{F in } steps \cdot min^{-1} \times 1.33 \times 1.8) + \text{resting } \dot{V}O_2$$

1. Calculate the $\dot{V}O_2$ for the stepping frequency (F).

$$\dot{V}O_2 = \text{stepping frequency (F)} \times 0.20$$
$$= 24\ steps \cdot min^{-1} \times 0.20$$
$$= 4.8\ ml \cdot kg^{-1} \cdot min^{-1}$$

2. Convert the bench height to meters (1 in. = 2.54 cm or 0.0254 m).

$$ht = 16\ in. \times 0.0254\ m$$
$$= 0.4064\ m$$

3. Calculate the $\dot{V}O_2$ for the vertical work performed during stepping.

$$\dot{V}O_2 = \text{bench ht} \times \text{stepping rate} \times 1.33 \times 1.8$$
$$= 0.4064\ m \times 24\ steps \cdot min^{-1} \times 1.33 \times 1.8$$
$$= 23.35\ ml \cdot kg^{-1} \cdot min^{-1}$$

4. Add resting $\dot{V}O_2$ to the calculated $\dot{V}O_2$ from steps 1 and 3.

$$\dot{V}O_2 = 4.8\ ml \cdot kg^{-1} \cdot min^{-1} + 23.35\ ml \cdot kg^{-1} \cdot min^{-1} + 3.5\ ml \cdot kg^{-1} \cdot min^{-1}$$
$$= 31.65\ ml \cdot kg^{-1} \cdot min^{-1}$$

The correlation coefficients for $\dot{V}O_2max$ ($r = 0.92$) and HR_{max} ($r = 0.96$) indicated a strong relationship between the Bruce protocol and the recumbent stepper protocol.

This test modality may be especially useful for assessing the cardiorespiratory fitness of individuals with neuromuscular disorders that impair gait, coordination, and balance. Seated steppers are now widely used as a training modality in rehabilitation, fitness centers, and retirement communities.

SUBMAXIMAL EXERCISE TEST PROTOCOLS

It is desirable to directly determine the functional cardiorespiratory capacity of the individual for classifying the aerobic fitness level and prescribing an aerobic exercise program. However, this is not always practical to do. The actual measurement of $\dot{V}O_2max$ requires expensive laboratory equipment, a considerable amount of time to administer, and a high level of motivation on the part of the client.

Alternatively, you can use submaximal exercise tests to predict or estimate the $\dot{V}O_2max$ of the individual. Many of these tests are similar to the maximal exercise tests described previously but differ in that they are terminated at some predetermined HR intensity. You will monitor the HR, BP, and RPE during the submaximal exercise test. The treadmill, cycle ergometer, and bench stepping exercises are commonly used for submaximal exercise testing.

ASSUMPTIONS OF SUBMAXIMAL EXERCISE TESTS

Submaximal exercise tests assume that a *steady-state HR* is achieved and is consistent for each exercise work rate. Steady-state HR usually is achieved in 3 to 4 min at a constant, submaximal work rate. Also, it is assumed that a *linear relationship exists between* $\dot{V}O_2$ *and HR* within the range of 110 to 150 bpm. The HR and work rate from two submaximal work outputs can be plotted (i.e., HR-$\dot{V}O_2$ relationship) and extrapolated to HR_{max} to estimate $\dot{V}O_2max$ from submaximal data (see figure 4.10). Although the linear relationship between HR and $\dot{V}O_2$ holds for light-to-moderate workloads, the relationship between oxygen uptake and work rate becomes curvilinear at heavier workloads. If your clients are taking medications that alter HR, you should not use submaximal HR data to estimate their $\dot{V}O_2max$.

Another assumption of submaximal testing is that the *mechanical efficiency during cycling or treadmill exercise is constant for all individuals.* However, a client with poor mechanical efficiency while cycling has a higher submaximal HR at a given workload, and the actual $\dot{V}O_2max$ is underestimated due to this inefficiency. As a result, $\dot{V}O_2max$ predicted by submaximal exercise tests tends to be overestimated for highly trained individuals and underestimated for untrained, sedentary individuals.

Submaximal tests also assume that the *HR_{max} for clients of a given age is similar.* The HR_{max}, however, has been shown to vary as much as ±11 bpm, even after controlling for variability due to age and training status (Londeree and Moeschberger 1984). Also, for submaximal tests, the HR_{max} is estimated from age. The equation $HR_{max} = 220 - \text{age}$ is widely used. The HR_{max} of approximately 5% to 7% of men and women is more than 15 bpm less than their age-predicted HR_{max}. On the other hand, 9% to 13% have HR_{max} values that exceed their age-predicted HR_{max} by more than 15 bpm (Whaley et al. 1992). Because of interindividual variability in HR_{max} and the potential inaccuracy with use of age-predicted HR_{max}, there may be considerable error (±10–15%) in estimating your client's $\dot{V}O_2max$, especially when submaximal data are extrapolated to an age-predicted HR_{max}.

In addition, Tanaka, Monahan, and Seals (2001) noted that the traditional age-predicted HR_{max} equation (220 – age) overestimates the measured HR_{max} of younger individuals and increasingly underestimates the actual HR_{max} of individuals older than 40 yr. Using data from a meta-analysis of 351 studies that included more than 18,000 healthy, nonsmoking adults and from a controlled laboratory-based study of 514 healthy adults (18–81 yr), the authors reported that age singly accounts for 80% of the variance in HR_{max}, independent of gender and physical activity status. They derived the following equation to predict HR_{max} from age: $HR_{max} = 208 - (0.7 \times \text{age})$.

HR_{max} estimates from this equation differ from those of the traditional equation, particularly in older (>40 yr) adults. For example, the age-predicted HR_{max} for a 60 yr old client is 166 bpm for the revised equation (208 – (0.7 × 60) = 166 bpm) and 160 bpm for the traditional equation (220 – 60 = 160 bpm).

Gellish and colleagues (2007) used longitudinal modeling to track the relationship between HR_{max} and age as individuals age. Their data yielded a linear prediction equation [$HR_{max} = 207 - (0.7 \times \text{age})$] that is similar to the equation derived by Tanaka and colleagues (2001). The confidence interval for predicting HR_{max} of adults 30 to 75 yr was ±5 to 8 bpm. Using a nonlinear model produced a tighter confidence interval of only ±2 to 5 bpm; however, this quadratic equation, $HR_{max} = 192 - (0.007 \times \text{age}^2)$, is not as practical to use.

After determining there was no difference in HR_{max} compared to that obtained through treadmill testing (190.0 ± 7.5 bpm), Cleary and colleagues (2011) suggested that the highest HR (190.1 ± 7.9 bpm) from two 200 m maximal exertion sprints is a suitable alternative to the age-related HR_{max} prediction equations for adults (18–33 yr). Of interest, they found that the Gellish quadratic equation and the gender-specific equations of Fairbarn and colleagues (1994) (women: [$HR_{max} = 201 - (0.63 \times \text{age})$]; men: $HR_{max} = [208 - (0.80 \times \text{age})]$) produced HR_{max} estimations similar to that from the 200 m sprint.

Because of interindividual variability in HR_{max} and the potential inaccuracy of age-predicted HR_{max} equations, the actual HR_{max} should be measured directly (by ECG or HR monitor) whenever possible. An accurate HR_{max} is particularly important in situations in which

- the exercise test is terminated at a predetermined percentage of either HR_{max} (%HR_{max} method) or heart rate reserve [HRR = % ($HR_{max} - HR_{rest}$) + HR_{rest}],
- the client's $\dot{V}O_2max$ is estimated from submaximal exercise test data that are extrapolated to an age-predicted HR_{max},
- or HR_{max} is used to determine target exercise HRs for aerobic exercise prescriptions (see chapter 5).

TREADMILL SUBMAXIMAL EXERCISE TESTS

Video 4.5

Treadmill submaximal tests provide an estimate of functional cardiorespiratory capacity ($\dot{V}O_2max$) and assume a linear increase in HR with successive increments in workload. Compared to clients with low cardiorespiratory fitness levels, the well-conditioned individual presumably is able to perform a greater quantity of work at a given submaximal HR.

You can use treadmill maximal test protocols (figure 4.2) to identify the slope of the individual's HR response to exercise. The $\dot{V}O_2max$ can be predicted from either one (single-stage model) or two (multistage model) submaximal HRs. The accuracy of the single-stage model is similar to that of the multistage model.

Multistage Model

To estimate $\dot{V}O_2max$ with the multistage model, use the HR and workload data from two or more submaximal stages of the treadmill test. Be sure your client reaches steady-state HRs between 115 and 150 bpm (Golding 2000). Determine the slope (*b*) by calculating the ratio of the difference between the two submaximal (SM) workloads (expressed as $\dot{V}O_2$) and the corresponding change in submaximal HRs:

$$b = (SM_2 - SM_1) / (HR_2 - HR_1)$$

Calculate the $\dot{V}O_2$ for each workload using the ACSM metabolic equation (table 4.3), and use the following equation to predict $\dot{V}O_2max$:

$$\dot{V}O_2max = SM_2 + b(HR_{max} - HR_2)$$

If the actual maximal HR is not known, estimate it using one of the age-predicted HR_{max} equations previously mentioned. See "Multistage Model for Estimating $\dot{V}O_2max$" for an example that illustrates how $\dot{V}O_2max$ is estimated from submaximal treadmill test data for a 38 yr old male. In this example, the Bruce protocol was administered to the client. Please note that this model may be used for any multistage GXT test.

MULTISTAGE MODEL FOR ESTIMATING $\dot{V}O_2$MAX

Submaximal Data From Bruce Protocol

Stage 2[a]

$\dot{V}O_2$[b] = 24.5 ml·kg^{-1}·min^{-1} (SM_2)

HR = 145 bpm (HR_2)

Stage 1[a]

$\dot{V}O_2$ = 16.1 ml·kg^{-1}·min^{-1} (SM_1)

HR = 130 bpm (HR_1)

Maximal HR: 220 – age = 182 bpm

Slope (b) = (SM_2 – SM_1) / (HR_2 – HR_1)

b = (24.5 – 16.1) / (145 – 130)

b = 8.4 / 15

b = 0.56

$\dot{V}O_2$max: = SM_2 + b(HR_{max} – HR_2)

= 24.5 + 0.56(182 – 145)

= 24.5 + 20.72

$\dot{V}O_2$max = 45.22 ml·kg^{-1}·min^{-1}

[a]Stages 1 and 2 refer to the last two stages of the GXT completed by the client, and not the first and second stage of the test protocol. For example, if the client completes three stages of the submaximal exercise test protocol, data from stage 2 and stage 3 are used to estimate $\dot{V}O_2$.

[b]$\dot{V}O_2$ is calculated using ACSM metabolic equations (see table 4.3). $\dot{V}O_2$ can be expressed in L·min^{-1}, ml·kg^{-1}·min^{-1}, or METs.

Single-Stage Model

To estimate $\dot{V}O_2$max with the single-stage model, use one submaximal HR and one workload. The steady-state submaximal HR during a single-stage GXT should reach 130 to 150 bpm. "Formulas for Men and Women" shows formulas that have been developed (Shephard 1972).

$SM_{\dot{V}O_2}$ is calculated using the ACSM metabolic equations (see table 4.3). Estimate HR_{max} (if not known) using one of the age-predicted HR_{max} formulas; HR_{SM} is the submaximal HR.

"Single-Stage Model for Estimating $\dot{V}O_2$max" provides an example to illustrate how this model is used to predict $\dot{V}O_2$max from submaximal treadmill data for a 45 yr old female. In this example, the Balke protocol was administered. Please note that this model may be used for any GXT protocol.

Formulas for Men and Women

Men

$\dot{V}O_2$max = $SM_{\dot{V}O_2}$ × [(HR_{max} – 61) / (HR_{SM} – 61)]

Women

$\dot{V}O_2$max = $SM_{\dot{V}O_2}$ × [(HR_{max} – 72) / (HR_{SM} – 72)]

SINGLE-STAGE MODEL FOR ESTIMATING $\dot{V}O_2$MAX

Submaximal Data From Balke Protocol: Stage 3

$$\dot{V}O_2 = 5.0 \text{ METs } (SM_{\dot{V}O_2})$$

$$HR = 148 \text{ bpm } (HR_{SM})$$

Maximal HR: 220 – age = 175 bpm

$$\dot{V}O_2\text{max:} = SM_{\dot{V}O_2} \times [(HR_{max} - 72) / (HR_{SM} - 72)]$$

$$= 5 \times [(175 - 72) / (148 - 72)]$$

$$= 5 \times (103 / 76)$$

$$= 6.8 \text{ METs}$$

Single-Stage Treadmill Walking Test

Ebbeling and colleagues (1991) developed a single-stage treadmill walking test suitable for estimating $\dot{V}O_2$max of low-risk, healthy adults 20 to 59 yr. The Ebbeling treadmill test also produced high test-retest reliability and validity with $\dot{V}O_2$max for a sample of middle-aged (45–65 yr) women (Mitros et al. 2011). For this protocol, walking speed is individualized and ranges from 2.0 to 4.5 mph (53.6–120.6 m·min^{-1}) depending on your client's age, gender, and fitness level. Establish a walking pace during a 4 min warm-up at 0% grade. The warm-up work bout should produce a HR within 50% to 70% of the individual's age-predicted HR_{max}. The test consists of brisk walking at the selected pace for an additional 4 min at 5% grade. Record the steady-state HR at this workload, and use it in the following equation to estimate $\dot{V}O_2$max in ml/kg/min:

$$\begin{aligned}\dot{V}O_2\text{max} = {} & 15.1 + 21.8(\text{speed in mph}\\ & - 0.327(\text{HR in bpm})\\ & - 0.263(\text{speed} \times \text{age in years})\\ & + 0.00504(\text{HR} \times \text{age})\\ & + 5.48(\text{gender: female} = 0;\ \text{male} = 1)\end{aligned}$$

Single-Stage Treadmill Jogging Test

You can estimate the $\dot{V}O_2$max of younger adults (18–28 yr) using a single-stage treadmill jogging test (George et al. 1993). For this test, select a comfortable jogging pace ranging from 4.3 to 7.5 mph (115.2–201 m·min^{-1}), but not more than 6.5 mph (174.2 m·min^{-1}) for women and 7.5 mph (201 m·min^{-1}) for men. Have the client jog at a constant speed for about 3 min. The steady-state exercise HR should not exceed 180 bpm. Estimate $\dot{V}O_2$max (ml/kg/min) using the following equation:

$$\begin{aligned}\dot{V}O_2\text{max} = {} & 54.07 - 0.1938(\text{body weight in kg})\\ & + 4.47(\text{speed in mph})\\ & - 0.1453(\text{HR in bpm})\\ & + 7.062(\text{gender: female} = 0;\ \text{male} = 1)\end{aligned}$$

CYCLE ERGOMETER SUBMAXIMAL EXERCISE TESTS

Video 4.6

Cycle ergometer multistage submaximal tests can be used to predict $\dot{V}O_2$max. These tests are either continuous or discontinuous and are based on the assumption that HR and oxygen uptake are linear functions of work rate. The HR response to submaximal workloads is used to predict $\dot{V}O_2$max.

Åstrand-Ryhming Cycle Ergometer Submaximal Exercise Test Protocol

The Åstrand-Ryhming protocol (1954) is a single-stage test that uses a nomogram to predict $\dot{V}O_2$max from HR response to one 6 min submaximal workload. A power output is selected that produces a HR between 125 and 170 bpm. The initial workload is usually 450 to 600 kgm·min^{-1} (75–100 W) for trained, physically active women and 600 to 900 kgm·min^{-1} (100–150 W) for trained, physically active men. An initial workload of 300 kgm·min^{-1} (50 W) may be used for unconditioned or older individuals.

During the test, measure the HR every minute and record the average HR during the fifth and sixth minutes. If the difference between these two HRs exceeds 5 or 6 bpm, extend the work bout until a steady-state HR is achieved. If the HR is less than 130 bpm at the end of the exercise bout, increase the workload by 300 kgm·min^{-1} (50 W) and have the client exercise an additional 6 min.

To estimate $\dot{V}O_2$max for this protocol, use the modified Åstrand-Ryhming nomogram (see figure 4.8). This nomogram estimates $\dot{V}O_2$max (in L·min^{-1}) from submaximal treadmill, cycle ergometer, and step test data. For each test mode, the submaximal HR is plotted with either oxygen cost for treadmill exercise ($\dot{V}O_2$ in L·min^{-1}), power output (kgm·min^{-1}) for cycle ergometer exercise, or body weight (kg) for stepping exercise. For the cycle ergometer test, plot the client's power output (kgm·min^{-1}) and the steady-state exercise HR in the corresponding columns of the Åstrand-Ryhming nomogram (see figure 4.8). Connect these points with a ruler and read the estimated $\dot{V}O_2$max at the point where the line intersects the $\dot{V}O_2$max column.

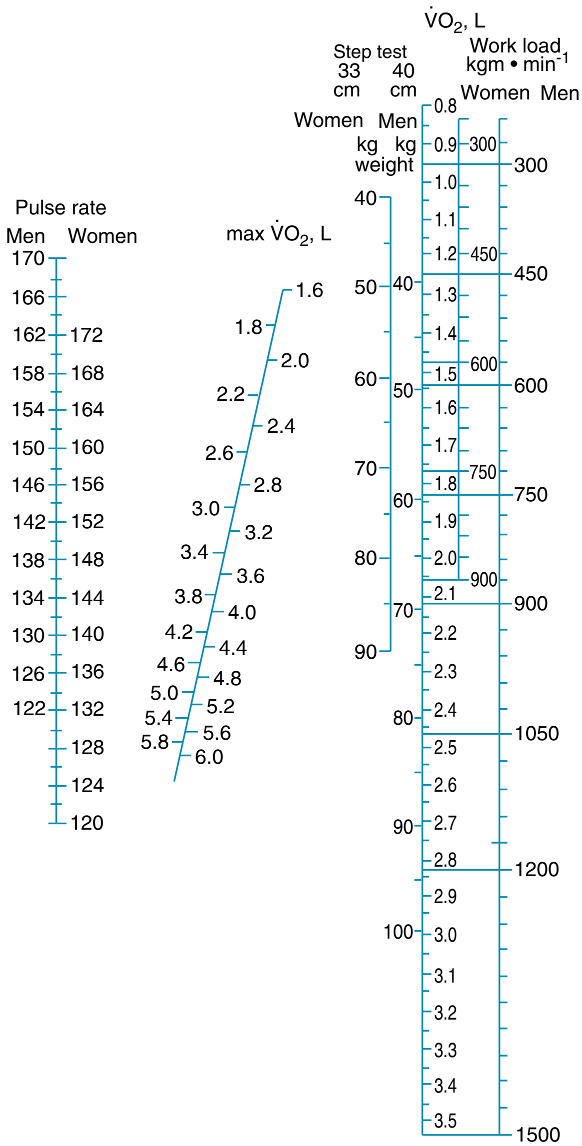


FIGURE 4.8 Modified Åstrand-Ryhming nomogram.

From "Aerobic Capacity in Men and Women with Special Reference to Age" by I. Åstrand, 1960. *Acta Physiologica Scandinavica* 49 (Suppl. 169), p. 51. Copyright 1960 by *Acta Physiologica Scandinavica*. Reprinted by permission.

The correlation between measured $\dot{V}O_2$max and the $\dot{V}O_2$max estimated from this nomogram is r = 0.74. The prediction error is ±10% and ±15%, respectively, for well-trained and untrained individuals (Åstrand and Rodahl 1977). A cross-validation study of this protocol and nomogram yielded a validity coefficient of 0.82 and a prediction error of 5.1 ml·kg^{-1}·min^{-1} for estimating the $\dot{V}O_2$max of adults 18 to 44 yr (Swain et al. 2004).

For clients younger or older than 25 yr, you must use the following age-correction factors to adjust the $\dot{V}O_2$max predicted from the nomogram for the effect of age. For example, if the estimated $\dot{V}O_2$max from the nomogram is 3.2 L·min^{-1} for a 45 yr old client, the adjusted $\dot{V}O_2$max is 2.5 L·min^{-1} (3.2 × 0.78 = 2.5 L·min^{-1}).

AGE-CORRECTION FACTORS FOR ÅSTRAND-RYHMING NOMOGRAM

Age	Correction factor
15	1.10
25	1.00
35	0.87
40	0.83
45	0.78
50	0.75
55	0.71
60	0.68
65	0.65

YMCA Cycle Ergometer Submaximal Exercise Test Protocol

The YMCA protocol (Golding 2000) is a cycle ergometer submaximal test for women and men. This protocol uses three or four consecutive 3 min workloads on the cycle ergometer designed to raise the HR to between 110 bpm and 85% of the age-predicted HR_{max} for at least two consecutive workloads. The pedal rate is 50 rpm, and the initial workload is 150 kgm·min^{-1} (25 W). Using a friction-type cycle ergometer, set the resistance to 0.5 kg (0.5 kg × 50 rpm × 6 m = 150 kgm·min^{-1}). To achieve this work rate using a plate-loaded cycle ergometer, use one weight plate (1.0 kg) and reduce the pedaling frequency to 25 rpm (1.0 kg × 25 rpm × 6 m = 150 kgm·min^{-1}). Use the HR during the last minute of the initial workload to determine subsequent workloads (see figure 4.9). If the HR is less than 86 bpm, set the second workload at 600 kgm·min^{-1}. If HR is 86 to 100, the workload is 450 kgm·min^{-1} for the second stage of the protocol. If the HR at the end of the first workload exceeds 100 bpm, set the second workload at 300 kgm·min^{-1}.

Set the third and fourth workloads accordingly (see figure 4.9). Measure the HR during the last 30 sec of minutes 2 and 3 at each workload. If these HRs differ by more than 5 or 6 bpm, extend the workload an additional minute until the HR stabilizes. If the client's steady-state HR reaches or exceeds 85% of the age-predicted HR_{max} during the third workload, terminate the test.

Calculate the energy expenditure ($\dot{V}O_2$) for the last two workloads using the ACSM metabolic equations (see table 4.3). To estimate $\dot{V}O_2$max from these data, use the equations for the multistage model to calculate the slope of the line depicting the HR response to the last two workloads. Alternatively, you can graph these data to estimate $\dot{V}O_2$max (see figure 4.10). To do this, plot the $\dot{V}O_2$ for each workload and corresponding HRs. Connect these two data points with a straight edge, extending the line so that it intersects the predicted maximal HR line. To extrapolate $\dot{V}O_2$max, drop a perpendicular line from the point of intersection to the *x*-axis of the graph. If this is done carefully, the graphing method and multistage method will yield similar estimates of $\dot{V}O_2$max.

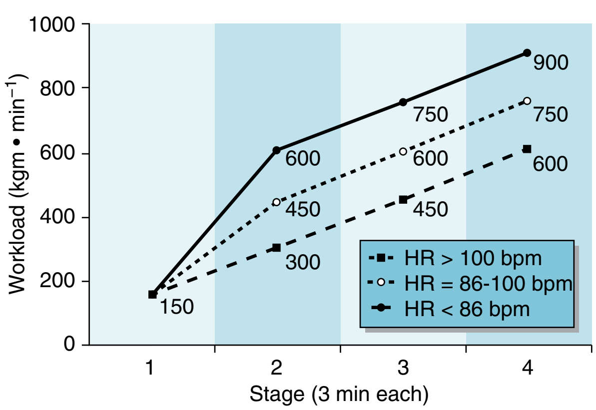


FIGURE 4.9 YMCA cycle ergometer protocol.

Swain Cycle Ergometer Submaximal Exercise Test Protocol

Swain and colleagues (2004) devised a submaximal cycle ergometry protocol for estimating $\dot{V}O_2$max based on the relationship between heart rate reserve (HRR) and $\dot{V}O_2$ reserve ($\dot{V}O_2$R) rather than on the HR-$\dot{V}O_2$ relationship. This protocol gradually approaches a target HR of 65% to 75% HRR in 1 min stages. This target HR zone is equivalent to 65% to 75% $\dot{V}O_2$R. When the client reaches her target HR, she continues to exercise at that workload for an additional 5 min. The initial work rate and increments in work rate differ depending on the client's body mass and activity level (see figure 4.11). The predictive validity of this test was good (r = 0.89; *SEE* = 4.0 ml·kg^{-1}·min^{-1}) for estimating the $\dot{V}O_2$max of adults ages 18 to 44 yr. However, more cross-validation studies are needed to determine this test's applicability to older or high-risk clients.

Figure 4.11 illustrates the Swain test protocols for active and inactive clients who weigh <90 kg or ≥90 kg (198 lb). To select the appropriate protocol and to calculate your client's estimated $\dot{V}O_2$max, follow the instructions in "Preliminary Procedures and General Instructions for Swain Protocol", p. 106 (Swain et al. 2004).

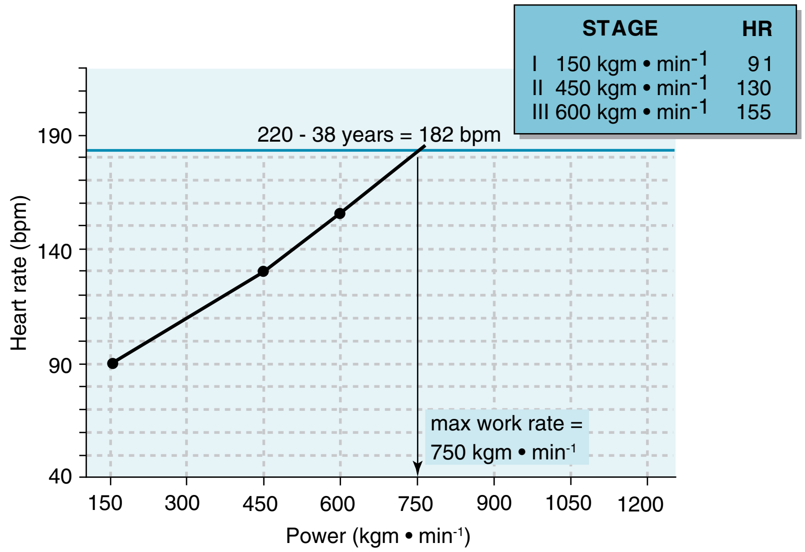


FIGURE 4.10 Plotting heart rate versus submaximal work rates to estimate maximal work capacity and $\dot{V}O_2$max.

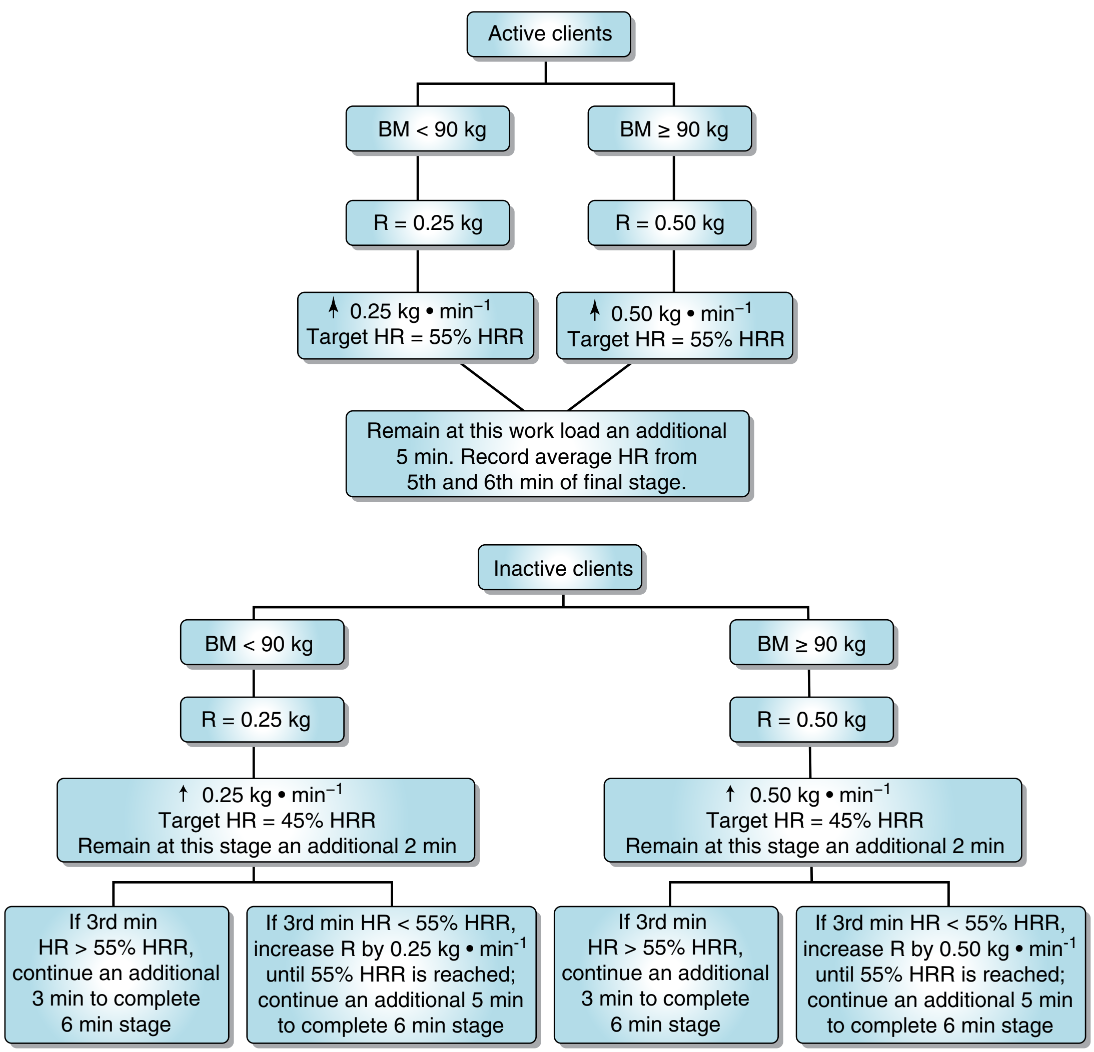


FIGURE 4.11 Swain cycle ergometer protocol for active clients and inactive clients.

PRELIMINARY PROCEDURES AND GENERAL INSTRUCTIONS FOR SWAIN PROTOCOL

To select the protocol, follow these steps:

- Measure the body weight and record your client's age.
- Classify your client's activity level as either *active* (>90 min/wk of vigorous activity or >120 min/wk of moderate-intensity exercise) or *inactive* (<90 min/wk of vigorous activity or <120 min/wk of moderate-intensity exercise). Vigorous activities include running, vigorous cycling, or any equivalent; moderate-intensity activities include brisk walking, moderate cycling, or any equivalent.
- Estimate your client's age-predicted HR_{max} (220 – age). Calculate the target exercise HRs corresponding to 45%, 55%, and 75% HRR (see figure 5.3, p. 128, for an example). Target HR = %HRR × (HR_{max} – HR_{rest}) + HR_{rest}.
- Select a protocol based on your client's body weight and activity level. Instruct your client to maintain a 60 rpm pedaling frequency throughout the test.
- Measure exercise HRs during the last 15 sec of each minute of the test. Terminate the test immediately if the target HR corresponding to 75% HRR is exceeded.

To estimate maximum workload and the corresponding $\dot{V}O_2$max from the final 6 min stage of this test, use the following steps:

- Calculate the power in watts (W) for the final 6 min workload. $Power_{6\text{-min}}$ (W) = resistance (kg) × 60 rpm × 9.81 m·sec^{-2}.
- Average the fifth- and sixth-minute HRs from the final stage ($HR_{6\text{-min}}$) and calculate the client's age-predicted HR_{max} using 220 – age.
- Calculate the client's %HRR for the final stage: %HRR = ($HR_{6\text{-min}}$ – HR_{rest}) / (HR_{max} – HR_{rest}).
- Estimate the client's maximum workload or power in watts (W) by dividing the power of the final stage, calculated in step 1, by the %HRR calculated in step 3: $power_{max}$ (W) = $power_{6\text{-min}}$ / %HRR.
- Use the ACSM metabolic equation for cycle ergometry to convert maximum power to an estimated $\dot{V}O_2$max: $\dot{V}O_2$max = 7 + [10.8 × $power_{max}$ (W) / body mass in kg].

Fox Single-Stage Cycle Ergometer Test Protocol

You can modify the maximal exercise test protocol (see figure 4.7) designed by Fox (1973) to predict $\dot{V}O_2$max (ml·min^{-1}). Have your client perform a single workload (i.e., 900 kgm·min^{-1} or 150 W) for 5 min. The standard error of estimate for this test is ±246 ml·min^{-1}, and the standard error of prediction is ±7.8%. The correlation between actual and predicted $\dot{V}O_2$max is $r = 0.76$. To estimate $\dot{V}O_2$max, measure the HR at the end of the fifth minute of exercise (HR_5) and use the following equation:

$$\dot{V}O_2\text{max (ml·min}^{-1}) = 6300 - 19.26(HR_5)$$

BENCH STEPPING SUBMAXIMAL EXERCISE TESTS

There are many step tests available to evaluate cardiorespiratory fitness; however, few provide equations for predicting $\dot{V}O_2$max. Only step test protocols with prediction equations are included in this section. Although these step test protocols were designed to be submaximal, the energy expenditure required of obese, short, or inactive individuals may exceed moderate-intensity exertion and approach $\dot{V}O_2$max levels (Hansen et al. 2011).

Åstrand-Ryhming Step Test Protocol

As mentioned previously, you can use the Åstrand-Ryhming nomogram (see figure 4.8) to predict $\dot{V}O_2$max from postexercise HR and body weight during bench stepping. For this protocol, the client steps at a rate of 22.5 steps·min^{-1} for 5 min. The bench height is 33 cm (13 in.) for women and 40 cm (15.75 in.) for men. Measure the postexercise HR by counting the number of beats between 15 and 30 sec immediately after exercise (convert this 15 sec count to beats per minute by multiplying by 4). Correct the predicted $\dot{V}O_2$max from the nomogram if your client is older or younger than 25 yr (using the age-correction factors).

Hansen et al. (2011) modified the bench height requirement and used the 40 cm platform for the middle-aged (45 ± 13 yr) participants at least 170 cm tall; the 33 cm platform was used for those shorter than 170 cm. Not everyone was able to complete the 5 min exercise period. Given the level of exertion required for stepping (from 75% to over 95% $\dot{V}O_2$max), Hansen and colleagues suggested that medical supervision of fixed-rate stepping tests may be required.

Queens College Step Test Protocol

In a step test to predict $\dot{V}O_2$max devised by McArdle and colleagues (1972), the client steps at a rate of 22 steps·min^{-1} (females) or 24 steps·min^{-1} (males) for 3 min. The bench height is 16.25 in. (41.3 cm). Have your client remain standing after the exercise. Wait 5 sec and then take a 15 sec HR count. Convert the count to beats per minute by multiplying by 4. If you are administering this test simultaneously to more than one client, you should teach your clients how to measure their own pulse rates (see "How to Measure Your Pulse Rate"). To estimate $\dot{V}O_2$max in ml·kg^{-1}·min^{-1}, use the equations listed in table 4.7. The standard error of prediction for these equations is ±16%.

ADDITIONAL MODES FOR SUBMAXIMAL EXERCISE TESTING

If you are working in the context of a health or fitness club, you may have access to stair climbers, recumbent steppers, and rowing ergometers. You can use some of these exercise machines for submaximal exercise testing of your clients.

Stair Climbing Submaximal Test Protocols

In light of the popularity of and continued interest in step aerobic training, you may choose to use a simulated stair climbing machine to estimate the aerobic fitness of some clients. The StairMaster 4000 PT and 6000 PT are two step ergometers commonly used in health and fitness settings. The StairMaster 4000 PT has step pedals that go up and down, whereas the 6000 PT model has a revolving staircase. Howley, Colacino, and Swensen (1992) reported that the HR response to increasing submaximal workloads (4.7 and 10 METs) on the StairMaster 4000 PT step

How to Measure Your Pulse Rate

1. Use your middle and index fingers to locate the radial pulse on the outside of your wrist just below the base of your thumb. Do not use your thumb to feel the pulse because it has a pulse of its own and may produce an inaccurate count.
2. If you cannot feel the radial pulse, try locating the carotid pulse by placing your fingers lightly on the front of your neck, just to the side of your voice box. Do not apply heavy pressure because this will cause your HR to slow down.
3. Use a stopwatch or the second hand of your wristwatch and count the number of pulse beats for a 6, 10, or 15 sec period.
4. Convert the pulse count to beats per minute using the following multipliers: 6 sec count times 10; 10 sec count times 6; and 15 sec count times 4.
5. Remember this value and record it on your scorecard.

ergometer was linear. Also, compared to values with treadmill exercise, the HRs measured during stepping were systematically higher (7–11 bpm) at each submaximal intensity. However, the MET values read from the step ergometer were about 20% higher than the measured MET values. To obtain more accurate MET values for each submaximal intensity, use the following equation:

actual METs = 0.556 + 0.745(StairMaster 4000 PT MET value)

The StairMaster 4000 PT test protocol, developed by the manufacturer, provides a relatively more accurate estimate of $\dot{V}O_2$max for young women (20–25 yr) who use this device for aerobic training (r = 0.57; *SEE* = 5.3 ml·kg^{-1}·min^{-1}; *CE* = 1.0 ml·kg^{-1}·min^{-1}) as compared to estimates for their untrained counterparts (r = 0.00; *SEE* = 6.7 ml·kg^{-1}·min^{-1}; *CE* = 6.9 ml·kg^{-1}·min^{-1}) (Roy et al. 2004). This finding illustrates that the exercise testing mode should match the exercise training mode (i.e., application of the specificity principle).

To estimate $\dot{V}O_2$max, measure the steady-state HR and calculate the corrected MET value for each of two submaximal exercise intensities (e.g., 4 and 7 METs). Each stage of the test should last 3 to 6 min in order to produce steady state. Then use either the multistage model formulas (see "Multistage Model") or the graphing method (see figure 4.10) to predict $\dot{V}O_2$max.

During the test, clients may hold the handrail lightly for balance but should not support their body weight. If they support their body weight, $\dot{V}O_2$max will be overestimated (Howley et al. 1992). Also, compared to the value with treadmill testing, your client's estimated $\dot{V}O_2$max may be lower because stair climbing produces systematically higher HRs at any given submaximal exercise intensity.

Recumbent Stepper Submaximal Test Protocol

The YMCA submaximal cycling protocol has been adapted for use with the NuStep T5xr recumbent stepper and can be used to estimate your client's $\dot{V}O_2$peak (r = .91; *SEE* = 4.09 ml·kg^{-1}·min^{-1}; *TE* = 4.11 ml·kg^{-1}·min^{-1}) (Billinger et al. 2012). The Billinger equation was designed for adults aged 20 to 60 yr. The client must maintain a stepping rate of 100 steps·min^{-1} throughout the protocol. Similar to the YMCA cycling protocol, the stage change is dependent on the client having attained a steady-state HR. The initial workload is 30 W, and it is increased every 3 min in accordance to the HR-derived protocol track. Use the HR during the last 10 seconds of the second and third minutes of each stage to determine if steady-state HR has been attained (within ± 5 bpm). If the HR at the end of the initial stage is less than 80 bpm, set the second workload at 125 W. If that HR is 80 to 89 bpm, the workload is 100 W for the second stage of the protocol. If the initial stage HR is 90 to 100 bpm, the second-stage workload is 75 W. If the HR at the end of the first workload exceeds 100 bpm, set the second workload at 50 W. Subsequent workloads increase 25 W every third minute thereafter, assuming a steady-state HR was achieved in the previous stage. The protocol terminates when the client reaches 85% of the age-predicted HR max or volitional exhaustion. Estimate $\dot{V}O_2$peak (ml/kg/min) using the following equation:

$$\begin{aligned}\dot{V}O_2\text{peak} = {} & 125.707 - (0.476 \times \text{age, yr}) \\ & + (7.686 \times \text{sex}) - (0.451 \times \text{wt, kg}) \\ & + (0.179 \times W_{\text{end\_submax}}) \\ & - (0.415 \times HR_{\text{end\_submax}})\end{aligned}$$

Note: for sex, 0 = female and 1 = male.
$W_{\text{end\_submax}}$ = watts equivalent to final workload.
$HR_{\text{end\_submax}}$ = HR at test termination.

Rowing Ergometer Submaximal Test Protocols

Submaximal exercise protocols have been developed for the Concept II rowing ergometer and can be used to estimate your client's $\dot{V}O_2$max. The Hagerman (1993) protocol is designed for noncompetitive or unskilled rowers. Before beginning the test, set the fan blades in the fully closed position and select the small axle sprocket. For this test, select a submaximal exercise intensity (the HR should not exceed 170 bpm) that the client can sustain for 5 to 10 min. Measure the exercise HR at the end of each minute. Continue the rowing exercise until the client achieves a steady-state HR. Use the Hagerman (1993) nomogram (see figure 4.12) to estimate $\dot{V}O_2$max from the submaximal power output (watts) and the steady-state HR during the last minute of exercise.

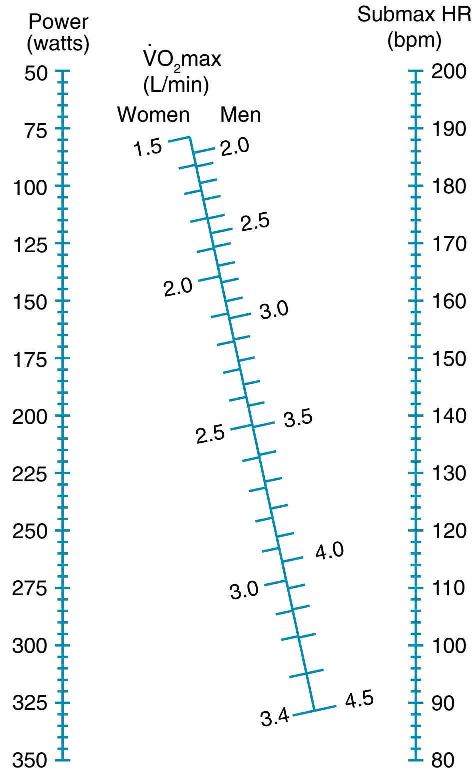


FIGURE 4.12 Concept II nomogram for estimating $\dot{V}O_2$max in noncompetitive and unskilled male and female rowers.

From *Concept II Rowing Ergometer Nomogram for Prediction of Maximal Oxygen Consumption* by Dr. Fritz Hagerman, Ohio University, Athens, OH. The nomogram is not appropriate for use with non-Concept II ergometers and is designed to be used by noncompetitive or unskilled rowers participating in aerobic conditioning programs. Adapted by permission of Concept II, INC., RR1, Box 110, Morrisville, VT. (800) 245-5676.

FIELD TESTS FOR ASSESSING AEROBIC FITNESS

The maximal and submaximal exercise tests using the treadmill or cycle ergometer are not well suited for measuring the cardiorespiratory fitness of large groups in a field situation. Thus, a number of performance tests such as distance runs have been devised to predict $\dot{V}O_2$max (see table 4.7). These tests are practical, inexpensive, less time-consuming than the treadmill or cycle ergometer tests, easy to administer to large groups, and suitable for personal training settings; they can be used to classify the cardiorespiratory fitness level of healthy men (≤45 yr) and women (≤55 yr). You cannot use field tests to detect CHD because HR, ECG, and BP are usually not monitored during the performance. Most field tests used to assess cardiorespiratory endurance involve walking, running, swimming, cycling, or bench stepping; they require that clients be able to accurately measure their postexercise HR. Pollock, Broida, and Kendrick (1972) found that with practice, men could learn to measure their own pulse rates accurately. The correlation between manual and electronic measurements of pulse rate ranged between $r = 0.91$ and 0.94. Similar results ($r = 0.95$) were reported for college women for pulse rates measured manually and electronically (Witten 1973). Prior to administering field tests that require the measurement of HR, you should teach your clients how to measure their pulse rates using the palpation technique described in “How to Measure Your Pulse Rate.” If you use a HR monitor, cell phone application, or pulse oximeter instead of palpation to determine postexercise HR, you are advised to record the HR displayed at the postexercise time interval designated by the protocol when it was created and validated (i.e., 15 sec postexercise for the 1 mi walk and 1 mi jogging tests). Using a HR captured at a different time interval may introduce additional error in the estimation of $\dot{V}O_2$max.

DISTANCE RUN TESTS

The most commonly used distance runs involve distances of 1.0 or 1.5 mi (1600 or 2400 m) to evaluate aerobic fitness. Distance run tests are based on the assumption that the fitter individual will be able to run a given distance in less time or to run a greater distance in a given period of time. Using factor analysis, Disch, Frankiewicz, and Jackson (1975) noted that runs greater than 1.0 mi tended to load exclusively on the endurance factor rather than the speed factor.

You should be aware that the relationship between distance runs and $\dot{V}O_2$max has not been firmly established. Although performance on a distance run can be accurately measured, it may not be an accurate index of $\dot{V}O_2$max or a substitute for the direct measurement of $\dot{V}O_2$max. Endurance running performance may be influenced by other factors such as motivation, percent fat (Cureton et al. 1978; Katch et al. 1973), running efficiency (pacing ability), and lactate threshold (Costill and Fox 1969; Costill, Thomason, and Roberts 1973).

Table 4.7 Prediction Equations for Cardiorespiratory Field Tests

Field test	Equation[a]	Source
	DISTANCE RUN/WALK	
1.0 mi steady-state jog	$\dot{V}O_2max$ = 100.5 – 0.1636(BW, kg) – 1.438(time, min) – 0.1928(HR, bpm) + 8.344(gender)[b]	George et al. (1993)
1.0 mi run/walk (8–17 yr)	$\dot{V}O_2max$ = 108.94 – 8.41(time, min) + 0.34(time, min)^2 + 0.21(age × gender)[b] – 0.84(BMI)[c]	Cureton et al. (1995)
1.5 mi run/walk	$\dot{V}O_2max$ = 88.02 – 0.1656(BW, kg) – 2.76(time, min) + 3.716(gender)[b]	George et al. (1993)
1.5 mi run/walk	$\dot{V}O_2max$ = 100.16 + 7.30(gender)[b] – 0.164(BW, kg) – 1.273(time, min) – 0.1563(HR, bpm)	Larsen et al. (2002)
12 min run	$\dot{V}O_2max$ = 0.0268(distance, m) – 11.3	Cooper (1968)
15 min run	$\dot{V}O_2max$ = 0.0178(distance, m) + 9.6	Balke (1963)
1.0 mi walk	$\dot{V}O_2max$ = 132.853 – 0.0769(BW, lb) – 0.3877(age, years) + 6.315(gender)[b] – 3.2649(time, min) – 0.1565(HR, bpm)	Kline et al. (1987)
	STEP TESTS	
Åstrand	Men: $\dot{V}O_2max$ (L·min^{-1}) = 3.744 [(BW + 5) / (HR – 62)] Women: $\dot{V}O_2max$ (L·min^{-1}) = 3.750 [(BW – 3) / (HR – 65)]	Marley and Linnerud (1976)
Queens College	Men: $\dot{V}O_2max$ = 111.33 – (0.42 HR, bpm) Women: $\dot{V}O_2max$ = 65.81 – (0.1847 HR, bpm)	McArdle et al. (1972)

[a]All equations estimate $\dot{V}O_2max$ in ml·kg^{-1}·min^{-1} unless otherwise specified.

[b]For gender, substitute 1 for males and 0 for females.

[c]BMI = body mass index or body weight (body weight [BW] in kg)/ht^2 (in meters).

HR = heart rate; m = meters.

The correlations between distance run tests and $\dot{V}O_2max$ tend to vary considerably (r = 0.27–0.90) depending on the subjects, sample size, and testing procedures (George et al. 1993; Rikli, Petray, and Baumgartner 1992; Zwiren et al. 1991). Generally, the longer the run, the higher the correlation with $\dot{V}O_2max$. On the basis of this observation, it is recommended that you select a test with a distance of at least 1.0 mi (1600 m) or a duration of at least 9 min.

The most widely used distance run tests are the 9 and 12 min runs and the 1.0 and 1.5 mi runs. Some physical fitness test batteries for children and adolescents recommend using either the 9 min or 1.0 mi run test.

9 or 12 Min Run Tests

To administer the 9 or 12 min run test, use a 400 m track or flat course with measured distances so that the number of laps completed can be easily counted and multiplied by the course distance. Place markers to divide the course into quarters or eighths of a mile so that you can quickly determine the exact distance covered in 9 or 12 min. Instruct your clients to run as far as possible. Walking is allowed, but the objective of these tests is to cover as much distance as possible in either 9 or 12 min. At the end of the test, calculate the total distance covered in meters and use the appropriate equation in table 4.7 to estimate the client's $\dot{V}O_2max$.

1.5-Mile Run/Walk Test

The 1.5 mi (2.4 km) run/walk test is conducted on a 400 m track or flat measured area. To measure the course, use an odometer or measuring wheel. For the 1.5 mi run, instruct your clients to cover the specified distance in the fastest possible time. Walking is allowed, but the objective is to cover the distance in the shortest possible time while maintaining a steady exercise pace. Call out the elapsed time (in minutes and seconds) as the client crosses the finish line. You can use a HR monitor to ensure that your client maintains a steady exercise pace during this test. Instruct your clients to keep their target HR between 60% and 90% HR_{max}. The exercise HR at the end of the test, along with gender, body mass, and elapsed exercise time, can be substituted into the Larsen equation (see table 4.7) to estimate the $\dot{V}O_2max$ of young (18–29 yr) adults (Larsen et al.

2002). Cross-validation of this equation yielded a high validity coefficient (r = 0.89) and small prediction errors (SEE = 2.5 ml·kg^{-1}·min^{-1}; TE = 2.68 ml·kg^{-1}·min^{-1}) for a sample of young military personnel (Taylor et al. 2002).

To use the $\dot{V}O_2$max prediction equations for the 1.5 mi run/walk test (see table 4.7), convert the seconds to minutes by dividing the seconds by 60. For example, if a client's time for the test is 12:30, the exercise time is converted to 12.5 min (30 / 60 sec = 0.5 min).

1.0-Mile Jogging Test

One limitation of distance run tests is that individuals are encouraged to run as fast as possible and give a maximal effort, thereby increasing the risk of cardiovascular and orthopedic injuries. The potential risk is even greater for untrained individuals who do not run or jog regularly and have difficulty selecting a proper jogging pace. To address this problem, George and colleagues (1993) developed a submaximal 1 mi (1.6 km) track jogging test for 18 to 29 yr old women and men that requires only moderate steady-state exertion.

For this test, instruct your clients to select a comfortable, moderate jogging pace and to measure their postexercise HR immediately following the test. The elapsed time for 1 mi should be at least 8 min for males and 9 min for females, and the postexercise HR (15 sec count × 4) should not exceed 180 bpm. To help establish a suitable pace, precede the timed 1 mi test with a 2 to 3 min warm-up. Use either an indoor or outdoor track for this test. Record the time required to jog 1 mi in minutes, and have your clients measure their postexercise HRs using the palpation technique (radial or carotid sites). Estimate the client's $\dot{V}O_2$max using the prediction equation for the 1.0 mi steady-state jog test (see table 4.7).

Walking Test

The Rockport Walking Institute (1986) has developed a walking test to assess cardiorespiratory fitness for men and women ages 20 to 69 yr. Because this test requires only fast walking, it is useful for testing older or sedentary individuals (Fenstermaker, Plowman, and Looney 1992). The test was developed and validated for a large, heterogeneous sample of 86 women and 83 men (Kline et al. 1987). The cross-validation analysis resulted in a high validity coefficient and small standard error of estimate (SEE), indicating that the 1.0 mi walking test yields a valid submaximal assessment of estimated $\dot{V}O_2$max. Other researchers have substantiated the predictive accuracy of this equation for women 65 yr of age and older (Fenstermaker et al. 1992), as well as military men aged 18 to 44 yr (Weiglein et al. 2011).

To administer this test, instruct your clients to walk 1.0 mi as quickly as possible and to take their HR immediately at the end of the test by counting the pulse for 15 sec. It is important that clients know how to take their pulse accurately. The walking course should be a measured mile that is flat and uninterrupted, preferably a 400 m track. Clients should warm up for 5 to 10 min before the test and wear good walking shoes and loose-fitting clothes.

To estimate your client's $\dot{V}O_2$max, use the generalized equation for the 1.0 mi walking test (see table 4.7). Alternatively, you can use the Rockport relative fitness charts (appendix B.2) to classify your client's cardiorespiratory fitness level. Locate the walking time and corresponding postexercise HR (bpm) on the appropriate chart for the individual's age and gender. These charts are based on body weights of 125 lb for women and 170 lb for men. If the client weighs substantially more than this, the cardiorespiratory fitness level will be overestimated.

STEP TESTS

The major advantage of using step tests to assess cardiorespiratory fitness is that they can be administered to large groups in a field situation without requiring expensive equipment or highly trained personnel. Most of these step tests use postexercise and recovery HRs to evaluate aerobic fitness, but they do not provide an estimate of the individual's $\dot{V}O_2$max. Step test protocols and scoring procedures are described in appendix B.3, "Step Test Protocols."

The validity of step tests is highly dependent on the accurate measurement of pulse rate. Step tests that use recovery HR tend to possess lower validity than those using the time required for the HR to reach a specified level during performance of a standardized workload (Baumgartner and Jackson 1975). The correlation coefficients between step test performance and $\dot{V}O_2$max range between r = 0.32 and 0.77 (Cureton and Sterling 1964; deVries and Klafs 1965; McArdle et al. 1972).

ADDITIONAL FIELD TESTS

In addition to running, walking, and step tests, cycling and swimming tests have been devised for use in field situations (Cooper 1977). The 12 min cycling test, using a bike with no more than three speeds, is conducted on a hard, flat surface when the wind velocity is less than 10 mph (268 m·min^{-1}). These conditions limit the effect of outside influences on the rider's performance. Five- and 10-speed bikes are not employed unless use of the lower gears can be restricted. Use an odometer to measure the distance traveled in 12 min. In the 12 min swimming test, the client may use any stroke and rest as needed. Norms for the 12 min cycling test and 12 min swimming test are available (Cooper 1977).

Of these two tests, the swimming test is the less preferred because the outcome is highly skill dependent. For example, a skilled swimmer with an average cardiorespiratory fitness level will probably be able to swim farther in 12 min than a poorly skilled swimmer with an above-average cardiorespiratory fitness level. In fact, Conley and colleagues (1991, 1992) reported that the 12 min swim has low validity (r = 0.34–0.42) as a cardiorespiratory field test for male and female recreational swimmers. Whenever possible, select an alternative field test and avoid using the 12 min swim test.

EXERCISE TESTING FOR CHILDREN AND OLDER ADULTS

You may need to modify the generic guidelines for exercise testing (see "General Principles of Exercise Testing") of low-risk adults when you are assessing cardiorespiratory fitness of children and older adults. You must take into account growth, maturation, and aging when selecting exercise testing modes and protocols for these groups.

ASSESSING CARDIORESPIRATORY FITNESS OF CHILDREN

In the laboratory setting, you can assess the cardiorespiratory fitness of children using either the treadmill or cycle ergometer. Treadmill testing is usually preferable, especially for younger children, because their shortened attention span may not allow them to maintain a constant pedaling rate during a cycle ergometer test. Also, children younger than 8 yr or shorter than 50 in. (127 cm) may not be tall enough to use a standard cycle ergometer. To accommodate children, modify the seat height, pedal crank length, and handlebar position.

For treadmill testing, you may choose to use the modified Balke protocol (see table 4.8) because the speed is constant and the means of increasing intensity is to change the grade. Either the modified Balke protocol or the modified Bruce protocol (i.e., 2 min instead of 3 min stages) may be used when assessing the cardiorespiratory fitness level for children. Age and gender endurance time norms for children (4–18 yr) for the modified Bruce protocol are available elsewhere (Wessel, Strasburger, and Mitchell 2001).

For cycle ergometer testing, you can use the McMaster protocol (see table 4.8). For this protocol, the pedaling frequency is 50 rpm, and increments in work rate are based on the child's height. As an alternative, a new steep ramp cycling protocol (SRP) has demonstrated both high reliability and validity for accurately assessing $\dot{V}O_2$peak of children and adolescents (Bongers et al. 2013). All children participated in a step ramp trial. Following a 3 min warm-up at a power output of 25 W, the ramp trial began with workload increments of either 10, 15, or 20 W per 10 sec; the increments were determined by participant height (<120 cm, 120–150 cm, and >150 cm, respectively). The ramp protocol continued until the pedaling cadence fell below 60 rpm and the participant exhibited other signs of maximal exertion. The steep ramp protocol was validated against a separate maximal exertion cycling protocol with metabolic gas collection; the following equation was subsequently derived: $\dot{V}O_2$peak (ml·min^{-1}) = 8.262 × W_{SRP} +177.096 (R^2 = 0.917; *SEE* = 237.4 ml·min^{-1}). The mean difference between predicted and measured $\dot{V}O_2$peak was 0.3 ml·min^{-1}, and no systematic bias was noted in the Bland and Altman analysis. Test-retest comparison of the SRP indicated high reproducibility of peak power output (ICC = 0.986).

Children, like adults, may not exhibit a plateau in oxygen consumption during ramp protocol testing. Only 34% of the children undergoing metabolic gas analysis in the study by Bongers and colleagues (2013) demonstrated a plateau in $\dot{V}O_2$. Barker and

Table 4.8 Graded Exercise Test Protocols for Children (Skinner 1993)

MODIFIED BALKE TREADMILL PROTOCOL				
Activity classification	Speed (mph)	Initial grade (%)	Increment (%)	Duration (min)
Poorly fit	3.0	6	2	2
Sedentary	3.25	6	2	2
Active	5.0	0	2.5	2
Athletes	5.25	0	2.5	2

MCMASTER CYCLE ERGOMETER PROTOCOL			
Height (cm)	Initial work rate: kgm·min^{-1} (watts)	Increments: kgm·min^{-1} (watts)	Duration (min)
<120	75 (12.5)	75 (12.5)	2
120-139.9	75 (12.5)	150 (25)	2
140-159.9	150 (25)	150 (25)	2
≥160	150 (25)	300 (50) for boys 150 (25) for girls	2

colleagues (2011) confirmed that children exerted their maximal effort during a ramp cycling protocol after resting 15 min and then performing a supramaximal cycling trial at 105% of the peak power output attained during the ramp protocol. Subsequent analysis revealed similar oxygen consumption values between the two cycling protocols. In addition to noting a low incidence of a plateau during the ramp cycling trial, Barker and colleagues (2011) commented that had they relied on the other secondary indicators of maximal exertion (i.e., RER and HR), they would have underestimated $\dot{V}O_2$max by 10% to 20%, on average, in their sample of healthy 9 and 10 yr olds.

Field tests, such as the 1.0 mi (1.6 km) run/walk, are widely used to assess the cardiorespiratory fitness of children 5 to 17 yr of age. These tests are part of the Physical Best Program (American Alliance for Health, Physical Education, Recreation and Dance 1988), Fitnessgram (Cooper Institute for Aerobics Research 1994), and the President's Challenge Test (President's Council on Physical Fitness and Sports 1997), as well as national physical fitness surveys of children and youth (Ross and Pate 1987). To estimate $\dot{V}O_2$peak of 8 to 17 yr olds for the 1.0 mi run/walk test, you can use a generalized prediction equation (see table 4.7) (Cureton et al. 1995). For younger children (5–7 yr), the 0.5 mi (.8 km) run/walk test is recommended (Rikli, Petray, and Baumgartner 1992). Criterion-referenced standards for the 1.0 mi test are available elsewhere (American Alliance for Health, Physical Education, Recreation and Dance 1988; Cooper Institute for Aerobics Research 1994).

In Canada and Europe, the multistage 20 m shuttle run test, developed by Leger and colleagues (1988), is a popular alternative to distance running/walking field tests to estimate the aerobic fitness of children (8–19 yr) in educational settings. This test has been cross-validated using other samples of European, Canadian, and American children (Anderson 1992; Mahar et al. 2011; van Mechelen, Holbil, and Kemper 1986).

For this test, children run back and forth continuously on a 20 m (indoor or outdoor) course. The running speed is set using a sound signal emitted from a prerecorded tape. The starting pace is 8.5 km·hr^{-1}, and the speed is increased 0.5 km·hr^{-1} each minute until they can no longer maintain the pace. The maximal aerobic speed at this stage is used, in combination with age, in the original equation to estimate $\dot{V}O_2$max (ml/kg/min) is as follows:

$$\begin{aligned}\dot{V}O_2\text{max} = {} & 31.025 + 3.238(\text{speed, km·hr}^{-1} \\ & - 3.248(\text{age, yr}) \\ & + 0.1536(\text{age} \times \text{speed})\end{aligned}$$

Mahar and colleagues (2011) evaluated this and several other equations for a sample of school children. In an attempt to improve the fitness category classification resulting from these equations, they devised and cross-validated quadratic and linear equations that improve both the prediction of $\dot{V}O_2max$ and the fitness level categorization of children aged 10 to 16 yr.

$$\dot{V}O_2max = 41.76799 + (0.49261 \times \text{laps}) - (0.00290 \times \text{laps}^2) - (0.61613 \times \text{BMI}) + (0.34787 \times \text{gender} \times \text{age})$$, where boys = 1 and girls = 0; R = 0.75, $R^2 = 0.56$, *SEE* = 6.17 ml·kg^{-1}·min^{-1})

$$\dot{V}O_2max = 40.34533 + (0.21426 \times \text{laps}) - (0.79472 \times \text{BMI}) + (4.27293 \times \text{gender}) + (0.79444 \times \text{age})$$ R = 0.74, $R^2 = 0.54$, *SEE* = 6.29 ml·kg^{-1}·min^{-1})

Two other incremental running tests have been validated against a graded treadmill test and shown reliable in terms of test-retest determination of maximal heart rate. Bendiksen and colleagues (2012) investigated the suitability of the modified Yo-Yo Intermittent Recovery Level 1 test (YYIR1C) and the Andersen test for assessing the cardiovascular health of children aged 6 to 10 yr. The criterion measure was the maximal heart rate attained during an incremental treadmill test terminated at either volitional exhaustion, predetermined physiologic criteria (HR > 200 bpm, RER > 0.99, or a leveling off of oxygen consumption), or demonstration of subjective criteria such as an unwillingness to continue or uncoordinated running. The YYIR1C was performed by having the child run back and forth between two cones (or lines) spaced 16 m apart. After returning to the starting point, the child engaged in a 10 sec active recovery by jogging around a third cone located 4 m behind the starting location. The speed at which the child had to complete the 16 m laps up and back was controlled by sounds coming from a CD player playing the standard YYIR1 disc. The 16 m running pace became progressively faster, while the active recovery period remained at 10 sec. The child ran until failing twice to complete the 16 m distance within the designated time increment. The maximal heart rate attained and total distances covered were recorded. Similarly, in the Andersen test, children ran back and forth between two cones (or lines) placed 20 m apart. However, the children ran as fast as possible and took one step beyond each demarcation before turning and running back. The children ran in this manner for 15 sec, at which time a whistle was blown and the children stopped as quickly as possible (within 2 steps) to rest for 15 sec. The last 3 sec of the rest period were counted off (e.g., "3, 2, 1, run"). According to protocol, this pattern continued for 10 min. As was done for the YYIR1C test, the maximal heart rate and total distances covered were recorded. For the entire group of children, the average maximal heart rates from the YYIR1C and Andersen tests were similar, at 207 and 206 bpm, respectively, and slightly higher than that from the incremental treadmill test (203 bpm). Consequently, Bendiksen and colleagues (2012) reported that these two field tests are sensitive enough to detect fitness-based differences in this age group.

ASSESSING CARDIORESPIRATORY FITNESS OF OLDER ADULTS

To assess the cardiorespiratory fitness of elderly clients, you can use modified treadmill and cycle ergometer protocols. The following modifications for standard GXT protocols are recommended:

- Extend the warm-up to more than 3 min.
- Set an initial exercise intensity of 2 to 3 METs; work increments should be 0.5 to 1.0 MET (e.g., Naughton treadmill protocol; see table 4.4).
- Adjust (reduce) the treadmill speed to the walking ability of your client when needed.
- Extend the duration of each work stage (at least 3 min), allowing enough time for the client to attain steady state.
- Select a protocol likely to produce a total test time of 8 to 12 min.

Select treadmill protocols that increase grade, instead of speed, especially for older clients with poor ambulation. You can modify the standard Balke protocol (see figure 4.2) by having the client walk at 0% grade and 3.0 (4.8 km·hr^{-1}) mph or slower initially and by increasing the duration of each stage to at least 3 min. If elderly clients are more comfortable holding on to the handrails during a treadmill test, you can use the standard Bruce protocol and the McConnell and Clark (1987) prediction equation to estimate their $\dot{V}O_2max$ (see table 4.5). Alternatively, you could use cycle ergometer GXTs for older individuals with poor balance, poor neuromuscular coordination, or impaired vision. You can also use field tests to estimate the cardiorespiratory fitness of your older (60–94 yr) clients. The Senior Fitness Test Battery (Rikli and Jones 2013) includes two measures of aerobic endurance: the 6 min walking test and the 2 min step test.

6 Min Walking Test

Purpose: Assess aerobic endurance.

Application: Measure ability to perform activities of daily living such as walking, stair climbing, shopping, and sightseeing.

Equipment: You will need a 5 × 20 yd (4.6 × 18.3 m) rectangular walking area, a measuring tape, a stopwatch, four cones, masking tape, index cards, and chairs.

Test procedures: Use masking tape or chalk to mark 5 yd (4.6 m) lines on a flat, rectangular course. Place cones on the inside corners of the rectangle. Instruct participants to walk (not jog) as fast as possible around the course for 6 min. Partners can keep track of the total number of laps and distance covered by marking the index card each time a lap is completed. Administer one trial; measure total distance to the nearest 5 yd. Test two or more people at a time for motivation.

Scoring: Calculate the total distance covered in 6 min. Each mark on the index card represents 50 yd (45.6 m). Use table 4.9 to determine a client's percentile ranking.

Safety tips: Place chairs around the outside of the walking course in case a client needs to sit and rest during the test. Select a well-lit, level walking area with a nonslip surface. Discontinue the test if the client shows signs of overexertion. Have the client cool down by stepping in place for 1 min.

Validity and reliability: The 6 min walking distance was positively related (r = 0.78) to submaximal treadmill walking time (Bruce protocol, time to reach 85% HR_{max}). This walking test detects the expected performance declines across age groups and discriminates between individuals with high and low physical activity levels and functional ability test scores. The test-retest reliability was r = 0.94.

Casanova and colleagues (2011) followed standard procedure to evaluate the 6 min walking test performance of 444 adults (40–80 yr) from seven countries. The effect of age on distance walked was significant for ages ≥60 yr, regardless of gender. They found no difference in distance walked based on self-reported activity levels (sedentary vs. physically active). Casanova and associates reported geographic variations in the distance walked that could not be explained by anthropometric variables. Consequently, they urge caution when using existing predictive equations and standard curves when interpreting results of the 6 min walking test.

2 Min Step Test

Purpose: Alternative test of aerobic endurance when time, space, or weather prohibits administering the 6 min walking test.

Application: Measure ability to perform activities of daily living such as walking, stair climbing, shopping, and sightseeing.

Equipment: You will need a stopwatch, a tape measure, masking tape, and a tally counter to count steps.

Test procedures: Determine the minimum knee-stepping height of the client by identifying the midpoint between the kneecap (midpatellar level) and iliac crest. Mark this point on the anterior aspect of the client's thigh and on a nearby wall or chair. These marks are used to monitor knee height during the test. Ask the client to step in place for 2 min, lifting the right knee as high as the target level marked on the wall. Use the tally counter to count the number of times the right knee reaches the target level. If the proper knee height cannot be maintained, ask the client to slow down or stop until he can execute proper form; keep the stopwatch running. Administer one trial.

Scoring: Count the number of times the right knee reaches the target level in 2 min. Use table 4.10 to determine your client's percentile ranking.

Table 4.9 6 Min Walking Test Norms for Older Adults[a]

	60-64 YR		65-69 YR		70-74 YR		75-79 YR		80-84 YR		85-89 YR		90-94 YR	
Percentile rank	F	M	F	M	F	M	F	M	F	M	F	M	F	M
95	741	825	734	800	709	779	696	762	654	721	638	710	564	646
90	711	792	697	763	673	743	655	716	612	678	591	659	518	592
85	690	770	673	738	650	718	628	686	584	649	560	625	488	557
80	674	751	653	718	630	698	605	661	560	625	534	596	463	527
75	659	736	636	700	614	680	585	639	540	604	512	572	441	502
70	647	722	621	685	599	665	568	621	523	586	493	551	423	480
65	636	710	607	671	586	652	553	604	508	571	476	532	406	461
60	624	697	593	657	572	638	538	586	491	554	458	512	388	440
55	614	686	581	644	561	625	524	571	477	540	443	495	373	422
50	603	674	568	631	548	612	509	555	462	524	426	477	357	403
45	592	662	555	618	535	599	494	539	447	508	409	459	341	384
40	582	651	543	605	524	586	480	524	433	494	394	442	326	366
35	570	638	529	591	510	572	465	506	416	477	376	422	308	345
30	559	626	515	577	497	559	450	489	401	462	359	403	291	326
25	547	612	500	562	482	544	433	471	384	444	340	382	273	304
20	532	597	483	544	466	526	413	449	364	423	318	358	251	279
15	516	578	463	524	446	506	390	424	340	399	292	329	226	249
10	495	556	439	499	423	481	363	394	312	370	261	295	196	214
5	465	523	402	462	387	445	322	348	270	327	214	244	150	160

F = females; M = males.

[a]Values represent distance in yards; to convert yards to meters, multiply by 0.91.

Adapted, by permission, from R. Rikli and C. Jones, 2013, *Senior fitness test manual,* 2nd ed. (Champaign, IL: Human Kinetics), 156.

Table 4.10 2 Min Step Test Norms for Older Adults[a]

	60-64 YR		65-69 YR		70-74 YR		75-79 YR		80-84 YR		85-89 YR		90-94 YR	
Percentile rank	F	M	F	M	F	M	F	M	F	M	F	M	F	M
95	130	135	133	139	125	133	123	135	113	126	106	114	92	112
90	122	128	123	130	116	124	115	126	104	118	98	106	85	102
85	116	123	117	125	110	119	109	119	99	112	93	100	80	96
80	111	119	112	120	105	114	104	114	94	107	88	95	76	91
75	107	115	107	116	101	110	100	109	90	103	85	91	72	86
70	103	112	104	113	97	107	96	105	87	99	81	87	69	83
65	100	109	100	110	94	104	93	102	84	96	79	84	66	79
60	97	106	96	107	90	101	90	98	81	93	76	81	63	76
55	94	104	93	104	87	98	87	95	78	90	73	78	61	72
50	91	101	90	101	84	95	84	91	75	87	70	75	58	69
45	88	98	87	98	81	92	81	87	72	84	67	72	55	66
40	85	96	84	95	78	89	78	84	69	81	64	69	53	62
35	82	93	80	92	74	86	75	80	66	78	61	66	50	59
30	79	90	76	89	71	83	72	77	63	75	59	63	47	55
25	75	87	73	86	68	80	68	73	60	71	55	59	44	52
20	71	83	68	82	63	76	64	68	56	67	52	55	40	47
15	66	79	63	77	58	71	59	63	51	62	47	50	36	42
10	60	74	57	72	52	66	53	56	46	56	42	44	31	36
5	52	67	47	67	43	67	45	47	37	48	39	36	24	26

F = females; M = males.

[a]Values represent number of times right knee reaches target level.

Adapted, by permission, from R. Rikli and C. Jones, 2013, *Senior fitness test manual,* 2nd ed. (Champaign, IL: Human Kinetics), 157.

Safety tips: Clients with poor balance should stand close to a wall, doorway, or chair for support in case they lose their balance during the test. Spot each client carefully. Have the client cool down after the test by walking slowly for 1 min. Discontinue the test if your client shows signs of overexertion.

Validity and reliability: The 2 min step test scores were moderately correlated (r = 0.73–0.74) with Rockport 1 mi walking scores and treadmill walking (Bruce protocol, time to reach 85% HR_{max}) in older adults. This step test detected expected performance declines across age groups and discriminated between exercisers and nonexercisers. The test-retest reliability was $r = 0.90$.

SOURCES FOR EQUIPMENT

Product	Supplier's contact information
Cycle ergometer (Lode, electronically braked)	AEI Technologies, Inc. (800) 793-7751 www.aeitechnologies.com
Cycle ergometer (Monark)	Claflin Medical Equipment Co. (800) 338-2372 www.claflinequip.com
Cycle ergometer (Bodyguard, Tunturi, Schwinn)	U.S. Fitness Products (888) 761-1638 www.usafitness.com
Elliptical trainers	Life Fitness (800) 351-3737 www.lifefitness.com Precor (800) 786-8404 www.precor.com
Nordic ski machine	Nordic Track (888) 308-9616 www.nordictrack.com
Recumbent stepper	NuStep, Inc. (800) 322-4434 www.nustep.com
Rowing ergometer	Concept 2, Inc. (800) 245-5676 www.concept2.com
Stair climbing machines	Nautilus, Inc. (800) 628-8458 www.nautilus.com
Treadmill (Quinton)	Cardiac Science (800) 426-0337 www.cardiacscience.com

Key Points

- The best way to assess cardiorespiratory capacity (cardiorespiratory fitness) is through a GXT in which the functional $\dot{V}O_2$max is measured.
- Unless contraindications to exercise are observed, you should administer a maximal exercise test to moderate- and high-risk men and women before they begin a vigorous exercise program.
- Before, during, and after a maximal or submaximal exercise test, closely monitor the HR, BP, and RPE.
- Treadmill, cycle ergometer, and bench stepping are the most commonly used modes of exercise for exercise testing.
- The choice of exercise mode and exercise test protocol depends on the purpose of the test and on the age, gender, and health and fitness status of the individual.
- Submaximal exercise tests are used to estimate the functional cardiorespiratory capacity by predicting the $\dot{V}O_2$max of the individual. Failure to meet the assumptions underlying submaximal exercise tests produces a ±10% to 20% error in the prediction of $\dot{V}O_2$max from submaximal HR data.
- Field tests are the least desirable way of assessing aerobic fitness and should not be used for diagnostic purposes. However, field tests are useful for assessing the cardiorespiratory fitness of large groups.
- Commonly used field tests include distance runs, walking tests, and step tests.
- Distance runs should last at least 9 min to assess aerobic function. Distance runs usually range between 1 and 2 mi (1600 and 3200 m) or 9 and 12 min.
- The validity of step tests for assessing cardiorespiratory fitness is highly dependent on obesity, height, fitness level, and the accurate measurement of HR; step test validity is usually somewhat lower than the validity of distance run tests.
- For children and older adults, select a treadmill protocol that increases grade rather than speed.
- The 6 min walking test or 2 min step test can be used to assess cardiorespiratory fitness of older adults in field settings.

Key Terms

Learn the definition for each of the following key terms. Definitions of key terms can be found in the glossary.

absolute $\dot{V}O_2$
cardiorespiratory endurance
continuous exercise test
discontinuous exercise test
graded exercise test (GXT)
gross $\dot{V}O_2$
maximal exercise test
maximum oxygen uptake ($\dot{V}O_2$max)
net $\dot{V}O_2$
ramp protocols
rating of perceived exertion (RPE)
relative $\dot{V}O_2$max
respiratory exchange ratio (RER)
submaximal exercise test
$\dot{V}O_2$max
$\dot{V}O_2$peak

Review Questions

In addition to being able to define each of the key terms listed, test your knowledge and understanding of the material by answering the following review questions.

1. What is the most valid and direct measure of functional cardiorespiratory capacity?
2. What is the difference between absolute and relative $\dot{V}O_2$?
3. What is the difference between gross and net $\dot{V}O_2$?
4. What is the difference between $\dot{V}O_2$max and $\dot{V}O_2$peak?

5. What factors should you consider when choosing a maximal or submaximal exercise test protocol for your client?
6. Identify the ACSM criteria for attainment of $\dot{V}O_2max$ during a GXT.
7. During a GXT, what three variables are monitored at regular intervals?
8. List three reasons for stopping a GXT.
9. What is active recovery, and why is it recommended for graded exercise testing?
10. What differences exist among continuous, discontinuous, and ramp exercise testing protocols?
11. Calculate the gross $\dot{V}O_2$ for a 60 kg woman running on a treadmill at a speed of 6.0 mph and a grade of 10%.
12. Calculate the gross $\dot{V}O_2$ for an 80 kg man cycling on Monark cycle ergometer at a pedaling frequency of 70 rpm and a resistance of 3.5 kg.
13. Calculate the energy expenditure for bench stepping using an 8 in. step and a cadence of 30 steps·min^{-1}.
14. Name three types of field tests for estimating aerobic capacity.
15. Which type of testing, treadmill or cycle ergometer, should be used for assessing the cardiorespiratory fitness of children?
16. How should standard GXT protocols be modified for testing of older adults?

CHAPTER 5

Designing Cardiorespiratory Exercise Programs

KEY QUESTIONS

- What are the basic components of an aerobic exercise prescription?
- How is the aerobic exercise prescription individualized to meet each client's goals and interests?
- What methods are used to prescribe and monitor exercise intensity?
- Which exercise modes are best suited for an aerobic exercise prescription?
- How often does a client need to exercise to improve and maintain aerobic fitness?
- How long does a client need to exercise to improve aerobic fitness?
- Is discontinuous aerobic training as effective as continuous training?
- How effective are multimodal, cross-training programs?
- What are the physiological benefits of aerobic exercise training?

Once you have assessed an individual's cardiorespiratory fitness status, you are responsible for planning an aerobic exercise program to develop and maintain the cardiorespiratory endurance of that program participant—a program that will meet the individual's needs and interests, taking into account age, gender, physical fitness level, and exercise habits. Appendix A.7, "Lifestyle Evaluation," provides forms that will help you determine your clients' exercise patterns and preferences.

In designing the exercise prescription, keep in mind that some people engage in aerobic exercise to improve their health status or reduce their disease risk, while others are primarily interested in enhancing their physical fitness ($\dot{V}O_2max$) levels. Given that the quantity of exercise needed to promote health is less than that needed to develop and maintain higher levels of physical fitness, you must adjust the exercise prescription according to your client's primary goal.

This chapter provides guidelines for writing individualized exercise prescriptions that promote health status as well as develop and maintain cardiorespiratory fitness. It compares various training methods and aerobic exercise modes, and presents examples of individualized exercise programs.

THE EXERCISE PRESCRIPTION

It is important to consider your client's goals and purposes for engaging in an exercise program. The primary goal for exercising may affect the mode, intensity, frequency, duration, and progression of the exercise prescription. For example, the quantity of physical activity needed to achieve health benefits or reduce one's risk of illness and death is less than the amount of activity typically prescribed when the client's goal is to make substantial improvements in cardiorespiratory fitness. When the primary goal for the exercise prescription is improved health, refer to "Guidelines for Exercise Prescription for Improved Health."

On the other hand, when the primary goal for the exercise prescription is to improve cardiorespiratory fitness, refer to "ACSM Guidelines for Exercise Prescription for Improved Health and Cardiorespiratory Fitness."

ELEMENTS OF A CARDIORESPIRATORY EXERCISE WORKOUT

Each exercise workout of the aerobic exercise prescription and program should include the following phases:

- Warm-up (5–10 min)
- Endurance conditioning (20–60 min)
- Cool-down (5–10 min)
- Stretching (≥10 min)

The purpose of the warm-up is to increase blood flow to the working cardiac and skeletal muscles, increase body temperature, decrease the chance of muscle and joint injury, and lessen the chance of abnormal cardiac rhythms. During the warm-up, the tempo of the exercise is gradually increased to prepare the body for a higher intensity of exercise performed during the conditioning phase. The warm-up starts with 5 to 10 min of low-intensity (<40% $\dot{V}O_2$reserve [$\dot{V}O_2$R]) to moderate-intensity (40–60% $\dot{V}O_2$R) aerobic activity (e.g., brisk walking for clients who jog or slow jogging for clients who run during their endurance conditioning phase).

During the endurance conditioning phase of the workout, the aerobic exercise is performed according to the exercise prescription following the **FITT-VP principle** (i.e., F = frequency; I = intensity; T = time, duration; T = type, mode of activity; V = volume, quantity; P = progression) (ACSM 2014). This phase usually lasts 20 to 60 min, depending on the exercise intensity. Exercise bouts of 10 min are acceptable as long as your client accumulates at least 20 min that day. The conditioning phase is followed immediately by the cool-down phase.

A cool-down phase immediately after endurance exercise is needed to reduce the risk of cardiovascular complications caused by stopping exercise suddenly. During cool-down, the individual continues exercising (e.g., walking, jogging, or cycling) at a low intensity for 5 to 10 min. This light activity allows the heart rate (HR) and blood pressure (BP) to return to near baseline levels, prevents the pooling of blood in the extremities, and reduces the possibility of dizziness and fainting. The continued pumping action of the muscles increases the venous return and speeds up the recovery process.

The stretching phase usually lasts at least 10 min and is performed after the warm-up or cool-down phase. Static stretching exercises for the legs, lower back, abdomen, hips, groin, and shoulders are usually included (for specific flexibility exercises, see appendix F.1). Stretching exercises after the cool-down phase may help to reduce the chance of muscle cramps or muscle soreness.

Guidelines for Exercise Prescription for Improved Health

The following guidelines are from the U.S. Department of Health and Human Services (2008).

1. Mode: Select endurance-type physical activities.
2. Intensity: Prescribe at least moderate-intensity physical activities (3 to 6 METs [metabolic equivalents]).
3. Frequency and duration: Schedule at least 150 to 300 min per week (e.g., 30 min, 5 days/wk or 60 min, 3 days/wk). Duration varies according to the type and intensity of activity (see "Examples of Moderate-Intensity and Vigorous-Intensity Aerobic Activities," chapter 1).

ACSM 2014 Guidelines for Exercise Prescription for Improved Health and Cardiorespiratory Fitness (FITT-VP)

1. Frequency: Schedule moderate-intensity exercise at least 5 days/wk; vigorous-intensity exercise at least 3 days/wk; or a combination of moderate- and vigorous-intensity exercise 3 to 5 days/wk.
2. Intensity: Prescribe moderate-intensity (3.0–6.0 METs or 40% to <60% $\dot{V}O_2R$ or HRR) or vigorous-intensity (>6.0 METs or ≥60% to 90% $\dot{V}O_2R$ or HRR) or a combination of moderate- and vigorous-intensity exercise. Intensity varies depending on client's cardiorespiratory fitness classification.
3. Progression: Gradually adjust the exercise prescription for each client in accordance with the conditioning effect, participant characteristics, new exercise test results, or performance during the exercise sessions. The rate of progression depends on the individual's age, functional capacity, health status, and goals. For apparently healthy adults, increases in duration of 5 to 10 min every 1 to 2 wk for the first 4 to 6 wk of their exercise program are reasonable. Typically, the aerobic exercise prescription consists of three stages: initial conditioning, improvement, and maintenance.
4. Time (Duration): Schedule 30 to 60 min of moderate-intensity exercise (≥150 $\text{min}\cdot\text{wk}^{-1}$), 20 to 60 min of vigorous-intensity exercise (≥75 $\text{min}\cdot\text{wk}^{-1}$), or a combination of moderate- and vigorous-intensity exercise to attain recommended targeted volumes of exercise.
5. Type (Mode): Select rhythmical aerobic activities that can be maintained continuously and that involve large muscle groups and require little skill to perform (see "Classification of Aerobic Exercise Modalities").
6. Volume (Quantity): For most adults, target approximately 1000 $\text{kcal}\cdot\text{wk}^{-1}$ moderate-intensity exercise or physical activity (150 min/wk at 3.0–6.0 METs or 40% to <60% $\dot{V}O_2R$). When combined with the recommended duration, daily pedometer step counts (≥5400 to 7900 $\text{steps}\cdot\text{day}^{-1}$) fulfill this category. An energy expenditure between 500 and 1000 $\text{MET}\cdot\text{min}\cdot\text{wk}^{-1}$ is the recommended quantity of exercise or physical activity for most adults. To compute **$\text{MET}\cdot\text{min}\cdot\text{wk}^{-1}$**, multiply the MET value of an activity by the number of minutes it is performed in the week.

TYPES (MODES) OF EXERCISE

If the primary goal of the exercise program is to develop and maintain cardiorespiratory fitness, prescribe aerobic activities using large muscle groups in a continuous, rhythmical fashion. In the initial and improvement stages of the exercise program, it is important to closely monitor the exercise intensity. Therefore, you should select modes of exercise that allow the individual to maintain a constant exercise intensity and that are not highly dependent on the participant's skill. **Type A activities** require minimal skill or physical fitness to perform. Activities such as walking, cycling, and aqua-aerobics are best suited for this purpose. **Type B activities** are vigorous-intensity exercises that require minimal skill but average physical fitness. Jogging, step aerobics, and spinning are examples of type B activities. You may prescribe type B activities in the initial and improvement stages for individuals who exercise regularly. **Type C activities** include endurance activities that require both skill and average physical fitness levels. Swimming, skating, and cross-country skiing should be prescribed only for individuals who have acquired these skills or who possess adequate physical fitness levels to learn these skills. **Type D activities** are recreational sports that may improve physical fitness. These should be performed in addition to the person's regular aerobic exercise program.

Examples of type D activities are racket sports, hiking, soccer, basketball, and downhill skiing. You should consider using type C and D activities to add variety in the later stages (maintenance stage) of your client's exercise program.

In addition to walking, jogging, and cycling, other exercise modalities provide a sufficient cardiorespiratory demand for improving aerobic fitness. Exercise modalities such as bench step aerobics, machine-based stair climbing, elliptical training, and rowing offer your exercise program participants a variety of options for their exercise prescription. Many individuals prefer to cross-train to add variety and enjoyment to their aerobic workouts. But are these exercise modes just as effective as traditional type A and B activities (walking, jogging, and cycling)? The answer to this question is not simple, and it depends on the method (%$\dot{V}O_2$max or perceived exertion) used to equate different exercise modalities.

During exercise at a prescribed percentage of $\dot{V}O_2$max, Thomas and colleagues (1995) noted that six different aerobic exercise modes (treadmill jogging, Nordic skiing, shuffle skiing, stepping, cycling, and rowing) produced relatively similar cardiovascular responses (see figure 5.1), but that cycling resulted in a significantly higher perceived exertion (RPE) compared to the other modes. Likewise, other researchers have reported that the relationship between HR and $\dot{V}O_2$ at constant, submaximal intensities was similar for treadmill jogging, in-line skating (Wallick et al. 1995), and aerobic dancing with arms used extensively above the head or kept below the shoulders (Berry et al. 1992). In contrast, Parker and colleagues (1989) reported that the average steady-state HR during 20 min of aerobic dancing was significantly higher than that for treadmill jogging when the subjects exercised at the same relative intensity (60% $\dot{V}O_2$max). Likewise, Howley, Colacino, and Swensen (1992) noted that HR response during electronic stepping ergometer exercise was systematically higher than that with treadmill exercise at the same submaximal $\dot{V}O_2$. Also, supporting the body weight during step ergometer exercise significantly reduced the HR and oxygen consumption compared to lightly holding on to the handrails for balance.

When exercise modes are equated using subjective RPEs, research suggests that treadmill jogging may be superior to other aerobic exercise modes in terms of total oxygen consumption and rate of energy expenditure (Hulsey et al. 2012; Kravitz, Robergs, and Heyward 1996; Kravitz et al. 1997b; Zeni, Hoffman, and Clifford 1996). Subjects exercising on seven different modalities at a somewhat hard (RPE = 13 or 14) intensity for 15 to 20 min experienced

CLASSIFICATION OF AEROBIC EXERCISE MODALITIES[a]

This list contains examples of moderate amounts of physical activity. More vigorous activities, such as stair walking and running, require less time (15 min). On the other hand, less vigorous activities, like washing and waxing the car, require more time (45–60 min).

Type A Activities
- Cycling (indoors)
- Walking
- Aqua-aerobics
- Slow dancing

Type B Activities
- Jogging and running
- Rowing[b]
- Stair climbing[b]
- Simulated climbing[b]
- Nordic skiing[b]
- Elliptical training[b]
- Spinning
- Fast dancing

Type C Activities
- Aerobic dancing
- Bench step aerobics
- In-line skating
- Nordic skiing (outdoors)
- Rope skiing
- Swimming

Type D Activities
- Basketball
- Downhill skiing
- Handball
- Racket sports
- Hiking
- Swimming

[a]Type A activities require minimal skill and physical fitness, type B activities require average physical fitness but minimal skill, type C activities require both skill and average physical fitness levels, and type D activities are recreational sports that should be prescribed only in addition to a regular, aerobic exercise program.

[b]Machine-based activities.

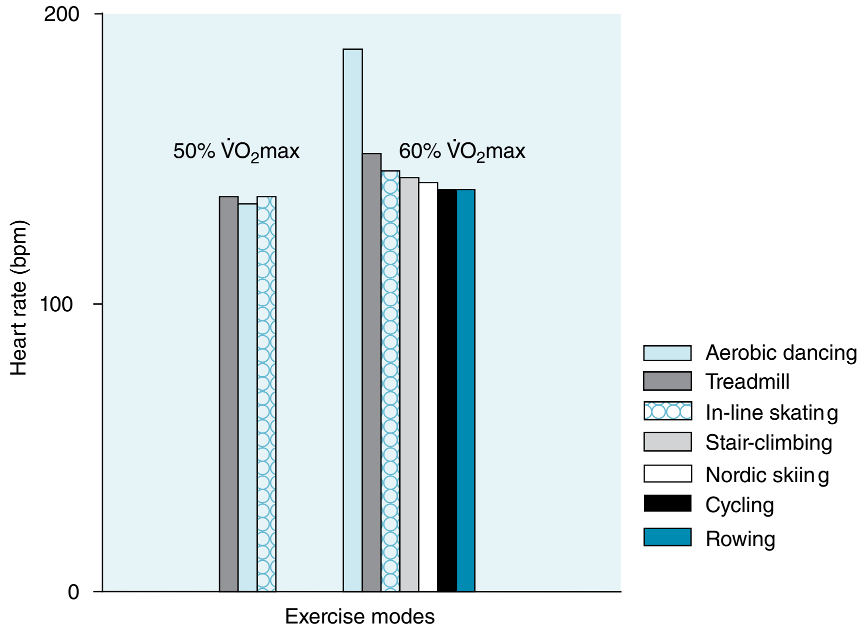


FIGURE 5.1 Comparison of steady-state heart rate response at submaximal exercise intensities for various aerobic exercise modes.

a greater total oxygen consumption for treadmill jogging compared to stepping, rowing, Nordic skiing, cycling, shuffle skiing, and aerobic riding (Kravitz et al. 1997b; Thomas et al. 1995). Also, the rate of energy expenditure during treadmill exercise was 20% to 40% greater than during stationary cycling (Kravitz et al. 1997b; Zeni et al. 1996), 57% greater than during aerobic riding (Kravitz et al. 1996, Kravitz et al. 1997b), 42% higher than arm crank exercise (Schrieks, Varnes, and Hodges 2011), and 25 to 39% greater than kettlebell swinging intervals (Hulsey et al. 2012). In addition, steady-state exercise HRs were higher (see figure 5.2) for treadmill jogging compared to cycling and aerobic riding (Kravitz et al. 1996; Kravitz et al. 1997b; Zeni et al. 1996). Also, the average net energy expenditure of young adults (18–28 yr; 29.1–55.2 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$) was 5.56 $kcal{\cdot}min^{-1}$ higher over 1600 m when running (160 $m{\cdot}min^{-1}$) compared to walking (86 $m{\cdot}min^{-1}$) on a treadmill (Wilkin, Cheryl, and Haddock 2012).

When selecting aerobic exercise modes for your client's exercise prescription, you should consider how easily the exercise intensity can be graded and adjusted in order to overload the cardiorespiratory system throughout the improvement stage. For aerobic dance and bench step aerobic exercise, work rates can be progressively increased by means of quicker cadences, different bench heights (Olson et al. 1991), and upper body exercise using light (1–4 lb [0.45–1.8 kg]) handheld weights (Kravitz et al. 1997a). The intensity of in-line skating can be effectively graded by increasing the skating velocity (Wallick et al. 1995). The intensity of rowing, stair climbing, and simulated whole-body climbing exercise can be incremented progressively using a variety of exercise machines (Brahler and Blank 1995; Howley et al. 1992).

Prescribe rope-skipping activities with caution; the exercise intensity for skipping 60 to 80 $skips{\cdot}min^{-1}$ is approximately 9 METs. This value exceeds the maximum MET capacity of most sedentary individuals. Also, the exercise intensity is not easily graded because doubling the rate of skipping increases the energy requirement by only 2 to 3 METs. Town, Sol, and Sinning (1980) reported an average energy expenditure of 11.7 to 12.5 METs for skipping at rates of 125, 135, and 145 $skips{\cdot}min^{-1}$. They concluded that rope skipping is a strenuous exercise that may not serve well as a form of graded aerobic exercise.

When selecting exercise modes for your older clients, you need to consider their functional aerobic capacity, musculoskeletal problems, and neuromuscular coordination (impaired vision or balance). Select activities that are enjoyable and convenient.

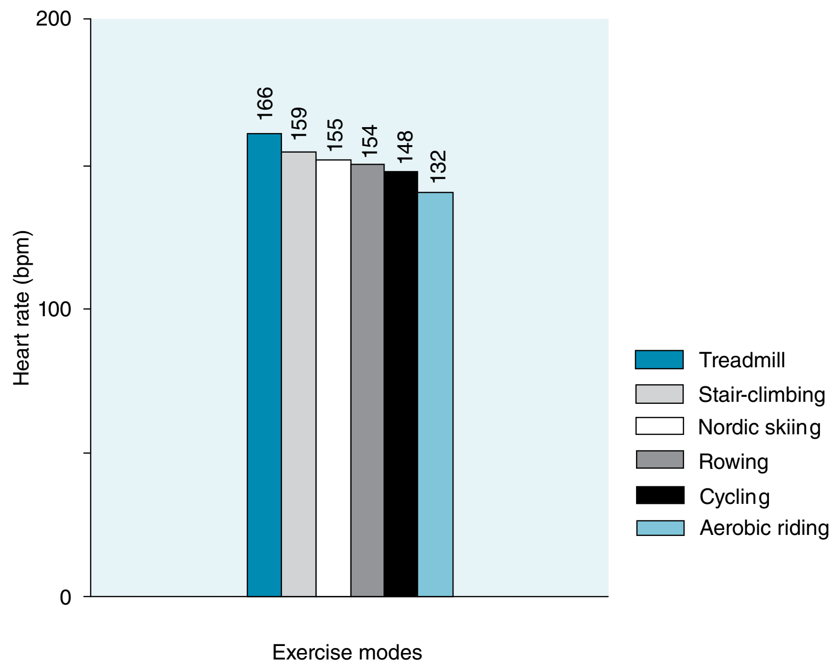


FIGURE 5.2 Comparison of steady-state heart rate response at somewhat hard intensity (rating of perceived exertion = 13 or 14) for various aerobic exercise modes.

For many older adults, walking is an excellent mode. Stationary cycling and aquatic exercise can be used for individuals with impaired vision or balance. Research suggests that tai chi increases balance, muscular strength, and flexibility as well as cardiorespiratory fitness ($\dot{V}O_2$peak) of older adults (Chewning, Yu, and Johnson 2000; Lan et al. 1998).

INTENSITY OF EXERCISE

Exercise intensity is a key factor in determining physiological adaptations to the exercise stimulus (Egan et al. 2010). Traditionally, exercise intensity has been expressed as a straight percentage of either the individual's maximal aerobic capacity ($\dot{V}O_2$max), peak oxygen consumption ($\dot{V}O_2$peak), or heart rate reserve (HRR). However, research has suggested that the %$\dot{V}O_2$ max is not equivalent (1:1 ratio) to the %HRR for cycling and treadmill exercise (Azevedo et al. 2011; Swain and Leutholtz 1997; Swain et al. 1998). The ACSM changed its recommendation regarding the method used to calculate exercise intensity for aerobic exercise prescriptions. Instead of expressing relative intensity as a straight percentage of $\dot{V}O_2$max (%$\dot{V}O_2$max), the ACSM recommends using the **percent $\dot{V}O_2$max reserve (%$\dot{V}O_2$R)**. The $\dot{V}O_2$R is the difference between the $\dot{V}O_2$max and resting oxygen consumption ($\dot{V}O_2$rest). With this modification, percent values for the %$\dot{V}O_2$R and %HRR methods for prescribing exercise intensity are approximately equal, thereby improving the accuracy of calculating a target $\dot{V}O_2$, particularly for clients who are engaging in low-intensity aerobic exercise (Swain 1999). There is individual variability in resting oxygen consumption; this introduces questions regarding the assumed constant (1 MET = 3.5 ml·kg^{-1}·min^{-1}) ascribed to $\dot{V}O_2$rest. Consequently, when it is available, the actual $\dot{V}O_2$rest should be used when determining $\dot{V}O_2$R (da Cunha, de Tarso Veras Farinatti, and Midgley 2011).

Regardless of the method used, intensity and duration of exercise are indirectly related. In other words, the higher the exercise intensity, the shorter the duration of exercise required and vice versa. Before prescribing the exercise intensity for aerobic exercise, carefully evaluate the individual's initial cardiorespiratory fitness classification, goals for the program, exercise preferences, and injury risks. Your client can improve cardiorespiratory fitness with either lower-intensity, longer-duration exercise or higher-intensity, shorter-duration exercise. For most individuals, low-to-moderate intensities of longer duration are recommended; higher-intensity exercise increases the risk of orthopedic injury and discourages continued participation in the exercise program.

Part of the art of exercise prescription is being able to select an exercise intensity that is adequate to stress the cardiovascular system without overtaxing it. According to the ACSM (2014), the initial exercise intensity for apparently healthy adults is 40% to <90% $\dot{V}O_2R$ or HRR, depending on their initial physical fitness classification (i.e., fair to excellent cardiorespiratory fitness level). Lower-intensity exercise (30–40% $\dot{V}O_2R$ or HRR) may be sufficient to provide important health benefits for sedentary clients or older individuals with poor initial cardiorespiratory fitness levels. For most individuals, intensities of 55% to 80% $\dot{V}O_2R$ are sufficient to improve cardiorespiratory fitness. As a general rule, the more fit the individual, the higher the exercise intensity needs to be to produce further improvement in cardiorespiratory fitness. In fact, Azevedo and colleagues (2011) reported that the ventilatory threshold for highly fit men (18–58 yr) occurred between 70% and 93% HRR. This finding suggests that highly fit individuals may require a higher exercise intensity than what is generally prescribed for the average adult. Exercise intensity can be prescribed using the $\dot{V}O_2$ reserve, HR, or RPE method.

$\dot{V}O_2$Reserve (MET) Method

First, measure the client's functional aerobic capacity ($\dot{V}O_2max$ or $\dot{V}O_2peak$) using a graded exercise test (see chapter 4). Express the client's $\dot{V}O_2max$ in relative terms, that is, $ml \cdot kg^{-1} \cdot min^{-1}$ or METs (metabolic equivalents). The $\dot{V}O_2R$ calculations presented here assume that 1 MET is approximately equal to 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. Therefore, given a $\dot{V}O_2max$ of 35 $ml \cdot kg^{-1} \cdot min^{-1}$, for example, the metabolic equivalent would be 10 METs (35 / 3.5 = 10 METs).

Next determine the **$\dot{V}O_2$reserve ($\dot{V}O_2R$)**. As mentioned previously, the $\dot{V}O_2R$ is the difference between $\dot{V}O_2max$ and $\dot{V}O_2rest$ ($\dot{V}O_2R = \dot{V}O_2max - \dot{V}O_2rest$). The percent of $\dot{V}O_2R$ depends on the initial cardiorespiratory fitness level of the client. To calculate the target $\dot{V}O_2$ (in METs) based on the $\dot{V}O_2R$, use the following equation:

$$\text{target } \dot{V}O_2 = [\text{relative exercise intensity (\%)} \times \dot{V}O_2R] + \dot{V}O_2rest$$

For example, the target $\dot{V}O_2$ corresponding to 50% $\dot{V}O_2R$ for a client with a $\dot{V}O_2max$ of 10 METs is calculated as follows:

$$\begin{aligned} \text{target } \dot{V}O_2 &= [0.50 \times (10 - 1 \text{ MET})] + 1 \text{ MET} \\ &= (0.50 \times 9 \text{ METs}) + 1 \text{ MET} \\ &= 4.5 + 1.0 \text{ METs, or } 5.5 \text{ METs} \end{aligned}$$

The exercise intensity (METs) for walking, jogging, running, cycling, and bench-stepping activities is directly related to the speed of movement, power output, or mass lifted. Use the ACSM equations (table 4.3) to calculate the speed or work rates corresponding to a specific MET intensity for the exercise prescription. For example, to estimate how fast a woman should jog on a level course to be exercising at an intensity of 8 METs, follow these steps:

1. Convert the METs to $ml \cdot kg^{-1} \cdot min^{-1}$.

$$\begin{aligned} \dot{V}O_2 &= 8 \text{ METs} \times 3.5 \ ml \cdot kg^{-1} \cdot min^{-1} \\ &= 28 \ ml \cdot kg^{-1} \cdot min^{-1} \end{aligned}$$

2. Substitute known values into the ACSM running equation and solve for speed.

$$28 \ ml \cdot kg^{-1} \cdot min^{-1} = [\text{speed } (m \cdot min^{-1}) \times 0.2] + 3.5 \ ml \cdot kg^{-1} \cdot min^{-1}$$

$$\begin{aligned} 28.0 \ ml \cdot kg^{-1} \cdot min^{-1} - 3.5 &= \text{speed } (m \cdot min^{-1}) \times 0.2 \\ 122.5 \ m \cdot min^{-1} &= \text{speed} \end{aligned}$$

3. Convert speed to mph.

$$1 \text{ mph} = 26.8 \ m \cdot min^{-1}$$

$$122.5 \ m \cdot min^{-1} / 26.8 \ m \cdot min^{-1} = 4.57 \text{ mph}$$

4. Convert mph to minute per mile pace.

$$\begin{aligned} \text{pace} &= 60 \text{ min/hr} / \text{mph} \\ &= 60 \text{ min/hr} / 4.57 \text{ mph} \\ &= 13.1 \ min \cdot mi^{-1} \text{ (or } 8.1 \ min \cdot km^{-1}) \end{aligned}$$

Average MET values for selected conditioning exercises, sports, and recreational activities are presented in appendix E.4, "Gross Energy Expenditure for Conditioning Exercises, Sports, and Recreational Activities." When estimating MET values for children and adolescents, use the compendium of energy expenditures (MET values) developed for youth (see Ridley, Ainsworth, and Olds 2008). Prescribing exercise intensity using only MET values has certain limitations. The caloric costs (i.e., average MET values) of conditioning exercises are only estimates of energy expenditure. The caloric costs of activities, particularly type C activities, vary greatly with the individual's skill level. Although these MET estimates provide a starting point for prescribing exercise intensity, environmental factors such as heat, humidity, altitude, and pollution may alter the HR and RPE responses to exercise. Therefore, you should use the HR or RPE method along with the MET method to ensure that the exercise intensity does not exceed safe limits.

Heart Rate Methods

There are three ways to prescribe exercise intensity for your clients using HR data. Each of these approaches is based on the assumption that HR is a linear function of exercise intensity (i.e., the higher the exercise intensity, the higher the HR).

Heart Rate Versus MET Graphing Method

When a submaximal or maximal graded exercise test (GXT) is administered, the client's steady-state HR response to each stage of the exercise test can be plotted (see figure 5.3). The HRmax is the HR observed at the highest exercise intensity during a maximal GXT. For submaximal GXTs, you can estimate your client's HRmax using one of the age-predicted HRmax formulas (e.g., 220 – age). From this graph, you can obtain HRs corresponding to given percentages of the estimated functional capacity or $\dot{V}O_2$max. In our example, the functional capacity of the individual is 7.4 METs, and the HRmax is 195 bpm. The HRs corresponding to exercise intensities of 4.8 and 6.4 METs (60–85% $\dot{V}O_2$R) are 139 and 175 bpm, respectively. During exercise workouts, the individual should measure the HR using an HR monitor or palpation to verify that the appropriate exercise intensity is reached.

It is important to note that the HR response to graded exercise is dependent to some extent on the mode of exercise testing. For example, compared to treadmill testing, exercising on an electronic step ergometer elicits higher HRs, and stationary cycling typically results in somewhat lower HRs at the same relative exercise intensities. When using this method to obtain HRs for an exercise prescription, be sure to match the exercise testing and training modes by selecting a testing mode that elicits HR responses that are similar to those obtained for the

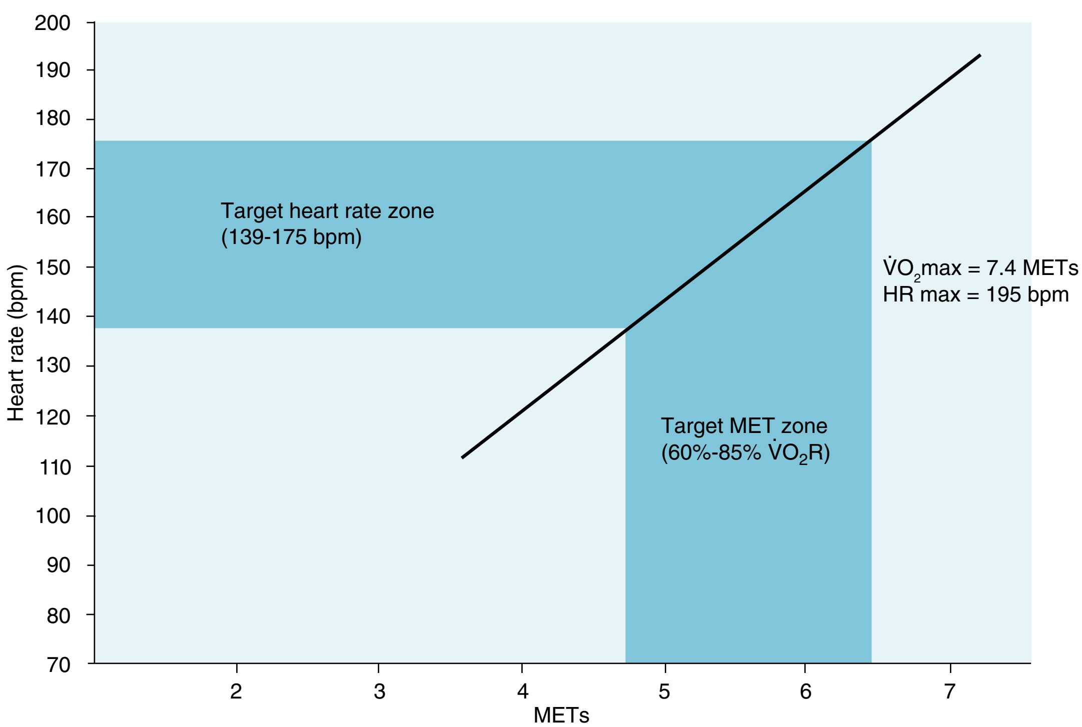


FIGURE 5.3 Plotting target heart rate zone using graded exercise test data (heart rate vs. METs). HRmax = maximal heart rate; $\dot{V}O_2$R = oxygen reserve.

training mode (see figure 5.1). For example, if your client chooses in-line skating as a training mode, you should administer a treadmill GXT, given that the relationship between HR and $\dot{V}O_2$ at submaximal exercise intensities is similar for these two exercise modes (Berry et al. 1992).

Heart Rate Reserve Method

When HR data from a GXT are not available, you can use the **Karvonen method**, or **percent heart rate reserve (%HRR) method**, to determine target HRs for your client's exercise prescription. The **heart rate reserve (HRR)** method takes into account the resting HR and maximal HR. The HRR is the difference between the maximal HR and resting HR. A percentage of HRR is added to the client's resting HR to determine the target exercise HR:

$$\text{target HR} = [\%\text{ exercise intensity} \times (\text{HRmax} - \text{HRrest})] + \text{HRrest}$$

As previously mentioned, the percent values for the HRR method closely approximate the percent values for the $\dot{V}O_2R$ method (Azevedo et al. 2011; Lounana et al. 2007; Swain and Leutholtz 1997). The ACSM (2014) recommends using 40% to <90% HRR. For example, if

$$\text{maximal HR} = 178\text{ bpm},$$

$$\text{resting HR} = 68\text{ bpm, and}$$

$$\text{exercise intensity} = 60\%\text{ HRR, then}$$

$$\text{target exercise HR} = 0.60(178 - 68) + 68 \text{ or } 134\text{ bpm.}$$

Percentage of Maximal Heart Rate Method

You also can use a straight percentage of maximal HR (**percent heart rate maximum, %HRmax**) to estimate exercise intensity and determine target exercise HR. This method is based on the fact that the %HRmax is related to % $\dot{V}O_2R$ and %HRR. In table 5.1, we can see that 67% and 94% HRmax correspond to exercise intensities of 45% and 85% $\dot{V}O_2R$ or HRR. Using this method, you will typically prescribe target HRs between 64% and 96% HRmax depending on the fitness level of your client.

With use of this technique, the actual maximal HR must be known or must be predicted either from the HR response to submaximal workloads or from the HRmax prediction equations such as 220 – age or 206.9 – (0.67 × age). For example, if the age-predicted maximal HR is 180 bpm and the exercise intensity is set at 70% HRmax, the target exercise HR is equal to 126 bpm.

$$\%\text{HRmax} \times \text{HRmax} = \text{target HR}$$

$$0.70 \times 180\text{ bpm} = 126\text{ bpm}$$

Compared to the Karvonen (%HRR) method, the %HRmax method tends to give a lower value when the same relative intensity is used. If in our example the client's resting HR is 80 bpm, the target HR using the Karvonen method is 150 bpm [0.70 × (180 – 80) + 80 bpm] compared to 126 bpm for the %HRmax method.

Limitations of Heart Rate Methods

Exclusive use of HR to develop intensity recommendations for your client's exercise prescription may lead to large errors in estimating relative exercise intensities (%$\dot{V}O_2R$) for some individuals. This is especially true when HRmax is predicted from age (220 – age) instead of being directly measured. In about 30% of the population, an age-predicted prescription of 60% HRR may be as low as 70% or as high as 80% of the actual HRmax (Dishman 1994). Measured HRmax varies with exercise mode. Therefore, your client's perceived effort may differ among exercise modes even during exercise at the same submaximal HR. Also, medications, emotional

Table 5.1 Comparison of Methods for Prescribing Exercise Intensity for Healthy Adults

CR fitness classification	%HRR or %$\dot{V}O_2R$	%HRmax	RPE
Poor	30-45	57-67	Light-moderate
Fair	40-55	64-74	Light-moderate
Average	55-70	74-84	Moderate-hard
Good	65-80	80-91	Moderate-hard
Excellent	70-< 90	84-96	Somewhat hard-hard

HRR = heart rate reserve; RPE = rating of perceived exertion.

states, and environmental factors (e.g., temperature, humidity, and air pollution) can affect your client's exercise training HRs. You should consider using RPEs to adjust the exercise intensity in such situations.

Ratings of Perceived Exertion Method

In light of the limitations associated with using HR for setting exercise intensity, consider using a combination of HR and RPE in developing prescriptions for your clients. You can use RPEs to prescribe and monitor exercise intensity (Birk and Birk 1987). The ACSM (2014) recommends the use of RPE values (10-point scale) to prescribe exercise intensity for older adults (moderate intensity: 5 to 6; vigorous intensity: 7 to 8). The RPE scales (see table 4.2 and appendix B.4) are valid and reliable tools for assessing the level of physical exertion during continuous aerobic exercise (Birk and Birk 1987; Borg and Linderholm 1967; Dunbar et al. 1992; Guidetti et al. 2011; Krause et al. 2012; Mays et al. 2010; Robertson 2004; Scherr et al. 2012).

During the GXT, the client rates the intensity of each stage of the test using a RPE scale. You can use the intensities (METs) corresponding to somewhat hard (6 on OMNI scale or 12 on Borg RPE scale) to hard (8 on OMNI scale or 16 on Borg RPE scale) to set the minimum and maximum training intensities for the exercise prescription. Compared to the %HRR method, RPEs between 12 and 16 closely approximate 40% and 84% HRR, respectively (Pollock et al. 1998). Strong correlations between the OMNI-RPE and $\dot{V}O_2$ (r = 0.93–0.96) as well as HR (r = 0.96–0.97) and the Borg RPE scale (r = 0.96–0.98) were reported (Mays et al. 2010). Similarly, Scherr and colleagues (2012) reported a correlation between RPE (6–20 scale) and blood lactate (r = 0.84 for a quadratic regression) that was higher than that between RPE and HR (r = 0.74 for a linear regression); their sample consisted of 2560 Caucasians (13–83 yr) who were classified as either sedentary (failed to meet the ACSM's recommended guidelines for physical activity) or athletic (performed at least 10 hr of exercise weekly or were members of a national team). As reported by Scherr and colleagues (2012), the relationships between RPE and associated exercise intensity variables (HR or blood lactate) were strong and independent of gender, medical history, age, level of physical activity, and testing modality (treadmill or stationary cycle).

With practice, an individual can learn to associate RPE with a specific target exercise HR, especially at higher exercise intensities (Smutok, Skrinar, and Pandolf 1980). Thus, the RPE can be used instead of HR, or in combination with HR, to monitor training intensity and to adjust the exercise prescription for conditioning effects. Parfitt, Evans, and Eston (2012) reported that sedentary clients are able to successfully use RPE to monitor their exercise intensity. Those who exercised 3 days/wk at an RPE of 13 (somewhat hard) on the Borg 6–20 scale improved their aerobic capacity by 17% in 8 wk. Moreover, the majority of the exercise intervention group perceived their exercise sessions as being pleasant and reported that their selected exercise intensity felt good (Parfitt, Evans, and Eston 2012). Interestingly, Scherr and colleagues (2012) confirmed that an RPE in the range of 11 to 13 is appropriate for untrained or less-fit individuals, while those with higher levels of fitness would benefit from aerobic training in the RPE range of 13 to 15. Compared to men, women are more likely to overestimate RPE, especially if the women are infrequent exercisers. In contrast, men and regular exercisers tend to underestimate their level of physical activity compared to accelerometry data (Skatrud-Mickelson et al. 2011). Consequently, as an exercise professional, you must remain aware that some of your clients may likely misestimate their level of exertion.

One advantage of RPE as a method of monitoring exercise intensity is that your clients do not need to stop exercising in order to check their HRs. Unfortunately, exercising at a given RPE value produces very different metabolic responses when performing kettlebell swings (34.1 $ml \cdot kg^{-1} \cdot min^{-1}$) compared to treadmill running (46.7 $ml \cdot kg^{-1} \cdot min^{-1}$) (Hulsey et al. 2012). For an extensive review of research pertaining to the use of perceived exertion for prescribing exercise intensity, see the studies of Dishman (1994) and Robertson (2004). Parfitt and colleagues (2012) describe how allowing clients to select their exercise intensity based on RPE theoretically supports the sense of self-determination and perception of exercise autonomy, both of which may improve client adherence to an exercise prescription.

Monitoring Exercise Intensity

Throughout the aerobic exercise program, carefully monitor exercise intensity in order to ensure your client's safety and to confirm that your client is exercising at or near the prescribed intensity. The HR and RPE methods can be used for this purpose. Teach your clients how to monitor exercise intensity using HR palpation techniques (see chapter 2), HR monitors, and the RPE scales (see table 4.2).

Research assessing the validity and reliability of using motion and physiological response monitors to track exercise intensity for a variety of exercise modalities is ongoing. Some exercise modalities are more suitable than others when monitoring HR via technology. In addition to working well for land-based exercise, some HR monitors work well in fresh water (e.g., swimming pools) but must be waterproofed for use in salt water (i.e., swimming in the ocean). Raffaelli and colleagues (2012) reported that monitoring intensity during water aerobics is better done by HR palpation than accelerometry.

Some clients may prefer using a talk test to monitor their exertion. The **talk test** is a measure of the client's ability to converse comfortably while exercising, and it is based on the relationship between exercise intensity and pulmonary ventilation. **Pulmonary ventilation**, or the movement of air into and out of the lungs, increases linearly with exercise intensity ($\dot{V}O_2$) up to a point. At the breaking point, known as the **ventilatory threshold**, pulmonary ventilation increases exponentially relative to the exercise intensity and rate of oxygen consumed. At the ventilatory threshold, it becomes difficult to speak during exercise. However, Quinn and Coons (2011) found that the talk test was more strongly associated with **lactate threshold** (exercise intensity at which blood lactate value increases by at least 1 $mmol \cdot L^{-1}$ compared to the previous blood sample) and RPE than with the ventilatory threshold in young men. Studies of college-age students (Persinger et al. 2004), clinically stable cardiac patients (Voelker et al. 2002), and athletes (Jeans et al. 2011; Recalde et al. 2002) showed that individuals who pass the talk test are exercising at intensities that are within the accepted guidelines for the exercise prescription. Those failing the talk test are exercising at intensities that exceed the prescribed level. The talk test provides a fairly precise and consistent method for monitoring exercise during stationary cycling and treadmill exercise (Persinger et al. 2004).

Similarly, the **counting talk test (CTT)** is an objective method for monitoring exercise intensity (Loose et al. 2012). The counting talk test is normalized relative to how far one can count during rest; following a maximal inhalation, one begins counting at a comfortable pace (i.e., one one-thousand, two one-thousand, and so on). The highest digit counted prior to a second inhalation is the number (CTT_{rest}) used for future exercise intensity determinations. During exercise, the counting procedure is repeated with the highest number spoken before breathing again divided by the baseline value to derive a $\%CTT_{rest}$. Exercising at 30% to 40% CTT_{rest} or 40% to 50% CTT_{rest} is equivalent to being in the moderate- to vigorous-intensity range for those with a CTT_{rest} of at least 25 or <25, respectively. The CTT is reliable as well as significantly and inversely related to %HRR and RPE ($r = -0.64$ to -0.77) for walking, stationary cycling, elliptical training, and stair stepping (Loose et al. 2012).

FREQUENCY OF EXERCISE

The frequency of the exercise sessions depends on your client's caloric goals, health and fitness level, preferences, and time constraints. For health benefits, individuals should exercise at a moderate intensity at least 5 days per week. Individuals with fair to excellent cardiorespiratory fitness levels should exercise at a moderate to vigorous intensity a minimum of three times per week to produce significant changes in aerobic endurance (ACSM 2014). Individuals with poor cardiorespiratory fitness levels should exercise at light to moderate intensities a minimum of 5 days a week. Multiple daily exercise bouts of at least 10 min duration each may be prescribed for sedentary clients having poor aerobic fitness.

In terms of improving $\dot{V}O_2max$, the sequence of exercise sessions seems to be less important than the total work (volume) performed during the training. Similar improvements were noted for individuals who trained every other day (M-W-F) and three consecutive days (M-T-W) (Moffatt, Stamford, and Neill 1977). The ACSM (2014) recommends exercising on alternate days during the initial stages of training to lessen the chance of bone or joint injury.

Also, older adults who can tolerate vigorous exercise should work out at least 3 days/wk, with a day of rest between each exercise session (ACSM 2014).

TIME (DURATION) OF EXERCISE

As an exercise specialist, you must prescribe an appropriate combination of exercise intensity and duration so that the individual adequately stresses the cardiorespiratory system without overexertion. As mentioned earlier, the intensity and duration of exercise are inversely related (the lower the exercise intensity, the longer the duration of the exercise). The ACSM (2014) recommends 20 to 60 min of continuous or intermittent activity. Apparently healthy individuals usually can sustain exercise intensities of 60% to <90% $\dot{V}O_2R$ for 20 to 30 min. To improve functional capacity ($\dot{V}O_2max$), exercise of moderate intensity and duration (30–60 min) is recommended for most adults (ACSM 2014). During the improvement stage, duration can be increased every 2 to 3 wk until participants can exercise continuously for 30 min at a moderate to vigorous intensity (ACSM 2014). Poorly conditioned and older individuals may be able to exercise continuously at a low intensity (<40% $\dot{V}O_2R$) for only 5 to 10 min. They may need to perform multiple sessions (e.g., two or three 10 min exercise bouts) in a given day to accumulate 20 to 30 min of aerobic exercise.

An alternative way of estimating the duration of exercise is to use the caloric cost of the exercise. To achieve health benefits, ACSM (2014) recommends targeting a minimum of 150 min/wk of moderate-intensity exercise; this is equivalent to a minimal weekly caloric threshold of 1000 kcal from physical activity or exercise. Consequently, you may target **caloric thresholds** of 150 to 400 kcal·day^{-1}; however, be aware that the ACSM (2014) cautions against using absolute exercise intensities (e.g., kcal·min^{-1}) since they do not account for individual differences in body weight, fitness level, or gender.

During the initial stage of the exercise program, however, weekly exercise caloric expenditure may be considerably lower (200–600 kcal·wk^{-1}). To attain 300 min/wk of moderate-intensity exercise in the improvement stage, your client's caloric expenditure must increase from 1000 to 2000 kcal·wk^{-1}. This can be accomplished by gradually increasing the frequency, intensity, and duration of the exercise. For example, in order for a 60 kg (132 lb) woman who is exercising at an intensity of 7 METs five times per week to reach a weekly net caloric threshold of 1500 kcal·wk^{-1}, she needs to expend 300 kcal per exercise session (1500 kcal / 5 = 300 kcal). You can estimate the gross caloric cost of her exercise (kcal·min^{-1}) using the following formula:

$$\text{gross caloric cost (kcal·min}^{-1}) = \text{METs} \times 3.5 \times \text{body mass in kg} / 200$$

To calculate the net caloric expenditure from her activity, subtract the resting oxygen consumption (1 MET) from the gross $\dot{V}O_2$ ($\dot{V}O_2$ cost of exercise +$\dot{V}O_2$rest) and substitute this value (7 – 1 = 6 METs) into the equation:

$$\text{net caloric cost} = 6\text{ METs} \times 3.5 \times 60\text{ kg} / 200$$
$$= 6.3\text{ kcal·min}^{-1}$$

Therefore, she needs to exercise approximately 48 min (300 kcal / 6.3 kcal·min^{-1}), five times per week, in order to achieve her weekly net caloric expenditure goal of 1500 kcal.

Santos and colleagues (2012) investigated the influence of body mass (60–100 kg) and fitness levels (16.4–61.2 ml·kg^{-1}·min^{-1}) on the energy expenditure and exercise program recommendations endorsed by the ACSM. Santos and colleagues derived equations for estimating individualized training intensity (%$\dot{V}O_2R$), duration (min/wk), frequency (days/wk), and weekly energy expenditure (kcal·wk^{-1}) to account for individual variability in a given exercise session. The energy expenditure equation suggested by the ACSM (2014) overestimated energy expenditure for individuals with low aerobic fitness levels while underestimating energy expenditure for everyone else. For additional information about their suggested adjustments to the ACSM equations and how these adjustments were derived, see Santos and colleagues (2012).

VOLUME OF EXERCISE

The frequency, intensity, and time of exercise determine the quantity or **volume of exercise**. The **MET·min** is an index of energy expenditure and is calculated by multiplying the MET value of activities by the number of minutes the activity is performed per week (e.g., 6 METS × 150 min = 900 MET·min·wk^{-1}). Using this measure of exercise volume, the total amount of physical activity can be standardized across individuals and types of activities (ACSM 2014). The ACSM (2014) recommends >500-1000 MET·min·wk^{-1} as a target volume of exercise for adults. This volume is equivalent to moderate-intensity (3 to 6 METs) exercise for about 150 min·wk^{-1}.

In addition, pedometers (see Chapter 3) can be used to quantify the amount of exercise. Total step counts of 5400 to 7900 steps per day meet the physical activity recommendations for most adults. Walking 1 mi at a moderate intensity (100 steps·min^{-1}) yields about 3000 to 4000 steps on average. It is best to use pedometer counts in combination with recommended time and duration of exercise (e.g., 100 steps·min^{-1}) for 30 min and 150 min·wk^{-1}.

PROGRESSION OF EXERCISE

Physiological changes associated with aerobic endurance training (see "Physiological Changes Induced by Cardiorespiratory Endurance Training") enable the individual to increase the total work performed. The greatest conditioning effects occur during the first 6 to 8 wk of the exercise program. Aerobic endurance may improve as much as 3% per week during the first month, 2% per week for the second month, and 1% per week or less thereafter. For continued improvements, the cardiorespiratory system must be overloaded through adjustments in the intensity and duration of the exercise to the new level of fitness. The degree and rate of improvement depend on the age, health status, and initial fitness level of the participant. For the average person, aerobic training programs generally produce a 5% to 20% increase in $\dot{V}O_2$max (Pollock 1973). Sedentary, inactive persons may improve as much as 40% in aerobic fitness, while elite athletes may improve only 5% because they begin at a level much closer to their genetic limits. We do not expect older individuals entering the exercise program to improve as quickly as younger individuals even when the initial fitness levels are the same.

STAGES OF PROGRESSION

As discussed in chapter 3, the three stages of progression for cardiorespiratory exercise programs are the initial conditioning, improvement, and maintenance stages.

Initial Conditioning

The **initial conditioning stage** may last 1 to 6 wk, depending on your client's rate of adaptation to the exercise program. In this stage, each exercise session should include a warm-up, moderate-intensity (3–6 METs) aerobic activity, low-intensity muscular fitness exercises, and a cool-down that emphasizes stretching exercises (ACSM 2006). Clients starting a moderate-intensity aerobic conditioning program should exercise a minimum of 3 days/wk. The duration of the aerobic exercise should be at least 20 min and progress to 30 min. After clients are able to sustain aerobic activity at 55% to 60% HRR for 30 min, they progress to the improvement stage.

Improvement

The **improvement stage** usually lasts 4 to 8 mo. During this stage, the rate of progression is more rapid. Intensity, duration, and frequency of exercise should always be increased independently. Either duration or frequency should be increased before intensity is increased. Increase the duration no more than 10 minutes per session every week or two in the first month until your clients are able to sustain moderate-to-vigorous exercise for 20 to 30 min. Frequency should progress from 3 to 5 days/wk. Once the desired duration and frequency are reached, the exercise intensity may be increased gradually to reduce the likelihood of injury, soreness, and overtraining (ACSM 2014).

Rate of progression during this stage depends on a number of factors. Cardiac patients, older adults, and less-fit individuals may need more time for the body to adapt to a higher conditioning intensity. Ultimately, older or less-fit adults should strive to achieve 30 to 60 min/day of moderate-intensity activity (5 or 6 on a 10 pt RPE scale) or 20 to 30 min/day of vigorous-intensity activity (>6 on a 10 pt RPE scale) or any equal combination thereof.

PHYSIOLOGICAL CHANGES INDUCED BY CARDIORESPIRATORY ENDURANCE TRAINING

Cardiorespiratory System

Increases	Decreases
Heart size and volume	Resting heart rate
Blood volume and total hemoglobin	Submaximal exercise heart rate
Stroke volume—rest and exercise	Blood pressure (if high)
Cardiac output—maximum	
$\dot{V}O_2max$	
Oxygen extraction from blood	
Lung volume	

Musculoskeletal System

Increases

Mitochondria—number and size

Myoglobin stores

Triglyceride stores

Oxidative phosphorylation

Other Systems

Increases	Decreases
Strength of connective tissues	Body weight (if overweight)
Heat acclimatization	Body fat
High-density lipoprotein cholesterol	Total cholesterol
Mood	Low-density lipoprotein cholesterol
Cognitive function	Depression
	Incidence of Alzheimer's disease

Maintenance

After achieving the desired level of cardiorespiratory fitness, an individual enters the **maintenance stage** of the exercise program. This stage continues on a regular, long-term basis if the individual has made a lifetime commitment to exercise.

The goal of this stage is to maintain the cardiorespiratory fitness level and the weekly exercise caloric expenditure achieved during the improvement stage. Have your client accomplish this goal by engaging in aerobic activities 3 to 5 days/wk at the intensity and duration that were reached at the end of the improvement stage. Reducing the training frequency from 5 to 3 days/wk does not adversely affect $\dot{V}O_2max$ as long as the training intensity remains the same. However, clients should participate in other activities an additional 2 or 3 days/wk. To this end, a variety of enjoyable activities from the type C and D classifications may be selected to counteract boredom and to maintain the interest level of the participant. For example, an individual who was running 5 days/wk at the end of the improvement stage may choose to run only 3 days/wk and substitute in-line skating and racquetball on the other 2 days.

AEROBIC TRAINING METHODS AND MODES

Either continuous or discontinuous training methods can improve cardiovascular endurance. **Continuous training** involves one continuous aerobic exercise bout performed at low-to-moderate intensities without rest intervals. **Discontinuous training** consists of several intermittent low- to high-intensity exercise bouts interspersed with rest periods. Both training methods produce significant improvements in $\dot{V}O_2$max (Morris et al. 2002). Research suggests that when the volume of exercise is controlled, high-intensity endurance interval training (90–95% HRmax; 95% $\dot{V}O_2$R) improves $\dot{V}O_2$max more than continuous, moderate-intensity (70% HRmax; 50% $\dot{V}O_2$R) aerobic exercise training in healthy adults (Gormley et al. 2008; Helgerud et al. 2007). However, one concern about high-intensity intermittent training is the possibility of exercise burnout. Pollock and colleagues (1977) reported that the dropout rate of adults in a high-intensity interval (discontinuous) training program was twice that of those in a continuous jogging program. Thus, for the typical client, **high-intensity interval training** may be better suited for stimulating short-term (e.g., 4 wk) improvements in cardiorespiratory fitness and for adding variety to the exercise program. Future research needs to address the long-term health benefits of interval training and its effects on exercise adherence for the general population.

CONTINUOUS TRAINING

All of the exercise modes listed as type A or B activities (see "Classification of Aerobic Exercise Modalities") are suitable for continuous training. One advantage of continuous training is that the prescribed exercise intensity (e.g., 75% HRR) is maintained fairly consistently throughout the duration of the steady-paced exercise. Generally, continuous exercise at low-to-moderate intensities is safer, more comfortable, and better suited for individuals initiating an aerobic exercise program.

Walking, Jogging, and Cycling

The most popular modes of continuous training are walking, jogging or running, and cycling. Exercise programs using walking, jogging, and cycling provide similar cardiovascular benefits (Pollock, Cureton, and Greninger 1969; Pollock et al. 1971, 1975; Wilmore et al. 1980). Improvements in $\dot{V}O_2$max are comparable for most commonly used exercise modes. Pollock and colleagues (1975) compared running, walking, and cycling exercise programs of middle-aged men who trained at 85% to 90% HRmax. All three groups showed significant improvements in $\dot{V}O_2$max. These results indicate that improvement in $\dot{V}O_2$max is independent of the mode of training when frequency, intensity, and duration of exercise are held constant and are prescribed in accordance with sound, scientific principles.

Aerobic Dance

Since the early 1970s, aerobic dance has continued to be a popular mode of exercise for improving and maintaining cardiorespiratory fitness. A number of excellent books provide detailed information about aerobic dance methods and techniques (Kuntzelman 1979; Wilmoth 1986). A typical aerobic dance workout consists of 8 to 10 min of stretching, calisthenics, and low-intensity exercise. This is followed by 15 to 45 min of either high- or low-impact aerobic dancing at the target training intensity. Handheld weights (1–4 lb [0.45–1.8 kg]) can be used to increase exercise intensity. Heart rates should be monitored at least six times during the exercise to ensure that the HR stays within the target zone. The 10 min cool-down period usually includes more stretching and calisthenic-type exercises.

Several studies conducted to assess the cardiorespiratory effect of aerobic dance training have documented average increases in $\dot{V}O_2$max of 10% or greater (Blessing et al. 1987; Milburn and Butts 1983; Parker et al. 1989; Williford et al. 1988). Milburn and Butts (1983) reported that aerobic dance was as effective as jogging for improving cardiorespiratory endurance when performed at similar intensity, frequency, and duration. The subjects trained 30 min, 4 days/wk for 7 wk, at 83% to 84% HRmax.

Bench Step Aerobics

Health and fitness clubs throughout the United States are promoting bench step training as an effective high-intensity, low-impact aerobic exercise mode. Step training uses whole-body movements on steps or benches, ranging in height from 4 to 12 in. (10.2–30.5 cm). Choreographed movement routines are performed to music. A typical bench step aerobic workout consists of 5 to 10 min of warm-up and 20 to 30 min of step training. This is followed by a short (3–5 min) cool-down.

Exercise training intensity can be graded through use of variations in stepping cadence or bench height. To reduce the risk of injury during stepping on and off the bench, bench heights of 6 to 8 in. (15.2–20.3 cm) and stepping cadences ranging from 118 to 128 steps·min^{-1} are recommended. In terms of energy expenditure, increasing bench height is more effective than increasing cadence. In a study comparing the energy expenditure of bench stepping at two different cadences (125 vs. 130 steps·min^{-1}) and bench heights (6 vs. 8 in., or 15.2 vs. 20.3 cm), there was no significant difference in energy expenditure (kcal·min^{-1}) between the two different cadences. Increasing bench height from 6 to 8 in. (15.2–20.3 cm), however, increased energy expenditure by 1.04 kcal·min^{-1} (Grier et al. 2002). Thus, it is more effective to alter the intensity of a typical aerobic stepping routine by increasing the step height than by increasing the stepping cadence.

Studies confirm that continuous step training at bench heights ranging from 6 to 12 in. (15.2–30.5 cm) provides an adequate training stimulus that meets current ACSM (2014) guidelines for intensity and duration (Olson et al. 1991; Petersen et al. 1993; Woodby-Brown, Berg, and Latin 1993). Monitoring the physiological responses of clients participating in step training is advised because those who are shorter or obese may be exercising at a higher training intensity than recommended, especially when stepping at higher bench heights (Hansen et al. 2011). Following 8 to 12 wk of step aerobic training, $\dot{V}O_2$max improves as much as 16% (Kravitz et al. 1993; Kravitz et al. 1997a; Velasquez and Wilmore 1992). In a study comparing bench step exercise with and without hand weights, use of 2 to 4 lb (0.9–1.8 kg) hand weights did not result in a greater improvement in $\dot{V}O_2$max than step training without hand weights (Kravitz et al. 1997a).

Step Ergometry and Stair Climbing

Step ergometry (machine-based stair climbing) is a popular exercise mode in health and fitness clubs. Research shows a linear HR response to graded submaximal exercise performed on stair climbing ergometers. However, the MET levels displayed on the StairMaster 4000 PT overestimate the actual MET intensity of the exercise (Howley et al. 1992). When prescribing exercise intensity using this type of stair climber, be certain to adjust the machine's estimates for each MET level using the following equation:

$$\text{actual METs} = 0.556 + 0.745\ (\text{StairMaster MET setting})$$

Although machine-based stair climbing provides a training stimulus that meets guidelines for exercise intensity, there are relatively few studies comparing the effectiveness of stair climbing training to other aerobic training modes (Howley et al. 1992; Thomas et al. 1995).

Elliptical Training

Elliptical training machines have become popular in the fitness industry. Elliptical trainers are designed for either upper body or combined upper and lower body exercise. The lower body motion during exercise on an elliptical trainer is a cross between the actions performed with machine-based stair climbing and upright stationary cycling. With elliptical trainers, the feet move in an egg-shaped or elliptical pattern, and the feet stay in contact with the footpads of the device throughout the exercise. Unlike running or jogging, this form of exercise may provide a high-intensity workout with low-impact forces comparable to those for walking (Porcari, Foster, and Schneider 2000). Although there is no research documenting the long-term effects of this type of training, preliminary data suggest that this exercise modality meets recommendations for developing and maintaining cardiorespiratory fitness (Kravitz et al. 1998; Porcari et al. 2000).

Kravitz and colleagues (1998) reported that the average energy expenditure during forward-backward exercise with no resistance and against resistance for 5 min (125 strides·min^{-1}) was, respectively, 8.1 and 10.7 kcal·min^{-1}. Exercise intensities ranged between 72.5% and 83.5% HRmax (age predicted). Compared to treadmill exercise, upper body elliptical training at self-selected intensities produced similar $\dot{V}O_2$, HR, and RPE responses (Crommett et al. 1999; Porcari et al. 2000). Although there was no difference in $\dot{V}O_2$ between combined upper and lower body elliptical training and treadmill exercise, upper and lower body elliptical training produced a significantly higher HR and RPE (Crommett et al. 1999). Also, Mier and Feito (2006) reported significantly different $\dot{V}O_2$, ventilation, and RPE values when comparing elliptical exercise performed using legs only ($\dot{V}O_2$: 18.7 ± 3.0 ml·kg^{-1}·min^{-1}; V_E: 38.9 ± 3.0 L·min^{-1}; RPE: 10.9 ± 1.9) with elliptical training using both arms and legs combined ($\dot{V}O_2$: 19.2 ± 3.0 ml·kg^{-1}·min^{-1}; V_E: 37.7 ± 8.3 L·min^{-1}; RPE: 10.3 ± 1.9) Additionally, they commented on the large interindividual variability in $\dot{V}O_2$ at each stage of exercise, possibly related to the gender, body composition, and elliptical training experience of the exerciser.

Aerobic Riding

Aerobic riding involves both upper and lower body muscle groups. For this reason, some manufacturers claim that this mode of exercise will automatically burn more calories than lower body–only exercise modes such as jogging, cycling, and stair climbing. One study, however, noted that the energy expenditure during 10 min of steady-state exercise at a somewhat hard intensity (RPE = 13) on an aerobic rider was significantly lower than the caloric expenditure for treadmill jogging, stationary cycling, and Nordic skiing (Kravitz et al. 1997b). Subjects reported that they felt a similar workout intensity, in terms of RPE, during aerobic riding. Aerobic riding appears to challenge the muscular system (subjects complained of muscular discomfort) more than the cardiovascular system. In fact, the relative submaximal $\dot{V}O_2$ (47% $\dot{V}O_2$max) for aerobic riding was significantly less than that for treadmill jogging (74% $\dot{V}O_2$max), Nordic skiing (68% $\dot{V}O_2$max), or stationary cycling (64% $\dot{V}O_2$max). Thus, aerobic riding may not be suitable for aerobic exercise prescriptions, particularly for individuals with above-average cardiorespiratory fitness.

Water-Based Exercise

Water-based exercise, such as water aerobics or walking in waist-deep water, has been promoted as an effective way to increase the cardiorespiratory fitness of young, middle-aged, and older adults. This exercise is especially popular among individuals who are older, overweight, or afflicted with orthopedic disabilities. A typical water-based exercise session includes the following phases:

- Warm-up—20 min of stretching before entering the pool, followed by walking slowly in the water
- Endurance phase—30 min of continuous walking and dancing in the water
- Resistance phase—10 min of resistance exercises performed underwater with dumbbells, barbell-like devices, and leg pads
- Cool-down—10 min of relaxation and floor exercises outside of the pool

In older women (60–75 yr) participating in water-based exercise training 3 days/wk for 12 wk, $\dot{V}O_2$peak increased by 12% while total cholesterol and low-density lipoprotein cholesterol decreased by 11% and 17%, respectively. Also, muscle strength and arm and leg power increased significantly in response to exercising the limbs against the resistance of water (Takeshima et al. 2002).

Innovative Aerobic Exercise Modes

New and innovative modes of aerobic exercise are introduced every year by the fitness industry in order to stimulate and maintain exercise participation of clients. Many of these new programs combine traditional exercise modes (e.g., stationary cycling, stepping, tai chi, and martial arts) with music. Fitness centers throughout the United States now offer group exercise classes using programs such as BodyCombat, RPM, BodyPump, BodyStep, and Tae Bo. BodyCombat is an aerobic workout that combines movements from karate, boxing, taekwondo, and tai chi with fast-paced music. RPM is an indoor cycling workout to music that includes warm-up, pace, hill, mixed terrain, interval, free spin, mountain climb, and stretch segments. BodyPump is a conditioning class that adds strength training with weights to aerobic workouts choreographed to music. Tae Bo is an aerobic exercise routine that combines music with elements of taekwondo and kick boxing to promote aerobic fitness.

Rixon and colleagues (2006) compared exercise HRs and estimates of energy expenditure for BodyCombat (73% HRmax; 9.7 kcal·min^{-1}), RPM (74.3% HRmax; 9.9 kcal·min^{-1}), BodyStep (72.4% HRmax; 9.6 kcal·min^{-1}), and BodyPump (60.2% HRmax; 8.0 kcal·min^{-1}) routines. With the exception of BodyPump, the intensity and duration of these exercise routines appear to be sufficient to meet physical activity recommendations for improving health and for weight management. Research studies are needed to determine the health benefits and effects of these exercise programs on aerobic fitness.

Kettlebell exercise is a novel and popular whole-body, aerobic training modality. It involves the rhythmic swinging and ballistic lifting of nonsymmetrical hand weights. Currently, the available research on this modality is sparse and equivocal. Farrar, Mayhew, and Koch (2010) found that kettlebell swinging is suitable for improving aerobic fitness. As expected, the average %HRmax during kettlebell exercise (87% HRmax) was higher than the corresponding average %$\dot{V}O_2$max (65.3% $\dot{V}O_2$max). Although kettlebell exercise may have potential as an aerobic training modality (Farrar et al. 2010), Jay and colleagues (2011) reported no significant improvements in aerobic capacity following an 8 wk kettlebell training intervention for a predominantly (85%) female sample of adults (44 yr and 23 kg·m^2 on average).

DISCONTINUOUS TRAINING

As mentioned previously, discontinuous training involves a series of low- to high-intensity exercise bouts interspersed with rest or relief periods. All of the exercise modes listed as type A and type B activities (see "Classification of Aerobic Exercise Modalities") are suitable for discontinuous training. Because of the intermittent nature of this form of training, the exercise intensity and total amount of work performed can be greater than with continuous training, making discontinuous training a versatile method that is widely used by athletes, as well as individuals with low cardiorespiratory fitness. In fact, the ACSM (2014) recommends the use of discontinuous (intermittent) training for symptomatic individuals who are able to tolerate only low-intensity exercise for short periods of time (3–5 min). Interval training, treading, spinning, and circuit resistance training are examples of intermittent or discontinuous training.

Interval Training

Interval training involves a repeated series of exercise work bouts interspersed with rest or relief periods. This method is popular among athletes because it allows them to exercise at higher relative intensities during the work interval than are possible with longer-duration, continuous training. Interval training programs also can be modified to improve speed and anaerobic endurance, as well as aerobic endurance, simply by changing the exercise intensity and length of the work and relief intervals.

Each work interval consists of running at a pace such that a distance of 1100 yd (1005 m) is covered in 3 to 4 min. The work interval is followed by a rest—relief interval of 1.5 to 2 min. This sequence is repeated three times. During the rest—relief interval, the individual usually walks or jogs while recovering from the work bout. For aerobic interval training, the ratio of work to rest—relief is usually 1:1 or 1:0.5. Each work interval is 3 to 5 min and is repeated three to seven times. The exercise intensity usually ranges between 70% and 85% $\dot{V}O_2$max. Apply the overload principle by increasing the exercise intensity or length of the work interval, decreasing the length of the rest—relief interval, or increasing the number of work intervals per exercise session. For a discussion of interval training and sample programs, including programs for developing speed and anaerobic endurance, refer to the work of Janssen (2001).

As highlighted in a recent review regarding the potential of high-intensity interval training (HIT) programs, Kessler, Sisson, and Short (2012) differentiated between **sprint interval training (SIT)** and **aerobic interval training (AIT)**. SIT is typically based on iterative combinations of 30 sec maximal exertion sprints and extended (approximately 4 min) recovery interludes on a stationary cycle. AIT is based on iterations of near maximal

(80–95% $\dot{V}O_2max$) 4 min bouts of treadmill or cycling exercise followed by 3 to 4 min recovery periods, and it appears to have broader application for nonathletes, sedentary, and clinical populations. However, the SIT and AIT protocols tend to vary widely in exercise session volume and number of exercise sessions. Both SIT and AIT protocols show similar if not larger increases in maximal aerobic capacity and insulin sensitivity compared to counterparts engaging in the standard continuous moderate-intensity exercise. This trend is pervasive even though the SIT and AIT groups exercise just a fraction of the time recommended by the ACSM and American Heart Association (AHA; 150 min/wk). HDL-C and body fat percentage have been favorably altered by AIT, as has blood pressure in those not already undergoing treatment for hypertension. However, a dose-response relationship is evident, since the duration of the HIT protocols on these cardiovascular risk factors varies. Kessler and colleagues (2012) also outlined the need for exercise session supervision early on in the HIT programs, which are rigorous and may not be appropriate for everyone. On the other hand, Gosselin and colleagues (2012) reported that HIT exercise is as physiologically taxing as moderate-intensity (70% $\dot{V}O_2max$) steady-state exercise for physically active adults (20–30 yr).

Sedentary but healthy adults underwent an AIT intervention that consisted of a single 10 min cycling bout at 60 W and an increasing number and duration of 10 sec maximal exertion sprints per session; the study period covered 6 wk with 3 sessions per wk. Not only did aerobic capacity increase by 12% and 15% for the women and men, respectively, insulin sensitivity increased dramatically (28%) for the men and no RPE values higher than 15 were reported (Metcalfe et al. 2012).

Recreationally active men served as their own controls in an investigation comparing high-intensity (90% $\dot{V}O_2max$) interval treadmill running (6 reps × 3 min·rep^{-1}) interspersed with moderate intensity (50% $\dot{V}O_2max$) active recovery (6 reps × 3 min·rep^{-1}) to a 50 min continuous treadmill running bout at moderate intensity (70% $\dot{V}O_2max$). Along with the 7 min warm-up and cool-down periods, the high-intensity protocol involved approximately 50 min of exercise. Although the %HRmax, %$\dot{V}O_2max$, and total energy expenditure were similar, RPE and perceived enjoyment were significantly higher for the high-intensity interval running protocol (Bartlett et al. 2011). An increased sense of enjoyment with exercise may lead to increased exercise adherence, although this needs to be investigated in less-fit individuals. Consequently, research on longer duration interventions are needed to determine if adherence and long-term physiological gains are possible with AIT and SIT programs.

An Interval Training Prescription to Develop Aerobic Endurance

Sets: One

Repetitions: 3 to 7

Distance: 1100 yd (1105 m)

Intensity: 70% to 85% $\dot{V}O_2max$

Time: 3 to 5 min

Rest–relief interval: 1.5 to 2 min

Treading and Spinning

Treading and **spinning** are two examples of interval training that have gained popularity in fitness clubs because of the variety and enjoyment they offer. Treading and spinning are group classes that involve walking, jogging, and running at various speeds and grades on a treadmill (treading) or stationary cycling at various cadences and resistances (spinning). A typical treading or spinning workout consists of 1:1 or 1.5:1 work-recovery intervals or stages that are repeated for a specified duration. For example, a 30 min treading class may consist of six stages. Each stage lasts 5 min (i.e., 3 min work interval and 2 min recovery interval). One can advance the intensity of the work interval by increasing the treadmill speed or grade. During the recovery interval, both the speed and grade of the treadmill are decreased (e.g., 2.5 mph [4 km·hr^{-1}] and 0% grade). Instructors individualize and adapt the workouts for their clients by adjusting the duration of the work-recovery intervals and varying the speed and grade.

In one study, researchers designed 30 min treading workouts for walkers and runners (Nichols, Sherman, and Abbott 2000). They reported that the average intensity of the walking protocol was 40% to 49% $\dot{V}O_2max$ for male and female walkers, respectively. For the running protocol, the average intensity of the work intervals was 76% to 80% $\dot{V}O_2max$ for male and female runners, respectively. The researchers suggested that these average intensities, as well as the duration of the workout (30 min), are sufficient to meet ACSM recommendations for an aerobic exercise prescription. More research is needed to determine the long-term training effects of treading and spinning on cardiorespiratory fitness.

Circuit Resistance Training

Use of circuit resistance training for the development of aerobic fitness, as well as muscular strength and tone, has received much attention. An example of a circuit resistance training program is presented in chapter 7 (see figure 7.1). Circuit resistance training usually consists of several circuits of resistance training with a minimal amount of rest between the exercise stations (15–20 sec). Alternatively, instead of rest, you can have your clients perform 1 to 3 min of aerobic exercise between each station. The aerobic stations may include activities such as stationary cycling, jogging in place, rope skipping, stair climbing, bench stepping, and rowing. This modification of the circuit is known as **super circuit resistance training**.

Gettman and Pollock (1981) reviewed the research dealing with the physiological benefits of circuit resistance training. Because it produces only a 5% increase in aerobic capacity as compared to a 15% to 25% increase with other forms of aerobic training, the authors concluded that circuit resistance training should not be used to develop aerobic fitness. Rather, it may be used during the maintenance stage of an aerobic exercise program.

PERSONALIZED EXERCISE PROGRAMS

The aerobic exercise prescription should be individualized to meet each client's training goals and interests. To do this, you need to consider your client's age, gender, physical fitness level, and exercise preferences. This section presents a sample case study and examples of individualized exercise prescriptions to illustrate how the exercise prescription may be personalized for each client.

CASE STUDY

Like any preventive or therapeutic intervention, exercise should be prescribed carefully. You must be able to evaluate your client's medical history, medical condition, physical fitness status, lifestyle characteristics, and interests before designing the exercise program. In addition, to test your ability to extract, analyze, and evaluate all pertinent information needed to design a safe exercise program for your client, many professional certification examinations require that you be able to analyze a case study. For these reasons, this section includes a sample case study.

A case study is a written narrative that summarizes client information that you will need to develop an accurate and safe individualized exercise prescription (Porter 1988). Important elements to focus on when reading and analyzing a case study are listed in "Essential Elements of a Case Study." First, identify the client's coronary heart disease (CHD) risk factors by focusing on information provided about age, family history of CHD, blood lipid profile (total cholesterol, high- and low-density lipoprotein cholesterol [HDL-C and LDL-C]), blood glucose levels, resting BP, physical activity, body fat level, and smoking. Become familiar with ideal or typical values for various blood chemistry tests so that you will be able to recognize normal or abnormal test results. Remember that each of the following factors places individuals at greater risk for CHD:

- Triglycerides ≥150 $mg \cdot dl^{-1}$
- Total cholesterol ≥200 $mg \cdot dl^{-1}$
- LDL-cholesterol ≥130 $mg \cdot dl^{-1}$
- HDL-cholesterol <40 $mg \cdot dl^{-1}$
- Total cholesterol/HDL ratio >5.0
- Blood glucose ≥110 $mg \cdot dl^{-1}$
- Systolic BP ≥140 or diastolic BP ≥90 mmHg

Use signs and symptoms of cardiovascular, pulmonary, and metabolic disease (see Appendix A.3) along with CHD risk factors to determine the client's CHD risk classification (low, moderate, or high risk). The CHD risk classification dictates how closely the client's exercise program needs to be monitored.

Pay close attention to information about the client's medical history and physical examination results. These may reveal signs or symptoms of CHD, particularly if shortness of breath, chest pains,

ESSENTIAL ELEMENTS OF A CASE STUDY

Demographic Factors

- Age
- Gender
- Ethnicity
- Occupation
- Height
- Body weight
- Family history of coronary heart disease

Medical History

Present symptoms

- Dyspnea or shortness of breath
- Angina or chest pain
- Leg cramps or claudication
- Musculoskeletal problems or limitations
- Medications

Past history

- Diseases
- Injuries
- Surgeries
- Lab tests

Lifestyle Assessment

- Alcohol and caffeine intake
- Smoking
- Nutritional intake, eating patterns
- Physical activity patterns and interests
- Sleeping habits
- Occupational stress level
- Mental status, family lifestyle

Physical Examination

- Blood pressure
- Heart and lung sounds
- Orthopedic problems or limitations

Laboratory Tests (Ideal or Typical Values)

- Triglycerides (<150 mg·dl^{-1})
- Total cholesterol (<200 mg·dl^{-1})
- LDL-cholesterol (<100 mg·dl^{-1})
- HDL-cholesterol (>40 mg·dl^{-1})
- Total cholesterol/HDL-cholesterol (<3.5)
- Blood glucose (60–110 mg·dl^{-1})
- Hemoglobin:
  13.5–17.5 g·dl^{-1} (men)
  11.5–15.5 g·dl^{-1} (women)
- Hematocrit:
  40–52% (men)
  36–48% (women)
- Potassium (3.5–5.5 meq·dl^{-1})
- Blood urea nitrogen (4–24 mg·dl^{-1})
- Creatinine (0.3–1.4 mg·dl^{-1})
- Iron:
  40–190 mg·dl^{-1} (men)
  35–180 mg·dl^{-1} (women)
- Calcium (8.5–10.5 mg·dl^{-1})

Physical Fitness Evaluation

- Cardiorespiratory fitness (HR, BP, $\dot{V}O_2$max)
- Body composition (% body fat)
- Musculoskeletal fitness (muscle and bone strength)
- Flexibility
- Balance

SAMPLE CASE STUDY

A 28 yr old female police officer (5 ft 5 in. or 165.1 cm; 140 lb or 63.6 kg; 28% body fat) has enrolled in the adult fitness program. Her job demands a fairly high level of physical fitness—a level she was able to achieve 6 yr ago when she passed the physical fitness test battery used by the police department. Before becoming a police officer, she jogged 20 min, usually three times a week. Since starting her job, she has had little or no time for exercise and has gained 15 lb (6.8 kg). She is divorced, and she works 8 hr a day and takes care of two children, ages 7 and 9. At least three times a week, she and the children dine out, usually at fast food restaurants like Burger King and Taco Bell. She reports that her job, along with the sole responsibility for raising her two children, is quite stressful. Occasionally she experiences headaches and a tightness in the back of her neck. Usually in the evening she has one glass of wine to relax.

Her medical history reveals that she smoked one pack of cigarettes a day for 4 yr while she was in college. She quit smoking 3 yr ago. Over the past 2 yr, she has tried some quick weight loss diets, with little success. She was hospitalized on two occasions to give birth to her children. She reports that her father died of heart disease when he was 52 and that her older brother has high blood pressure. Recently she had her blood chemistry analyzed because she was feeling light-headed and dizzy after eating. In an attempt to lose weight, she eats only one large meal a day, at dinnertime. Results of the blood analysis were total cholesterol = 220 $mg \cdot dl^{-1}$; triglycerides = 98 $mg \cdot dl^{-1}$; glucose = 82 $mg \cdot dl^{-1}$; high-density lipoprotein cholesterol = 37 $mg \cdot dl^{-1}$; and total cholesterol/high-density lipoprotein cholesterol ratio = 5.9.

The exercise evaluation yielded the following data:

- Mode, protocol: Treadmill, modified Bruce
- Resting data: HR = 75 bpm; BP = 140/82 mmHg
- Endpoint: Stage 4 (2.5 mph [4 $km \cdot hr^{-1}$], 12% grade). Test terminated because of fatigue.

Stage	METs	Duration (min)	HR (bpm)	BP (mmHg)	RPE
1	2.3	3	126	145/78	8
2	3.5	3	142	160/78	11
3	4.6	3	165	172/80	14
4	7.0	3	190	189/82	18

Analysis

1. Evaluate the client's CHD risk profile. Be certain to address each of the positive and negative risk factors.
2. Describe any special problems or limitations that need to be considered in designing an exercise program for this client.
3. Were the HR, BP, and RPE responses to the GXT normal? Explain.
4. What is the client's functional aerobic capacity in METs? Categorize her cardiorespiratory fitness level (see table 4.1).
5. Plot the HR versus METs on graph paper.
6. From the graph, determine the client's target HR zone for the aerobic exercise program. What HRs and RPEs correspond to 60%, 70%, and 75% of the client's $\dot{V}O_2R$?
7. The client expressed an interest in walking outside on a level track to develop aerobic fitness. Calculate her walking speed for each of the following training intensities: 60%, 70%, and 75% $\dot{V}O_2R$. Use the ACSM equations presented in table 4.3.
8. In addition to starting an aerobic exercise program, what suggestions do you have for this client for modifying her lifestyle?

See appendix B.5 for answers to these questions.

or leg cramps are reported or if high BP is detected. It is also important to note the types of medication the client is using. Drugs such as digitalis, beta-blockers, diuretics, vasodilators, bronchodilators, and insulin may alter the body's physiological responses during exercise and could affect the HR and BP responses reported for the GXT. Keep in mind that exercise programs need to be modified for individuals with musculoskeletal disorders such as arthritis, low back pain, osteoporosis, and chondromalacia. Next, be certain to key in on information regarding the client's lifestyle. Factors such as smoking, lack of physical activity, or diets high in saturated fats or cholesterol increase the risk of CHD, atherosclerosis, and hypertension. You often can target these factors for modification; they also help you assess the likelihood of the client's adherence to the exercise program (see table 3.3).

Examine the BP, HR, and RPE data for the GXT used to assess the client's functional aerobic capacity and cardiorespiratory fitness level. You need to be acutely aware of the normal and abnormal physiological responses to graded exercise. After assessing the client's CHD risk and cardiorespiratory fitness level, you can design an aerobic exercise program using a personalized exercise prescription of intensity, frequency, duration, mode, volume, and progression. To write the exercise prescription, use the results from the GXT (HR, RPE, functional MET capacity).

The sample case study is provided to test your ability to evaluate risk factors and GXT results and to prescribe an accurate and safe aerobic exercise program for this individual. See the results of the case study analysis in appendix B.5.

SAMPLE CYCLING PROGRAM

The sample cycling program shows a personalized cycling program for a 27 yr old female who was given a maximal GXT on a stationary cycle ergometer. Her measured $\dot{V}O_2max$ is 7.4 METs. The exercise intensity is based on a percentage of her $\dot{V}O_2$reserve (%$\dot{V}O_2$R), and the target exercise HRs corresponding to 60% (4.8 METs) and 80% $\dot{V}O_2$R (6.1 METs) are 139 bpm and 168 bpm, respectively (see figure 5.3). Thus, the training exercise HR should fall within this HR range. During the initial stage of the exercise program, the woman will cycle at a work rate corresponding to 60% $\dot{V}O_2$R (4.8 METs) for 2 wk.

During weeks 1 and 2, the exercise duration is increased by 5 min/wk (from 40 to 45 min). During the third week, relative exercise intensity rather than duration is increased by 5% (from 60% $\dot{V}O_2$R to 65% $\dot{V}O_2$R). The work rate corresponding to an exercise intensity is calculated using the ACSM formulas for leg ergometry (see table 4.3). For example, the work rate corresponding to 60% $\dot{V}O_2$R (4.8 METs or 16.8 ml·kg^{-1}·min^{-1}) is calculated as follows:

$$\dot{V}O_2\ (\text{ml·kg}^{-1}\text{·min}^{-1}) = W / M \times 1.8 + 3.5 + 3.5$$

where W = work rate in kgm·min^{-1}
and M = body mass in kg.

$$16.8 = W / 70\text{ kg} \times 1.8 + 7.0$$

$$16.8 - 7.0 = W / 70\text{ kg} \times 1.8$$

$$9.8 \times 70\text{ kg} / 1.8 = 381\text{ kgm·min}^{-1}$$

To calculate the resistance setting corresponding to 381 kgm·min^{-1} for a cycling cadence of 50 rpm, divide the work rate by the total distance the flywheel travels: 381 / 50 rpm × 6 = 1.27 kg, or 1.3 kg.

To calculate the net energy cost (kcal·min^{-1}) of cycling, subtract the resting $\dot{V}O_2$ (1 MET) from the gross $\dot{V}O_2$ for each intensity. Convert this net MET value to kcal·min^{-1} using the following formula:

$$\text{kcal·min}^{-1} = \text{METs} \times 3.5 \times \text{body mass (kg)} / 200$$

(e.g., 4.8 − 1.0 = 3.8 METs; 3.8 × 3.5 × 70 kg / 200 = 4.7 kcal·min^{-1})

In the initial stages of the program, the weekly net energy expenditure is between 752 and 1040 kcal. In the improvement stage, the exercise intensity, duration, and frequency are progressively increased, and the weekly net caloric expenditure ranges between 1040 and 1874 kcal. Only one variable—intensity, duration, or frequency—should be increased at a time. The variable that is increased during each stage of the progression for this exercise program is indicated by boldface. During the improvement stage, this client's net caloric expenditure due to exercise meets the caloric threshold between 1000 and 2000 kcal per week from physical activity recommended by the ACSM (2014). In the maintenance phase, tennis and aerobic dancing are added to give variety and to supplement the cycling program. The

ACSM (2014) guidelines were followed to calculate each component of this exercise prescription.

SAMPLE JOGGING PROGRAM

The sample jogging program is designed for a 29 yr old male who has an excellent cardiorespiratory fitness level. Since a GXT could not be administered, the $\dot{V}O_2$max was predicted from performance on the 12 min distance run test. The maximal HR was predicted using the formula 220 − age. Because this client is accustomed to jogging and his cardiorespiratory fitness level is classified as excellent, he is exempted from the initial stage and enters the improvement stage of the program immediately. During this time (20 wk), the exercise intensity is increased from 70% to 85% of the estimated $\dot{V}O_2R$. The speed corresponding to each MET intensity is calculated using the ACSM formulas for running on a level course (see table 4.3). The intensity, duration, and frequency of the exercise sessions provide a weekly net caloric expenditure between 1010 and 2170 kcal. During the first 4 wk of the program, this client's net rate of energy expenditure due to exercise is 10.2 kcal·min^{-1} (8.3 METs × 3.5 × 70 kg / 200 = 10.2 kcal·min^{-1}); thus, he will expend approximately 1010 kcal, jogging 33 min at a pace of 11:06 min·mi^{-1} three times per week (33 min × 10.2 kcal·min^{-1} × 3). To figure the distance covered, the exercise duration is divided by the running pace: 33 min / 11.1 min·mi^{-1} = 3 mi (5 km). During the improvement stage, the frequency of exercise sessions gradually progresses from 3 to 5 days/wk. During the maintenance stage, the running is reduced to 3 days/wk, and handball and basketball are added to the aerobic exercise program. The ACSM (2014) guidelines were followed to calculate each component of this exercise prescription.

SAMPLE MULTIMODAL EXERCISE PROGRAM

Some clients may prefer to engage in a variety of exercise modes (**cross-training**) to develop their cardiorespiratory fitness (see "Sample Multimodal Exercise Program"). In these cases, it is difficult to systematically prescribe increments in exercise intensity using METs or target HRs. Although MET equivalents for various activities are available (see appendix E.4), typically a range of values is given, making it difficult for you to accurately prescribe work rates corresponding to specific intensity recommendations in an exercise prescription. Also, the HR response to a given MET level is highly dependent on the exercise mode.

The degree of muscle mass involved in the activity, as well as whether the body weight is supported during exercise, can affect the HR response to a prescribed exercise intensity. For example, whole-body exercise modes, such as Nordic skiing and aerobic dancing, involve both upper and lower body musculature. These produce higher submaximal HRs than lower body exercise modes (e.g., cycling and jogging). Also, at any given exercise intensity, the HR response during weight-bearing exercise such as jogging is greater than that for non-weight-bearing exercise (e.g., cycling).

Therefore, you should use RPEs to progressively increase exercise intensity throughout the improvement stage of a multimodal aerobic exercise program (see table 4.2). To use the RPE safely and effectively, you will need to teach your clients to focus on and learn to monitor important exertional cues such as breathing effort (rate and depth of breathing) and muscular sensations (e.g., pain, warmth, and fatigue). Guidelines for developing multimodal exercise prescriptions are presented in this section.

For **multimodal exercise programs**, you should set exercise frequency and weekly net caloric expenditure goals for each client (see "Sample Multimodal Exercise Program"). Provide your clients with estimates of net energy expenditure (kcal·min^{-1}) for each of the aerobic activities they select for their exercise prescriptions. The exercise duration to achieve a specified weekly net caloric expenditure goal will vary depending on the activity mode chosen for each exercise session. Any combination of type A, B, or C activities can be used, provided that the client is able to maintain the prescribed RPE intensity for at least 20 min.

Flexibility is the key to successful multimodal exercise prescriptions. Clients should be free not only to select exercise modes of interest but also to decide on various combinations of frequency and duration as long as they meet the caloric thresholds specified in their exercise prescriptions for each week.

The primary advantages of multimodal exercise programs over single-mode (e.g., jogging or cycling) programs for many of your clients are

- greater likelihood of engaging in a safe and effective exercise program,
- overall greater enjoyment of physical activity and exercise,
- better understanding of how their bodies respond to exercise,
- more direct involvement and sense of control in developing and monitoring their exercise programs, and
- increased likelihood of incorporating physical activity and exercise into their lifestyles.

Guidelines for Multimodal Exercise Prescriptions

- **Modes:** Select at least three per week from type A and B activities.
- **Frequency:** Three to seven sessions a week. Engage in either type A, B, or C activities at least three times per week.
- **Intensity:** Rating of perceived exertion between 5 and 9 on 10-point OMNI scale.
- **Duration:** At least 15 min, preferably 20 to 30 min. Duration depends on energy cost (kcal·min^{-1}) of exercise mode.
- **Caloric expenditure:** 1000 to 2000 kcal/wk. Group C and D activities can be used to reach the weekly caloric expenditure goal, but they cannot be counted as one of the required aerobic activities.

SAMPLE HIT EXERCISE PROGRAM

The sample HIT program is designed for a 34 yr old, recreationally active male who has a fair cardiorespiratory fitness level and a limited amount of time per week to dedicate to aerobic training. Since he is satisfied with his body weight, his main goal is to improve his aerobic capacity. His $\dot{V}O_2$max was predicted from a multistage treadmill test, and his maximal HR was predicted using the formula 220 – age. Because this client is undertaking his first HIT exercise program and his cardiorespiratory fitness level is classified as fair, he is starting his program 5% above the exercise intensity targeted by the end (60% $\dot{V}O_2R$) of the standard initial conditioning stage. During the first 2 wk of his treadmill routine, the work and active recovery (rest) intervals are performed at 65% and 35% of his estimated $\dot{V}O_2R$, respectively. With the work and rest intervals both being 1 min in duration, his work-to-rest ratio is 1:1; he is initially scheduled to complete 15 repetitions per session three times per week. While the frequency and total duration of his exercise sessions remains constant, the intensity and duration of the work interval are systematically manipulated throughout the remaining 11 weeks of the program, as is the work-to-rest ratio (principle of progression). To calculate the average net kcal·min^{-1} expended in week 1: [Work: ((7 METs × 3.5 ml kg^{-1}·min^{-1} × 97.7 kg) / 200) = 11.97 kcal·min^{-1}; Rest: ((4.3 METs × 3.5 ml kg^{-1}·min^{-1} × 97.7 kg) / 200) = 7.35 kcal·min^{-1}; average net kcal·min^{-1} = ((11.97 × 15 min) + (7.35 × 15 min)) / 30 min = 9.7]. This represents the respective contributions of the work and rest intervals. The 2 wk block arrangement of exercise sessions provides a weekly net caloric expenditure between 869 and 1041 kcal and the opportunity to manipulate one programmatic variable at a time. As he advances through the improvement stage, adjustments are made to the intensity of the work interval, work-to-rest ratio, and number of repetitions. His ability to tolerate the progression must be closely monitored and his program adjusted accordingly. A reassessment of his estimated $\dot{V}O_2$max is recommended after the 6th wk. For additional information on the potential improvements in aerobic capacity or cardiometabolic disease risk following high-intensity interval training interventions, refer to the work of Bacon and colleagues (2013) and Kessler, Sisson, and Short (2012), respectively.

SAMPLE CYCLING PROGRAM

Client data

Age	27 yr
Gender	Female
Body weight	70 kg (154 lb)
Resting heart rate	67 bpm
Maximal heart rate	195 bpm (measured)
$\dot{V}O_2max$	26 ml·kg^{-1}·min^{-1} (measured) 7.4 METs
Graded exercise test	Cycle ergometer
Initial cardiorespiratory fitness level	Poor

Exercise prescription

Mode	Stationary cycling
Intensity	60–80% $\dot{V}O_2R$ 16.8–21.4 ml·kg^{-1}·min^{-1} 4.8–6.1 METs
Exercise heart rates (from figure 5.3)	139 bpm minimum 168 bpm maximum
RPE	5–8 (OMNI scale)
Duration	40–60 min
Frequency	4 or 5 days/wk

Cycling Program[a]

Phase (wk)	Intensity % $\dot{V}O_2R$	METs	HR (bpm)	RPE	Power output (W)	Resistance (kg)	Pedal rate (rpm)	Net kcal·min^{-1}	Time (min)	Frequency	Weekly net expenditure (kcal)
					INITIAL						
1	60	4.8	139	5	63	1.3	50	4.7	40	4	752
2	60	4.8	139	5	63	1.3	50	4.7	**45**	4	846
3	**65**	5.2	150	5-6	73	1.5	50	5.2	45	4	936
4	65	5.2	150	5-6	73	1.5	50	5.2	**50**	4	1040
					IMPROVEMENT						
5-8	65-**70**	5.2-5.5	150-155	5-6	73-80	1.5-1.6	50	5.2-5.5	50	4	1040-1103
9-12	65-70	5.2-5.5	150-155	5-6	73-80	1.5-1.6	50	5.2-5.5	**55**	4	1144-1210
13-16	70-**75**	5.5-5.8	152-162	6-7	80-86	1.6-1.7	50	5.5-5.9	55	4	1210-1298
17-20	75	5.8	162	7	86	1.7	50	5.9	**60**	4	1416
21-24	75	5.8	162	7	86	1.7	50	5.9	60	**5**	1770
25-28	**80**	6.1	168	8	93	1.9	50	6.2	60	5	1874
					MAINTENANCE						
24+											
Cycling	80	6.1	168	8	93	1.9	50	6.2	60	3	1116
Low-impact aerobics	65% HRR	5.0	150	6-7	–	–	–	4.9	60	1	294
Tennis	–	7.0	–	7-8	–	–	–	7.4	60	1	440

[a]Values in boldface indicate training variables that were increased during each stage of the exercise progression.

SAMPLE JOGGING PROGRAM

Client data

Age	29 yr
Gender	Male
Body weight	70 kg (154 lb)
Resting heart rate	50 bpm
Maximal heart rate	191 bpm (age predicted)
$\dot{V}O_2max$	45 ml·kg^{-1}·min^{-1} (predicted) 12.9 METs
Graded exercise test	None
Initial cardiorespiratory fitness level	Excellent

Exercise prescription

Mode	Jogging and running
Intensity	70–85% $\dot{V}O_2R$ 32.5–38.8 ml·kg^{-1}·min^{-1} 9.3–11.1 METs
Exercise heart rates	149 bpm minimum (70% HRR) 170 bpm maximum (85% HRR)
RPE	6–9 (OMNI scale)
Duration	33–35 min
Frequency	3–5 days/wk

Jogging Program[a]

Phase (wk)	Intensity % $\dot{V}O_2R$	METs	HR (bpm)	RPE	Pace: mph (min·mi^{-1})	Distance (miles)	Net kcal·min^{-1}	Time (min)	Frequency	Weekly net expenditure (kcal)
IMPROVEMENT										
1-4	70	9.3	149	6	5.4 (11:06)	3.0	10.2	33	3	1010
5-8	70-**80**	9.3-10.5	149-163	6-7	5.4-6.2 (9:40)	3.0-3.4	10.2-11.6	33	3	1010-1148
9-12	70-80	9.3-10.5	149-163	6-7	5.4-6.2 (9:40)	3.0-3.4	10.2-11.6	33	**4**	1347-1531
13-16	80-**85**	10.5-11.1	163-170	7-9	6.2-6.6 (9:05)	3.4-3.6	11.6-12.4	33	4	1531-1637
17-20	80-85	10.5-11.1	163-170	7-9	6.2-6.6 (9:05)	3.4-3.8	11.6-12.4	33-**35**	**5**	1914-2170
MAINTENANCE										
21+										
Jogging	85	11.2	170	7-9	6.6 (9:05)	3.8	12.4	35	3	1302
Handball	60	8.0	–	6-7	–	–	9.2	60	1	552
Basketball	60	8.0	–	6-7	–	–	9.2	60	1	552

[a]Values in boldface indicate training variables that are increased during each stage of the exercise progression.

SAMPLE MULTIMODAL EXERCISE PROGRAM

Client data

Age	44 yr
Sex	Female
Weight	68 kg (150 lb)
Resting heart rate	70 bpm
Maximal heart rate	170 bpm
$\dot{V}O_2max$	30 $ml \cdot kg^{-1} \cdot min^{-1}$ 8.6 METs
Graded exercise test	Treadmill maximal GXT (Bruce protocol)
Initial cardiorespiratory fitness level	Fair

Exercise prescription

Modes and estimates of gross caloric expenditure (METs) and net caloric expenditure (*$kcal \cdot min^{-1}$*)[a]	Stationary cycling (100 W): 5.5 METs; 5.4 $kcal \cdot min^{-1}$ Step aerobics (6.8 in. step): 8.5 METs; 8.9 $kcal \cdot min^{-1}$ Rowing (100 W): 7.0 METs; 7.1 $kcal \cdot min^{-1}$ Swimming (moderate effort): 7.0 METs; 7.1 $kcal \cdot min^{-1}$ Stair climbing (machine): 9.0 METs; 9.5 $kcal \cdot min^{-1}$ Hiking: 6.0 METs; 5.9 $kcal \cdot min^{-1}$ Resistance training (free weights, machines): 3.0 METs; 2.4 $kcal \cdot min^{-1}$
Intensity	RPE: 5–9 (OMNI scale)
Duration	20–60 min
Frequency	3-5 days/wk
Weekly caloric expenditure	500–1250 $kcal \cdot wk^{-1}$

Multimodal Exercise Program

Phase (wk)	Intensity (RPE)	Minimal duration (min)	Minimal frequency	Average kcal per workout	Weekly caloric goal
INITIAL					
1-2	5	20	3	133	500
3-4	5	25	3	200	600
IMPROVEMENT					
5-8	6	25	3	200	700
9-12	6	30	3	233	800
13-16	6-7	30	4	225	900
17-20	7-8	30	4	250	1000
21-24	8-9	30	5	250	1250
MAINTENANCE					
24+	8-9	30	5	250	1250

Examples

Week 1	Activity	Net kcal·min^{-1} estimates	Time (min)	Frequency	Kcal per workout (net)	Activity type[b]
Monday	Stationary cycling	5.4	20	1	108	A
Wednesday	Step aerobics	8.9	20	1	178	C
Friday	Stair climbing	9.5	30	1	285	B
		Totals*:	70	3	571	3
		Goals:	60	3	500	3
Week 21						
Monday	Swimming	7.1	35	1	248	C
Tuesday	Rowing	7.1	35	1	248	B
Wednesday	Stair climbing	9.5	30	1	285	B
Friday	Resistance training	2.4	40	1	96	D
Sunday	Hiking	5.9	60	1	354	D
		Totals*:	200	5	1231	4
		Goals:	150	5	1250	4

[a]Gross MET levels for activities from Ainsworth and colleagues (2000); net energy expenditure in kcal·min^{-1} = net MET level × 3.5 × BM (kg) / 200.
[b]Check all type A and B activities.
*Compare weekly totals to weekly goals.

SAMPLE HIT PROGRAM

Client data

Age	34 yr
Gender	Male
Body weight	97.7 kg (215 lb)
Resting heart rate	72 bpm
Maximal heart rate	186 bpm (predicted)
$\dot{V}O_2max$	39.5 ml·kg^{-1}·min^{-1} (predicted) 11.3 METs
Graded exercise test	Treadmill
Initial cardiorespiratory fitness level	Fair

Exercise prescription

Mode	Treadmill
Intensity	Work periods: 65% to 75% MET-R
	Rest periods: 35% MET-R
	Work periods: 15–20 min
	Rest periods: 10–15 min
Frequency	3 days/wk
Weekly caloric expenditure	869–1,041 kcal/wk

Phase (wks)	Intensity (% $\dot{V}O_2R$)	METs	Rest (% $\dot{V}O_2R$)	Work duration (min)	Rest duration (min)	Work: rest ratio	Repetitions	Frequency	Time (min)	Net kcal·min^{-1}	Expenditure per session (kcal)	Weekly net expenditure (kcal)
1-2	65	7.0	35	1.0	1.0	1:1	15	3	30	9.7	289.8	869
3-4	65	7.0	35	**1.5**	1.0	1.5:1	12	3	30	10.1	303.7	911
5-6	**70**	7.2	35	1.0	1.0	1:1	15	3	30	10.1	302.6	908
7-8	70	7.2	35	**1.5**	1.0	1.5:1	12	3	30	10.6	319.0	957
9-10	**75**	7.7	35	1.5	1.0	1.5:1	12	3	30	11.1	334.4	1003
11-12	75	7.7	35	**2.0**	1.0	2:1	10	3	30	11.6	347.1	1041

Key Points

- Always personalize cardiorespiratory exercise programs to meet the needs, interests, and abilities of each participant.
- The exercise prescription includes mode, frequency, intensity, duration, volume, and progression (FITT-VP principle) of exercise.
- Aerobic endurance activities involving large muscle groups are well suited for developing cardiorespiratory fitness. Type A and B activities such as walking, jogging, and cycling allow the individual to maintain steady-state exercise intensities and are not highly dependent on skill.
- Exercise intensity can be prescribed using the HR, $\dot{V}O_2R$, or RPE methods, or a combination of these methods.
- For the average healthy person, the cardiorespiratory exercise program should be at a moderate intensity of 40% to <60% $\dot{V}O_2R$, a duration of 30 to 60 min, and a frequency of 5 days/wk.
- More fit individuals can exercise at a vigorous intensity of ≥60% to 90% $\dot{V}O_2R$, 20 to 60 min/day, 3 days/wk.

- The cardiorespiratory exercise program includes three stages of progression: initial conditioning, improvement, and maintenance.
- Each exercise session includes warm-up, aerobic conditioning exercise, and cool-down.
- Continuous and discontinuous training methods are equally effective for improving cardiorespiratory fitness.
- AIT and SIT training programs may provide similar or better improvements in cardiometabolic factors in less time compared to continuous moderate-intensity programs. Additionally, they may improve adherence and increase enjoyment of exercise.
- Multimodal exercise prescriptions use a variety of type A, B, and C aerobic activities to improve cardiorespiratory endurance.

Key Terms

Learn the definition for each of the following key terms. Definitions of key terms can be found in the glossary.

aerobic interval training (AIT)
caloric threshold
continuous training
counting talk test (CTT)
cross-training
discontinuous training
FITT-VP principle
heart rate reserve (HRR)
high-intensity interval training
improvement stage
initial conditioning stage
interval training
Karvonen method
lactate threshold
maintenance stage
MET·min
multimodal exercise program
percent heart rate maximum (%HRmax)
percent heart rate reserve (%HRR) method
percent $\dot{V}O_2$max reserve (%$\dot{V}O_2R$)
pulmonary ventilation
spinning
sprint interval training (SIT)
super circuit resistance training
talk test
treading
type A, B, C, and D aerobic activities
ventilatory threshold
$\dot{V}O_2$reserve ($\dot{V}O_2R$)
volume of exercise

Review Questions

In addition to being able to define each of the key terms, test your knowledge and understanding of the material by answering the following review questions.

1. Name the four components of any aerobic exercise prescription.
2. What are the guidelines for an exercise prescription for improved health?
3. What are the guidelines for an exercise prescription for cardiorespiratory fitness?
4. Identify the three parts of an aerobic exercise workout and state the purpose of each part.
5. To classify an aerobic exercise mode as either a type A, B, C, or D activity, what criteria are used?
6. Give three examples each for type A, B, C, and D aerobic activities.
7. Describe three methods used to prescribe intensity for an aerobic exercise prescription.
8. Using the $\dot{V}O_2$reserve method, calculate the target $\dot{V}O$ for a client whose $\dot{V}O_2$max is 12 METs and relative exercise intensity is 70% $\dot{V}O_2R$.
9. Which method of prescribing intensity (%HRR or %HRmax) corresponds 1:1 with the % $\dot{V}O_2R$ method?

10. What are the limitations of using HR methods to monitor intensity of aerobic exercise?
11. Describe how RPEs can be used to prescribe and monitor the intensity of aerobic exercise.
12. Describe how your clients can use the talk test to monitor exercise intensity during their aerobic exercise workouts.
13. How does the talk test differ from the counting talk test?
14. What target caloric thresholds are recommended by ACSM for aerobic exercise workouts and weekly caloric expenditure from physical activity and exercise?
15. What is the recommended frequency of activity and exercise for improved health benefits? For improved cardiorespiratory fitness?
16. Name the three stages of a cardiorespiratory exercise program. For the average individual, what is the typical length (in weeks) of each stage?
17. What is the difference between continuous and discontinuous aerobic exercise training? Give examples of continuous and discontinuous training methods.
18. Compare the health benefits of aerobic interval training, sprint interval training, and continuous moderate-intensity exercise training programs?
19. What are the essential elements of a client case study?

APPENDIX A

Health and Fitness Appraisal

This appendix includes questionnaires and forms that you can duplicate and use for the pretest health screening of your clients. The PAR-Q (appendix A.1) is used to identify individuals who need medical clearance from their physicians before taking any physical fitness tests or starting an exercise program. The Medical History Questionnaire (appendix A.2) is used to obtain a personal and family health history for your client. As part of the pretest health screening, ask your clients if they have any of the conditions or symptoms listed in the Checklist for Signs and Symptoms of Disease (appendix A.3). The PARmed-X (appendix A.4) may be used by physicians to assess and convey medical clearance for physical activity participation of your clients. You can estimate your client's 10-yr risk of a first fatal cardiovascular event due to atherosclerosis with the SCORE system (Appendix A.5). Likewise, the Relative Risk Chart Appendix A.6) may be used to educate younger people how, relative to their age group peers, their risk for an atherosclerotic event is affected by lifestyle choices (smoking) and modifiable risk factors.

You can obtain a lifestyle profile for your clients by using either the Lifestyle Evaluation form or the Fantastic Lifestyle Checklist provided in appendix A.7. Be sure that each participant signs the Informed Consent (appendix A.8) before conducting any physical fitness tests or allowing your client to engage in an exercise program. Appendix A.9 includes Web sites for selected professional organizations and institutes.

Appendix A.1: Physical Activity Readiness Questionnaire

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

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 (for example, back, knee or hip) 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 a 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. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

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.

No changes permitted. You are encouraged to photocopy 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)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Source: *Physical Activity Readiness Questionnaire* (PAR-Q) © 2002. Used with permission from the Canadian Society for Exercise Physiology. www.csep.ca/forms.asp.

PAR-Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

Canada's **Physical Activity Guide** to Healthy Active Living

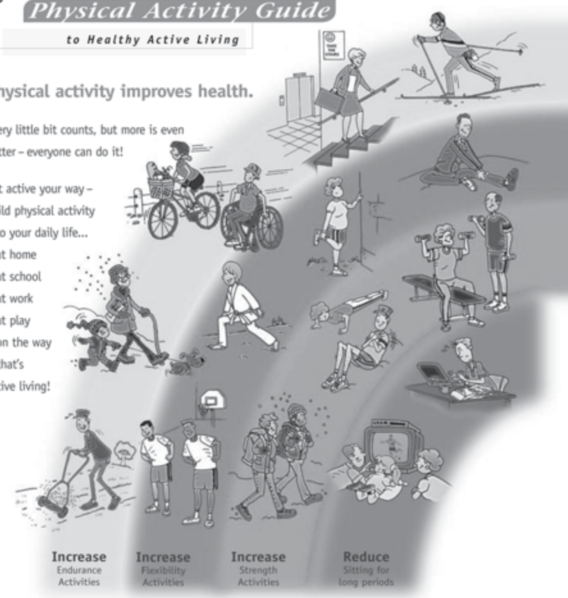
Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
- at school
- at work
- at play
- on the way

...that's active living!



Choose a variety of activities from these three groups:

Endurance
4-7 days a week
Continuous activities for your heart, lungs and circulatory system.

Flexibility
4-7 days a week
Gentle reaching, bending and stretching activities to keep your muscles relaxed and joints mobile.

Strength
2-4 days a week
Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the *Guide Handbook* and more information: **1-888-334-9769**, or **www.paguide.com**

Eating well is also important. Follow *Canada's Food Guide to Healthy Eating* to make wise food choices.

Get Active Your Way, Every Day – For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort

Very Light Effort	Light Effort *60 minutes*	Moderate Effort *30-60 minutes*	Vigorous Effort *20-30 minutes*	Maximum Effort
• Strolling • Dusting	• Light walking • Volleyball • Easy gardening • Stretching	• Brisk walking • Biking • Raking leaves • Swimming • Dancing • Water aerobics	• Aerobics • Jogging • Hockey • Basketball • Fast swimming • Fast dancing	• Sprinting • Racing
	Range needed to stay healthy			

You Can Do It – Getting started is easier than you think

Physical activity doesn't have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don't have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:	Health risks of inactivity:
• better health • improved fitness • better posture and balance • better self-esteem • weight control • stronger muscles and bones • feeling more energetic • relaxation and reduced stress • continued independent living in later life	• premature death • heart disease • obesity • high blood pressure • adult-onset diabetes • osteoporosis • stroke • depression • colon cancer

Health Canada Santé Canada

Canadian Society for Exercise Physiology

Active Living

Canada's Physical Activity Guide to Healthy Active Living

Source: *Canada's Physical Activity Guide to Healthy Active Living*, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. **J. Clin. Epidemiol.** 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy, In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health**. Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). **Can. J. Spt. Sci.** 17:4 338-345.

To order multiple printed copies of the PAR-Q, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (revisé 2002)».

Supported by: Health Canada Santé Canada

Source: *Physical Activity Readiness Questionnaire* (PAR-Q) © 2002. Used with permission from the Canadian Society for Exercise Physiology. www.csep.ca/forms.asp.

Appendix A.2: Medical History Questionnaire

Demographic Information

Last name		First name	Middle initial
Date of birth	Sex	Home phone	
Address	City, State		Zip code
Work phone	Family physician		

Section A

1. When was the last time you had a physical examination?
2. If you are allergic to any medications, foods, or other substances, please name them.
3. If you have been told that you have any chronic or serious illnesses, please list them.
4. Give the following information pertaining to the last 3 times you have been hospitalized. *Note:* Women, do not list normal pregnancies.

	Hospitalization 1	**Hospitalization 2**	**Hospitalization 3**
Reason for hospitalization	______	______	______
Month and year of hospitalization	______	______	______
Hospital	______	______	______
City and state	______	______	______

Section B

During the past 12 months

1. Has a physician prescribed any form of medication for you? ❒ Yes ❒ No
2. Has your weight fluctuated more than a few pounds? ❒ Yes ❒ No
3. Did you attempt to bring about this weight change through diet or exercise? ❒ Yes ❒ No
4. Have you experienced any faintness, light-headedness, or blackouts? ❒ Yes ❒ No
5. Have you occasionally had trouble sleeping? ❒ Yes ❒ No
6. Have you experienced any blurred vision? ❒ Yes ❒ No
7. Have you had any severe headaches? ❒ Yes ❒ No
8. Have you experienced chronic morning cough? ❒ Yes ❒ No
9. Have you experienced any temporary change in your speech pattern, such as slurring or loss of speech? ❒ Yes ❒ No
10. Have you felt unusually nervous or anxious for no apparent reason? ❒ Yes ❒ No
11. Have you experienced unusual heartbeats such as skipped beats or palpitations? ❒ Yes ❒ No
12. Have you experienced periods in which your heart felt as though it were racing for no apparent reason? ❒ Yes ❒ No

From Vivian H. Heyward and Ann L. Gibson, 2014, *Advanced Fitness Assessment and Exercise Prescription,* 7th ed. (Champaign, IL: Human Kinetics).

At present

1. Do you experience shortness or loss of breath while walking with others your own age? ❐ Yes ❐ No
2. Do you experience sudden tingling, numbness, or loss of feeling in your arms, hands, legs, feet, or face? ❐ Yes ❐ No
3. Have you ever noticed that your hands or feet sometimes feel cooler than other parts of your body? ❐ Yes ❐ No
4. Do you experience swelling of your feet and ankles? ❐ Yes ❐ No
5. Do you get pains or cramps in your legs? ❐ Yes ❐ No
6. Do you experience any pain or discomfort in your chest? ❐ Yes ❐ No
7. Do you experience any pressure or heaviness in your chest? ❐ Yes ❐ No
8. Have you ever been told that your blood pressure was abnormal? ❐ Yes ❐ No
9. Have you ever been told that your serum cholesterol or triglyceride level was high? ❐ Yes ❐ No
10. Do you have diabetes? ❐ Yes ❐ No

    If yes, how is it controlled?

    ❐ Dietary means ❐ Insulin injection

    ❐ Oral medication ❐ Uncontrolled
11. How often would you characterize your stress level as being high?

    ❐ Occasionally ❐ Frequently ❐ Constantly
12. Have you ever been told that you have any of the following illnesses? ❐ Yes ❐ No

    ❐ Myocardial infarction ❐ Arteriosclerosis ❐ Heart disease ❐ Thyroid disease

    ❐ Coronary thrombosis ❐ Rheumatic heart ❐ Heart attack ❐ Heart valve disease

    ❐ Coronary occlusion ❐ Heart failure ❐ Heart murmer

    ❐ Heart block ❐ Aneurysm ❐ Angina
13. Have you ever had any of the following medical procedures? ❐ Yes ❐ No

    ❐ Heart surgery ❐ Pacemaker implant

    ❐ Cardiac catheterization ❐ Defibrillator

    ❐ Coronary angioplasty ❐ Heart transplantation

Section C

Has any member of your immediate family been treated for or suspected to have had any of these conditions? Please identify their relationship to you (father, mother, sister, brother, etc.).

A. Diabetes

B. Heart disease

C. Stroke

D. High blood pressure

From Vivian H. Heyward and Ann L. Gibson, 2014, *Advanced Fitness Assessment and Exercise Prescription,* 7th ed. (Champaign, IL: Human Kinetics).

Appendix A.3: Checklist for Signs and Symptoms of Disease

Instructions: Ask your clients if they have any of the following conditions and risk factors. If so, refer them to their physicians to obtain a signed medical clearance prior to any exercise testing or participation. See the glossary on p. 411 for definitions of terms.

Client's name ______________________________ Date ______________

Condition	Yes	No	Comments
Cardiovascular			
Hypertension			
Hypercholesterolemia			
Heart murmurs			
Myocardial infarction (heart attack)			
Fainting/dizziness			
Claudication			
Chest pain			
Palpitations			
Ischemia			
Tachycardia (rhythm disturbances)			
Ankle edema			
Stroke			
Pulmonary			
Asthma			
Bronchitis			
Emphysema			
Nocturnal dyspnea			
Coughing up blood			
Exercise-induced asthma			
Breathlessness during or after mild exertion			
Metabolic			
Diabetes			
Obesity			

Condition	Yes	No	Comments
Metabolic *(continued)*			
Glucose intolerance			
McArdle's syndrome			
Hypoglycemia			
Thyroid disease			
Cirrhosis			
Musculoskeletal			
Osteoporosis			
Osteoarthritis			
Low back pain			
Prosthesis			
Muscular atrophy			
Swollen joints			
Orthopedic pain			
Artificial joints			
Risk factors*			
Male older than 45 yr			
Female older than 55 yr, or had hysterectomy, or are postmenopausal			
Smoking or quit smoking within previous 6 mo			
Blood pressure > 140/90 mmHg			
Don't know blood pressure			
Taking blood pressure medication			
Blood cholesterol > 200 mg · dl^{-1}			
Do not know cholesterol level			
Have close relative who had heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister)			
Physically inactive (<30 min of physical activity more than 4 days/wk)			
Overweight by more than 20 lb (9 kg)			

*If you have two or more risk factors, you should consult your physician before engaging in exercise.

From Vivian H. Heyward and Ann L. Gibson, 2014, *Advanced Fitness Assessment and Exercise Prescription,* 7th ed. (Champaign, IL: Human Kinetics).

Appendix A.4: Physical Activity Readiness Medical Examination

Physical Activity Readiness
Medical Examination
(revised 2002)

PARmed-X PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION

The PARmed-X is a physical activity-specific checklist to be used by a physician with patients who have had positive responses to the Physical Activity Readiness Questionnaire (PAR-Q). In addition, the Conveyance/Referral Form in the PARmed-X can be used to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

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. The PAR-Q by itself provides adequate screening for the majority of people. However, some individuals may require a medical evaluation and specific advice (exercise prescription) due to one or more positive responses to the PAR-Q.

Following the participant's evaluation by a physician, a physical activity plan should be devised in consultation with a physical activity professional (CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™). To assist in this, the following instructions are provided:

PAGE 1: • Sections A, B, C, and D should be completed by the participant BEFORE the examination by the physician. The bottom section is to be completed by the examining physician.

PAGES 2 & 3: • A checklist of medical conditions requiring special consideration and management.

PAGE 4: • Physical Activity & Lifestyle Advice for people who do not require specific instructions or prescribed exercise.

• Physical Activity Readiness Conveyance/Referral Form - an optional tear-off tab for the physician to convey clearance for physical activity participation, or to make a referral to a medically-supervised exercise program.

This section to be completed by the participant

A PERSONAL INFORMATION:

NAME ____________________

ADDRESS ____________________

____

TELEPHONE ____________________

BIRTHDATE ____________________ GENDER __________

MEDICAL No. ____________________

B PAR-Q: Please indicate the PAR-Q questions to which you answered YES

- ❑ Q 1 Heart condition
- ❑ Q 2 Chest pain during activity
- ❑ Q 3 Chest pain at rest
- ❑ Q 4 Loss of balance, dizziness
- ❑ Q 5 Bone or joint problem
- ❑ Q 6 Blood pressure or heart drugs
- ❑ Q 7 Other reason: ____________________

C RISK FACTORS FOR CARDIOVASCULAR DISEASE:
Check all that apply

- ❑ Less than 30 minutes of moderate physical activity most days of the week.
- ❑ Currently smoker (tobacco smoking 1 or more times per week).
- ❑ High blood pressure reported by physician after repeated measurements.
- ❑ High cholesterol level reported by physician.
- ❑ Excessive accumulation of fat around waist.
- ❑ Family history of heart disease.

Please note: *Many of these risk factors are modifiable. Please refer to page 4 and discuss with your physician.*

D PHYSICAL ACTIVITY INTENTIONS:

What physical activity do you intend to do?

____

____

____

This section to be completed by the examining physician

Physical Exam:

Ht	Wt	BP i) /
		BP ii) /

Conditions limiting physical activity:

❑ Cardiovascular ❑ Respiratory ❑ Other
❑ Musculoskeletal ❑ Abdominal

Tests required:

❑ ECG ❑ Exercise Test ❑ X-Ray
❑ Blood ❑ Urinalysis ❑ Other

Physical Activity Readiness Conveyance/Referral:

Based upon a current review of health status, I recommend:

Further Information:
❑ Attached
❑ To be forwarded
❑ Available on request

- ❑ No physical activity
- ❑ Only a medically-supervised exercise program until further medical clearance
- ❑ Progressive physical activity:
  - ❑ with avoidance of: ____________________
  - ❑ with inclusion of: ____________________
  - ❑ under the supervision of a CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™
- ❑ Unrestricted physical activity–start slowly and build up gradually

Source: *Physical Activity Readiness Medical Examination* (PARmed-X) © 2002. Used with permission from the Canadian Society for Exercise Physiology. www.csep.ca/forms.asp.

Physical Activity Readiness
Medical Examination
(revised 2002)

PARmed-X PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION

Following is a checklist of medical conditions for which a degree of precaution and/or special advice should be considered for those who answered "YES" to one or more questions on the PAR-Q, and people over the age of 69. Conditions are grouped by system. Three categories of precautions are provided. Comments under Advice are general, since details and alternatives require clinical judgement in each individual instance.

	Absolute Contraindications	Relative Contraindications	Special Prescriptive Conditions	ADVICE
	Permanent restriction or temporary restriction until condition is treated, stable, and/or past acute phase.	Highly variable. Value of exercise testing and/or program may exceed risk. Activity may be restricted. Desirable to maximize control of condition. Direct or indirect medical supervision of exercise program may be desirable.	Individualized prescriptive advice generally appropriate: • limitations imposed; and/or • special exercises prescribed. May require medical monitoring and/or initial supervision in exercise program.	
Cardiovascular	❑ aortic aneurysm (dissecting) ❑ aortic stenosis (severe) ❑ congestive heart failure ❑ crescendo angina ❑ myocardial infarction (acute) ❑ myocarditis (active or recent) ❑ pulmonary or systemic embolism—acute ❑ thrombophlebitis ❑ ventricular tachycardia and other dangerous dysrhythmias (e.g., multi-focal ventricular activity)	❑ aortic stenosis (moderate) ❑ subaortic stenosis (severe) ❑ marked cardiac enlargement ❑ supraventricular dysrhythmias (uncontrolled or high rate) ❑ ventricular ectopic activity (repetitive or frequent) ❑ ventricular aneurysm ❑ hypertension—untreated or uncontrolled severe (systemic or pulmonary) ❑ hypertrophic cardiomyopathy ❑ compensated congestive heart failure	❑ aortic (or pulmonary) stenosis—mild angina pectoris and other manifestations of coronary insufficiency (e.g., post-acute infarct) ❑ cyanotic heart disease ❑ shunts (intermittent or fixed) ❑ conduction disturbances • complete AV block • left BBB • Wolff-Parkinson-White syndrome ❑ dysrhythmias—controlled ❑ fixed rate pacemakers	• clinical exercise test may be warranted in selected cases, for specific determination of functional capacity and limitations and precautions (if any). • slow progression of exercise to levels based on test performance and individual tolerance. • consider individual need for initial conditioning program under medical supervision (indirect or direct).
			❑ intermittent claudication	progressive exercise to tolerance
			❑ hypertension: systolic 160-180; diastolic 105+	progressive exercise; care with medications (serum electrolytes; post-exercise syncope; etc.)
Infections	❑ acute infectious disease (regardless of etiology)	❑ subacute/chronic/recurrent infectious diseases (e.g., malaria, others)	❑ chronic infections ❑ HIV	variable as to condition
Metabolic		❑ uncontrolled metabolic disorders (diabetes mellitus, thyrotoxicosis, myxedema)	❑ renal, hepatic & other metabolic insufficiency	variable as to status
			❑ obesity ❑ single kidney	dietary moderation, and initial light exercises with slow progression (walking, swimming, cycling)
Pregnancy		❑ complicated pregnancy (e.g., toxemia, hemorrhage, incompetent cervix, etc.)	❑ advanced pregnancy (late 3rd trimester)	refer to the "PARmed-X for PREGNANCY"

References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. **J. Clin. Epidemiol.** 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy, In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health.** Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). **Can. J. Spt. Sci.** 17: 4 338-345.

The PAR-Q and PARmed-X were developed by the British Columbia Ministry of Health. They have been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Évaluation médicale de l'aptitude à l'activité physique (X-AAP)»

(continued)

Physical Activity Readiness
Medical Examination
(revised 2002)

	Special Prescriptive Conditions	ADVICE
Lung	❑ chronic pulmonary disorders	special relaxation and breathing exercises
	❑ obstructive lung disease ❑ asthma	breath control during endurance exercises to tolerance; avoid polluted air
	❑ exercise-induced bronchospasm	avoid hyperventilation during exercise; avoid extremely cold conditions; warm up adequately; utilize appropriate medication.
Musculoskeletal	❑ low back conditions (pathological, functional)	avoid or minimize exercise that precipitates or exasperates e.g., forced extreme flexion, extension, and violent twisting; correct posture, proper back exercises
	❑ arthritis—acute (infective, rheumatoid; gout)	treatment, plus judicious blend of rest, splinting and gentle movement
	❑ arthritis—subacute	progressive increase of active exercise therapy
	❑ arthritis—chronic (osteoarthritis and above conditions)	maintenance of mobility and strength; non-weightbearing exercises to minimize joint trauma (e.g., cycling, aquatic activity, etc.)
	❑ orthopaedic	highly variable and individualized
	❑ hernia	minimize straining and isometrics; stregthen abdominal muscles
	❑ osteoporosis or low bone density	avoid exercise with high risk for fracture such as push-ups, curl-ups, vertical jump and trunk forward flexion; engage in low-impact weight-bearing activities and resistance training
CNS	❑ convulsive disorder not completely controlled by medication	minimize or avoid exercise in hazardous environments and/or exercising alone (e.g., swimming, mountainclimbing, etc.)
	❑ recent concussion	thorough examination if history of two concussions; review for discontinuation of contact sport if three concussions, depending on duration of unconsciousness, retrograde amnesia, persistent headaches, and other objective evidence of cerebral damage
Blood	❑ anemia—severe (< 10 Gm/dl) ❑ electrolyte disturbances	control preferred; exercise as tolerated
Medications	❑ antianginal ❑ antiarrhythmic ❑ antihypertensive ❑ anticonvulsant ❑ beta-blockers ❑ digitalis preparations ❑ diuretics ❑ ganglionic blockers ❑ others	NOTE: consider underlying condition. Potential for: exertional syncope, electrolyte imbalance, bradycardia, dysrhythmias, impaired coordination and reaction time, heat intolerance. May alter resting and exercise ECG's and exercise test performance.
Other	❑ post-exercise syncope	moderate program
	❑ heat intolerance	prolong cool-down with light activities; avoid exercise in extreme heat
	❑ temporary minor illness	postpone until recovered
	❑ cancer	if potential metastases, test by cycle ergometry, consider non-weight bearing exercises; exercise at lower end of prescriptive range (40-65% of heart rate reserve), depending on condition and recent treatment (radiation, chemotherapy); monitor hemoglobin and lymphocyte counts; add dynamic lifting exercise to strengthen muscles, using machines rather than weights.

*Refer to special publications for elaboration as required

The following companion forms are available online: http://www.csep.ca/forms.asp

The **Physical Activity Readiness Questionnaire (PAR-Q)** - a questionnaire for people aged 15-69 to complete before becoming much more physically active.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for PREGNANCY)** - to be used by physicians with pregnant patients who wish to become more physically active.

For more information, please contact the:

Canadian Society for Exercise Physiology
202 - 185 Somerset St. West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565 • Online: www.csep.ca

Note to physical activity professionals...

It is a prudent practice to retain the completed Physical Activity Readiness Conveyance/Referral Form in the participant's file.

Supported by: Health Canada Santé Canada

Physical Activity Readiness
Medical Examination
(revised 2002)

PARmed-X PHYSICAL ACTIVITY READINESS MEDICAL EXAMINATION

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

PARmed-X Physical Activity Readiness Conveyance/Referral Form

Based upon a current review of the health status of ______________________________, I recommend:

- ❑ No physical activity
- ❑ Only a medically-supervised exercise program until further medical clearance
- ❑ Progressive physical activity
    - ❑ with avoidance of: ______________________________
    - ❑ with inclusion of: ______________________________
    - ❑ under the supervision of a CSEP-Professional Fitness & Lifestyle Consultant or CSEP-Exercise Therapist™
- ❑ Unrestricted physical activity — start slowly and build up gradually

Further Information:
- ❑ Attached
- ❑ To be forwarded
- ❑ Available on request

Physician/clinic stamp:

______________________________ M.D.

______________________________ 20______
(date)

NOTE: This physical activity clearance is valid for a maximum of six months from the date it is completed and becomes invalid if your medical condition becomes worse.

Source: *Physical Activity Readiness Medical Examination* (PARmed-X) © 2002. Used with permission from the Canadian Society for Exercise Physiology. www.csep.ca/forms.asp.

Appendix A.5: SCORE High and Low CVD Risk Charts

SCORE

- 15% and over
- 10%-14%
- 5%-9%
- 3%-4%
- 2%
- 1%
- <1%

10-year risk of fatal CVD in populations at ***high CVD risk***[a]

HIGH CVD RISK

Systolic blood pressure (mmHg) by Total cholesterol (mmol/L)

Age	Systolic blood pressure (mmHg)	Women Non-smoker 4	5	6	7	8	Women Smoker 4	5	6	7	8	Men Non-smoker 4	5	6	7	8	Men Smoker 4	5	6	7	8
65	180	7	8	9	10	12	13	15	17	19	22	14	16	19	22	26	26	30	35	41	47
	160	5	5	6	7	8	9	10	12	13	16	9	11	13	15	16	18	21	25	29	34
	140	3	3	4	5	6	6	7	8	9	11	6	8	9	11	13	13	15	17	20	24
	120	2	2	3	3	4	4	5	5	6	7	4	5	6	7	9	9	10	12	14	17
60	180	4	4	5	6	7	8	9	10	11	13	9	11	13	15	18	18	21	24	28	33
	160	3	3	3	4	5	5	6	7	8	9	6	7	9	10	12	12	14	17	20	24
	140	2	2	2	3	3	3	4	5	5	6	4	5	6	7	9	8	10	12	14	17
	120	1	1	2	2	2	2	3	3	4	4	3	3	4	5	6	6	7	8	10	12
55	180	2	2	3	3	4	4	5	5	6	7	6	7	8	10	12	12	13	16	19	22
	160	1	2	2	2	3	3	3	4	4	5	4	5	6	7	8	8	9	11	13	16
	140	1	1	1	1	2	2	2	2	3	3	3	3	4	5	6	5	6	8	9	11
	120	1	1	1	1	1	1	1	2	2	2	2	2	3	3	4	4	4	5	6	8
50	180	1	1	1	2	2	2	2	3	3	4	4	4	5	6	7	7	8	10	12	14
	160	1	1	1	1	1	1	2	2	2	3	2	3	3	4	5	5	6	7	8	10
	140	0	1	1	1	1	1	1	1	1	2	2	2	2	3	3	3	4	5	6	7
	120	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	4	5
40	180	0	0	0	0	0	0	0	0	1	1	1	1	1	2	2	2	2	3	3	4
	160	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	2	2	2	3
	140	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2
	120	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

150 200 250 300 mg/dL

Total cholesterol (mmol/L)

[a]To compute the 10-yr risk, multiply the value within the box by 3 for men and 4 for women
This chart should not be used for adults with CVD, chronic kidney disease, diabetes, or very high individual risk factors.

Reprinted, by permission, from J. Perk, 2012, “European Guidelines on cardiovascular disease prevention in clinical practice (version 2012): The Fifth Joint Task Force of the European Society of Cardiology and other societies on cardiovascular disease prevention in clinical practice (constituted by representatives of nine societies and by invited experts). Developed with the special contribution of the European Association for Cardiovascular Prevention & Rehabilitation (EACPR),” *European Heart Journal* 33(13): 1635-1701. www.escardio.org/guidelines.

SCORE

LOW CVD RISK

- 15% and over
- 10%-14%
- 5%-9%
- 3%-4%
- 2%
- 1%
- <1%

10-year risk of fatal CVD in populations at ***low CVD risk***[a]

		Women										Men									
		Non-smoker					Smoker					Non-smoker					Smoker				
Age	Systolic blood pressure (mmHg)	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8	4	5	6	7	8
65	180	4	5	6	6	7	9	9	11	12	14	8	9	10	12	14	15	17	20	23	26
	160	3	3	4	4	5	6	6	7	8	10	5	6	7	8	10	10	12	14	16	19
	140	2	2	2	3	3	4	4	5	6	7	4	4	5	6	7	7	8	9	11	13
	120	1	1	2	2	2	3	3	3	4	4	2	3	3	4	5	5	5	6	8	9
60	180	3	3	3	4	4	5	5	6	7	8	5	6	7	8	9	10	11	13	15	18
	160	2	2	2	2	3	3	4	4	5	5	3	4	5	5	6	7	8	9	11	13
	140	1	1	1	2	2	2	2	3	3	4	2	3	3	4	4	5	5	6	7	9
	120	1	1	1	1	1	1	2	2	2	3	2	2	2	3	3	3	4	4	5	6
55	180	1	1	2	2	2	3	3	3	4	4	3	4	4	5	6	6	7	8	10	12
	160	1	1	1	1	1	2	2	2	3	3	2	2	3	3	4	4	5	6	7	8
	140	1	1	1	1	1	1	1	1	2	2	1	2	2	2	3	3	3	4	5	6
	120	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	4
50	180	1	1	1	1	1	1	1	2	2	2	2	2	3	3	4	4	4	5	6	7
	160	0	0	1	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3	4	5
	140	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	3	3
	120	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2
40	180	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	2	2
	160	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1
	140	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1
	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

Total cholesterol (mmol/L)

150 200 250 300
mg/dL

[a]To compute the 10-yr risk, multiply the value within the box by 3 for men and 4 for women
This chart should not be used for adults with CVD, chronic kidney disease, diabetes, or very high individual risk factors.

Appendix A.6: Relative Risk Chart

Relative Risk Chart

This chart may be used to show younger people at low absolute risk that, relative to others in their age group, their risk may be many times higher than necessary. This may help to motivate decisions about avoidance of smoking, healthy nutrition, and exercise, as well as flagging those who may become candidates for medication.

Systolic blood pressure (mmHg)	Non-smoker					Smoker				
180	3	3	4	5	6	6	7	8	10	12
160	2	3	3	4	4	4	5	6	7	8
140	1	2	2	2	3	3	3	4	5	6
120	1	1	1	2	2	2	2	3	3	4
Cholesterol (mmol/L)	4	5	6	7	8	4	5	6	7	8

Please note that this chart shows RELATIVE not absolute risk. The risks are RELATIVE to 1 in the bottom left. Thus a person in the top right-hand box has a risk that is 12 times higher than a person in the bottom left.

Appendix A.7: Lifestyle Evaluation

Smoking habits

1. Have you ever smoked cigarettes, cigars, or a pipe? ❒ Yes ❒ No
2. Do you smoke presently? ❒ Yes ❒ No

   Cigarettes ______________ a day

   Cigars ______________ a day

   Pipefuls ______________ a day
3. At what age did you start smoking? ______________ years
4. If you have quit smoking, when did you quit? ______________

Drinking habits

1. During the past month, how many days did you drink alcoholic beverages? ______________
2. During the past month, how many times did you have 5 or more drinks per occasion? ______________
3. On average, how many glasses of beer, wine, or highballs do you consume a week?

   Beer ______________ glasses or cans

   Wine ______________ glasses

   Highballs ______________ glasses

   Other ______________ glasses

Exercise habits

1. Do you exercise vigorously on a regular basis? ❒ Yes ❒ No
2. What activities do you engage in on a regular basis?
3. If you walk, run, or jog, what is the average number of miles you cover each workout? ______________ miles
4. How many minutes on the average is each of your exercise workouts? ______________ minutes
5. How many workouts a week do you participate in on average? ______________ workouts
6. Is your occupation?

   ______________ Inactive (e.g., desk job)

   ______________ Light work (e.g., housework, light carpentry)

   ______________ Heavy work (e.g., heavy carpentry, lifting)

(continued)

7. Check those activities that you would prefer in a regular exercise program for yourself:

______	Walking, running, or jogging	______	Handball, racquetball, or squash
______	Stationary running	______	Basketball
______	Jumping rope	______	Swimming
______	Bicycling	______	Tennis
______	Stationary cycling	______	Aerobic dance
______	Step aerobics	______	Stair-climbing
		______	Other (specify)

Dietary habits

1. What is your current weight? ______ lb ______ kg height? ______ in. ______ cm
2. What would you like to weigh? ______ lb ______ kg
3. What is the most you ever weighed as an adult? ______ lb ______ kg
4. What is the least you ever weighed as an adult? ______ lb ______ kg
5. What weight-loss methods have you tried? ____

   ____
6. Which do you eat regularly?

   ❒ Breakfast ❒ Midafternoon snack

   ❒ Midmorning snack ❒ Dinner

   ❒ Lunch ❒ After-dinner snack
7. How often do you eat out each week? __________ times
8. What size portions do you normally have?

   ❒ Small ❒ Moderate ❒ Large ❒ Extra large ❒ Uncertain
9. How often do you eat more than one serving?

   ❒ Always ❒ Usually ❒ Sometimes ❒ Never
10. How long does it usually take you to eat a meal? __________ minutes
11. Do you eat while doing other activities (e.g., watching TV, reading, working)? __________
12. When you snack, how many times a week do you eat the following?

    Cookies, cake, pie ______ Candy ______ Diet soda ______

    Soft drinks ______ Doughnuts ______ Fruit ______

    Milk or milk beverage ______ Potato chips, pretzels, etc. ______

    Peanuts or other nuts ______ Ice cream ______

    Cheese and crackers ______ Other ____________________
13. How often do you eat dessert? __________ times a day __________ times a week
14. What dessert do you eat most often? ______________________________
15. How often do you eat fried foods? __________ times a week
16. Do you salt your food at the table? ❒ Yes ❒ No

    ❒ Before tasting it ❒ After tasting it

Appendix A.8: Fantastic Lifestyle Checklist

INSTRUCTIONS: Unless otherwise specified, place an 'X' beside the box which best describes your behaviour or situation in the past month. Explanations of questions and scoring are provided on the next page.

FAMILY FRIENDS	I have someone to talk to about things that are important to me	almost never		seldom		some of the time		fairly often		almost always	
	I give and receive affection	almost never		seldom		some of the time		fairly often		almost always	
ACTIVITY	I am vigorously active for at least 30 minutes per day e.g., running, cycling, etc.	less than once/week		1-2 times/week		3 times/week		4 times/week		5 or more times/week	
	I am moderately active (gardening, climbing stairs, walking, housework)	less than once/week		1-2 times/week		3 times/week		4 times/week		5 or more times/week	
NUTRITION	I eat a balanced diet (see explanation)	almost never		seldom		some of the time		fairly often		almost always	
	I often eat excess 1) sugar, or 2) salt, or 3) animal fats, or 4) junk foods.	four of these		three of these		two of these		one of these		none of these	
	I am within ____kg of my healthy weight	not within 8 kg (20 lbs)		8 kg (20 lbs)		6 kg (15 lbs)		4 kg (10 lbs)		2 kg (5 lbs)	
TOBACCO TOXICS	I smoke tobacco	more than 10 times/week		1 - 10 times/week		none in the past 6 months		none in the past year		none in the past 5 years	
	I use drugs such as marijuana, cocaine	sometimes								never	
	I overuse prescribed or 'over the counter' drugs	almost daily		fairly often		only occasionally		almost never		never	
	I drink caffeine-containing coffee, tea, or cola	more than 10/day		7-10/day		3-6/day		1-2/day		never	
ALCOHOL	My average alcohol intake per week is____ (see explanation)	more than 20 drinks		13-20 drinks		11-12 drinks		8-10 drinks		0-7 drinks	
	I drink more than four drinks on an occasion	almost daily		fairly often		only occasionally		almost never		never	
	I drive after drinking	sometimes								never	
SLEEP SEATBELTS STRESS SAFE SEX	I sleep well and feel rested	almost never		seldom		some of the time		fairly often		almost always	
	I use seatbelts	never		seldom		some of the time		most of the time		always	
	I am able to cope with the stresses in my life	almost never		seldom		some of the time		fairly often		almost always	
	I relax and enjoy leisure time	almost never		seldom		some of the time		fairly often		almost always	
	I practice safe sex (see explanation)	almost never		seldom		some of the time		fairly often		always	
TYPE of behaviour	I seem to be in a hurry	almost always		fairly often		some of the time		seldom		almost never	
	I feel angry or hostile	almost always		fairly often		some of the time		seldom		almost never	
INSIGHT	I am a postive or optimistic thinker	almost never		seldom		some of the time		fairly often		almost always	
	I feel tense or uptight	almost always		fairly often		some of the time		seldom		almost never	
	I feel sad or depressed	almost always		fairly often		some of the time		seldom		almost never	
CAREER	I am satisfied with my job or role	almost never		seldom		some of the time		fairly often		almost always	

STEP 1	Total the X's in each column	→	☐	☐	☐	☐	☐	
STEP 2	Multiply the totals by the numbers indicated (write your answer in the box below)	→	0	x 1	x 2	x 3	x 4	
STEP 3	Add your scores across the bottom for your grand total	→		☐ +	☐ +	☐ +	☐ =	☐

Grand total
(see explantion)

(continued)

Adapted, by permission, from D. Wilson, 1998, *Fantastic lifestyle assessment*.

Appendix A.8 (*continued)*

▼ A BALANCED DIET:

According to Canada's Food Guide to Healthy Eating (for people four years and over):

Different People Need Different Amounts of Food

The amount of food you need every day from the 4 food groups and other foods depends on your age, body size, activity level, whether you are male or female, and if your are pregnant or breast feeding. That's why the Food Guide gives a lower and higher number of servings for each food group. For example, young children can choose the lower number of servings, while male teenagers can select the higher number. Most other people can choose servings somewhere in between.

Grain Products	Vegetables & Fruit	Milk Products	Meat & Alternatives	Other Foods
Choose whole grain and enriched products more often.	Choose dark green and orange vegetables more often.	Choose lower fat milk products more often.	Choose leaner meats, poultry, and fish, as well as dried peas, beans, and lentils more often.	Taste and enjoyment can also come from other foods and beverages that are not part of the 4 food groups. Some of these are higher in fat or calories, so use these foods in moderation.
recommended number of servings per day:				
5-12	**5-10**	Children 4-9 years: 2-3 Youth 10-16 years: 3-4 Adults: 2-4 Pregnant and breast-feeding women: 3-4	**2-3**	

▼ ALCOHOL INTAKE:

1 drink equals:		Canadian	Metric	U.S.
1 bottle of beer	5% alcohol	12 oz.	340.8 ml	10 oz.
1 glass of wine	12% alcohol	5 oz.	142 ml	4.5 oz
1 shot of spirits	40% alcohol	1.5 oz	42.6 ml	1.25 oz.

▼ SAFE SEX:

Refers to the use of methods of preventing infection or conception.

WHAT DOES THE SCORE MEAN?

85-100	70-84	55-69	35-54	0-34
EXCELLENT	VERY GOOD	GOOD	FAIR	NEEDS IMPROVEMENT

NOTE: A low total score does not mean that you have failed. There is always the chance to change your lifestyle — starting now. Look at the areas where you scored a 0 or 1 and decide which areas you want to work on first.

TIPS:

1 Don't try to change all the areas at once. This will be too overwhelming for you.

2 Writing down your proposed changes and your overall goal will help you to succeed.

3 Make changes in small steps towards the overall goal.

4 Enlist the help of a friend to make similar changes and/or to support you in your attempts.

5 Congratulate yourself for achieving each step. Give yourself appropriate rewards.

6 Ask your physical activity professional (CSEP-Professional Fitness and Lifestyle Consultant), family physician, nurse or health department for more information on any of these areas.

Adapted, by permission, from D. Wilson, 1998, *Fantastic lifestyle assessment*.

Appendix A.9: Informed Consent

In order to assess cardiovascular function, body composition, and other physical fitness components, the undersigned hereby voluntarily consents to engage in one or more of the following tests (check the appropriate boxes):

- ❒ Graded exercise stress test
- ❒ Body composition tests
- ❒ Muscle fitness tests
- ❒ Flexibility tests
- ❒ Balance tests

Explanation of the tests

The graded exercise test is performed on a cycle ergometer or motor-driven treadmill. The workload is increased every few minutes until exhaustion or until other symptoms dictate that we terminate the test. You may stop the test at any time because of fatigue or discomfort.

The underwater weighing procedure involves being completely submerged in a tank or tub after fully exhaling the air from your lungs. You will be submerged for 3 to 5 seconds while we measure your underwater weight. This test provides an accurate assessment of your body composition.

For muscle fitness testing, you lift weights for a number of repetitions using barbells or exercise machines. These tests assess the strength and endurance of the major muscle groups in the body.

For evaluation of flexibility, you perform a number of tests. During these tests, we measure the range of motion in your joints.

For balance tests, we will be measuring the amount of time you can maintain certain stances or the distance you are able to reach without losing balance.

Risks and discomforts

During the graded exercise test, certain changes may occur. These changes include abnormal blood pressure responses, fainting, irregularities in heartbeat, and heart attack. Every effort is made to minimize these occurrences. Emergency equipment and trained personnel are available to deal with these situations if they occur.

You may experience some discomfort during the underwater weighing, especially after you expire all the air from your lungs. However, this discomfort is momentary, lasting only 3 to 5 seconds. If this test causes you too much discomfort, an alternative procedure (e.g., skinfold or bioelectrical impedance test) can be used to estimate your body composition.

There is a slight possibility of pulling a muscle or spraining a ligament during the muscle fitness and flexibility testing. In addition, you may experience muscle soreness 24 or 48 hours after testing. These risks can be minimized by performing warm-up exercises prior to taking the tests. If muscle soreness occurs, appropriate stretching exercises to relieve this soreness will be demonstrated.

Expected benefits from testing

These tests allow us to assess your physical working capacity and to appraise your physical fitness status. The results are used to prescribe a safe, sound exercise program for you. Records are kept strictly confidential unless you consent to release this information.

(continued)

From Vivian H. Heyward and Ann L. Gibson, 2014, *Advanced Fitness Assessment and Exercise Prescription,* 7th ed. (Champaign, IL: Human Kinetics).

Inquiries

Questions about the procedures used in the physical fitness tests are encouraged. If you have any questions or need additional information, please ask us to explain further.

Freedom of Consent

Your permission to perform these physical fitness tests is strictly voluntary. You are free to stop the tests at any point, if you so desire.

I have read this form carefully and I fully understand the test procedures that I will perform and the risks and discomforts. Knowing these risks and having had the opportunity to ask questions that have been answered to my satisfaction, I consent to participate in these tests.

Date	Signature of patient
Date	Signature of witness
Date	Signature of supervisor

Appendix A.10: Websites for Selected Professional Organizations and Institutes[a]

Name	Web site address
Aerobics and Fitness Association of America (AFAA)	www.afaa.com
American Association for Health, Physical Education, Recreation and Dance (AAHPERD)	www.aapherd.org
American Association of Cardiovascular and Pulmonary Rehabilitation (AACPR)	www.aacvpr.org
American College of Sports Medicine (ACSM)	www.acsm.org
American Council on Exercise (ACE)	www.acefitness.org
American Fitness Professionals and Associates (AFPA)	www.afpafitness.org
American Society of Exercise Physiologists (ASEP)	www.asep.org
Australian Association for Exercise and Sport Sciences (AAESS)	www.aaess.com.au
Canadian Academy of Sports Medicine (CASM)	www.casm-acms.org
Canadian Society for Exercise Physiology (CSEP)	www.csep.ca
Cooper Institute for Aerobics Research	www.cooperinst.org
Ethics and Safety Compliance Standards	www.escs.info
Gatorade Sport Science Institute (GSSI)	www.gssiweb.com
IDEA Health and Fitness Association	www.ideafit.com
Institute for Credentialing Excellence	www.credentialingexcellence.org
International Association of Fitness Certifying Agencies	www.iafca.org
International Federation of Sports Medicine (FIMS)	www.fims.org
International Fitness Professionals Association (IFPA)	www.ifpa-fitness.com
International Health, Racquet, & Sportsclub Association	www.ihrsa.org
International Society for Aging and Physical Activity (ISAPA)	www.isapa.org
National Athletic Trainers Association (NATA)	www.nata.org
National Board of Fitness Examiners	www.nbfe.org
National Commission for Certifying Agencies (NCCA)	www.credentialingexcellence.org/ncca
National Strength and Conditioning Association (NSCA)	www.nsca-lift.org
North American Society for Pediatric Exercise Medicine (NASPEM)	www.naspem.org
Sports Medicine Australia	www.sma.org.au
Sports Medicine New Zealand	www.sportsmedicine.co.nz

[a]Organizations and institutes dealing with exercise physiology, sports medicine, or physical fitness.

List of Abbreviations

Terms	
%BF	Percent body fat
AAHPERD	American Alliance for Health, Physical Education, Recreation and Dance
ACSM	American College of Sports Medicine
ADL	Activities of daily living
ADP	Air displacement plethysmography
AI	Adequate intake
AIT	Aerobic interval training
ATP	Adenosine triphosphate
AV	Atrioventricular
BIA	Bioelectrical impedance analysis
BIS	Bioimpedance spectroscopy
BM	Body mass
BMI	Body mass index
BMR	Basal metabolic rate
BP	Blood pressure
BSA	Body surface area
BV	Body volume
BW	Body weight
C	Circumference
CDC	Centers for Disease Control and Prevention
CE	Constant error
CHD	Coronary heart disease
CP	Creatine phosphate
CR	Contract-relax
CRAC	Contract-relax with agonist contraction
CSA	Cross-sectional area
CSEP	Canadian Society for Exercise Physiology
CTT	Counting talk test
CV	Cardiovascular
CVD	Cardiovascular disease
D	Skeletal diameter
Db	Body density
DBP	Diastolic blood pressure
DOMS	Delayed-onset muscle soreness
DXA	Dual-energy X-ray absorptiometry
ECG	Electrocardiogram
EDD	Exercise deficit disorder
EIMD	Exercise-induced muscle damage
EMG	Electromyography

Terms	
ESH-IP	European Society of Hypertension International Protocol
FFB	Fat-free body
FFM	Fat-free mass
FITT-VP	Frequency, intensity, time, type of exercise, volume, and progression
FM	Fat mass
FRC	Functional residual lung capacity
GH	Growth hormone
GI	Glycemic index
GIS	Geographical information system
GPS	Global positioning system
GV	Volume of air in gastrointestinal tract
GXT	Graded exercise test
HDL	High-density lipoprotein
HDL-C	High-density lipoprotein cholesterol
HIT	High-intensity interval training
HMB	β-hydroxy-β-methylbutyrate
HR	Heart rate
HRmax	Maximal heart rate
HRrest	Resting heart rate
HRR	Heart rate reserve
HT	Standing height
HT^2/R	Resistance index
HW	Hydrostatic weighing
LDL	Low-density lipoprotein
LDL-C	Low-density lipoprotein cholesterol
LP	Linear periodization
MET	Metabolic equivalent
MET·min	MET minutes
MRI	Magnetic resonance imaging
MVIC	Maximal voluntary isometric contraction
N	Sample size
NCEP	National Cholesterol Education Program
NHANES	National Health and Nutrition Examination Survey
NIDDM	Non-insulin-dependent diabetes mellitus
NIH	National Institutes of Health
NIR	Near-infrared interactance
P	Power output

Terms

PAL	Physical activity level
PAR-Q	Physical Activity Readiness Questionnaire
PARmed-X	Physical Activity Readiness Medical Examination Questionnaire
PEI	Physical efficiency index
PNF	Proprioceptive neuromuscular facilitation
$\dot{Q}$	Cardiac output
ρ	Specific resistivity
R	Resistance for bioimpedance analysis
r	Pearson product–moment correlation
RDA	Recommended dietary allowance
REE	Resting energy expenditure
rep	Repetition
RER	Respiratory exchange ratio
RLP	Reverse linear periodization
RM	Repetition maximum
Rmc	Multiple correlation coefficient
RMR	Resting metabolic rate
ROM	Range of motion
RPE	Rating of perceived exertion
RV	Residual (lung) volume
SAD	Sagittal abdominal diameter
SBP	Systolic blood pressure
SCENIHR	Scientific Committee on Emerging and Newly Identified Health
SEE	Standard error of estimate
SIT	Sprint interval training
SKF	Skinfold
ΣSKF	Sum of skinfolds
SRP	Steep ramp cycling protocol
SV	Stroke volume
TBW	Total body water
TC	Total cholesterol
TC/HDL-C	Ratio of total cholesterol to HDL-cholesterol
TE	Total error
TEE	Total energy expenditure
TGV	Thoracic gas volume
TLC	Total lung capacity
TLCNS	Total lung capacity, head not submerged
TMS	Transcranial magnetic stimulation
UWW	Underwater weight
UP	Undulating periodization
VLDL	Very low-density lipoprotein
$\dot{V}O_2$	Volume of oxygen consumed per minute
$\dot{V}O_2max$	Maximal oxygen uptake
$\dot{V}O_2R$	Oxygen uptake reserve
WBAN	Wireless body area network
WBV	Whole-body vibration
WHR	Waist-to-hip ratio
WHTR	Waist-to-height ratio
Xc	Reactance
YMCA	Young Men's Christian Association
YYIR1C	Modified Yo-Yo Intermittent Recovery Level 1 test for children
Z	Impedance

Units of Measure

bpm	beats per minute
C	Celsius
cc	cubic centimeter
cm	centimeter
dl	deciliter
F	Fahrenheit
ft-lb	foot-pound
g	gram
hr	hour
Hz	hertz
in.	inch
kcal	kilocalorie
kg	kilogram
kgm	kilogram-meter
kHz	kilohertz
km	kilometer
L	liter
lb	pound
m	meter
meq	milli-equivalent
mg	milligram
mi	mile
min	minute
ml	milliliter
mm	millimeter
mmHg	millimeters of mercury
mo	month
mph	miles per hour
N	newton
Nm	newton-meter
rpm	revolutions per minute
sec	second
W	watt
wk	week
yr	year
µg	microgram
µg RE	retinol equivalent
Ω	ohm

Glossary

absolute $\dot{V}O_2$—Measure of rate of oxygen consumption and energy cost of non-weight-bearing activities; measured in $L \cdot min^{-1}$ or $ml \cdot min^{-1}$.

accelerometer—Device used to record body acceleration minute to minute, providing detailed information about frequency, duration, intensity, and patterns of movement.

accommodating-resistance exercise—Type of exercise in which fluctuations in muscle force throughout the range of motion are matched by an equal counterforce as the speed of limb movement is kept at a constant velocity; isokinetic exercise.

acquired immune deficiency syndrome (AIDS)—Disease characterized as a deficiency in the body's immune system, caused by human immunodeficiency virus (HIV).

active-assisted stretching—Stretching technique that involves voluntarily moving a body part to the end of its active range of motion, followed by assistance in moving the body part beyond its active range of motion.

active stretching—Stretching technique that involves moving a body part without external assistance; voluntary muscle contraction.

activities of daily living (ADLs)—Normal everyday activities such as getting out of a chair or car, climbing stairs, shopping, dressing, and bathing.

acute-onset muscle soreness—Soreness or pain occurring during or immediately after exercise; caused by ischemia and accumulation of metabolic waste products in the muscle.

aerobic interval training (AIT)—Subclass of high-intensity interval training; consists of repeated combinations of near maximal (80–95% $\dot{V}O_2R$) 4 min bouts of exercise and rest or recovery periods of similar duration.

air displacement plethysmography (ADP)—Densitometric method to estimate body volume using air displacement and pressure-volume relationships.

allele—One member of a pair or series of genes that occupy a specific position on a specific chromosome.

android obesity—Type of obesity in which excess body fat is localized in the upper body; upper body obesity; apple-shaped body.

aneurysm—Dilation of a blood vessel wall causing a weakness in the vessel's wall; usually caused by atherosclerosis and hypertension.

angina pectoris—Chest pain.

ankylosis—Limited range of motion at a joint.

anorexia nervosa—Eating disorder characterized by excessive weight loss.

anthropometry—Measurement of body size and proportions including skinfold thicknesses, circumferences, bony widths and lengths, stature, and body weight.

aortic stenosis—Narrowing of the aortic valve, obstructing blood flow from the left ventricle into the aorta.

Archimedes' principle—Principle stating that weight loss underwater is directly proportional to the volume of water displaced by the body's volume.

arrhythmia—Abnormal heart rhythm.

arteriosclerosis—Hardening of the arteries, or thickening and loss of elasticity in the artery walls that obstruct blood flow; caused by deposits of fat, cholesterol, and other substances.

asthma—Respiratory disorder characterized by difficulty in breathing and wheezing due to constricted bronchi.

at risk for overweight—Characterizing children with a body mass index between the 85th and 94th percentiles for age and sex.

ataxia—Impaired ability to coordinate movement characterized by staggering gait or postural imbalance.

atherosclerosis—Buildup and deposition of fat and fibrous plaque in the inner walls of the coronary arteries.

atrial fibrillation—Cardiac dysrhythmia in which the atria quiver instead of pumping in an organized fashion.

atrial flutter—Type of atrial tachycardia in which the atria contract at rates of 230 to 380 bpm.

atrophy—A wasting or decrease in size of a body part.

attenuation—Weakening of X-ray energy as it passes through fat, lean tissue, and bone.

augmented unipolar leads—Three ECG leads (aVF, aVL, aVR) that compare voltage across each limb lead to the average voltage across the two opposite electrodes.

auscultation—Method used to measure heart rate or blood pressure by listening to heart and blood sounds.

balance—Complex construct involving multiple biomechanical, neurological, and environmental systems.

ballistic stretching—Type of stretching exercise that uses a fast bouncing motion to produce stretch and increase range of motion.

basal metabolic rate (BMR)—Measure of minimal amount of energy needed to maintain basic and essential physiological functions.

behavior modification model—Psychological theory of change; clients become actively involved with the change process by setting short- and long-term goals.

β-hydroxy-β-methylbutyrate (HMB)—Dietary supplement known to increase lean body mass and strength of individuals engaging in resistance training.

bias—In regression analysis, a systematic over- or underestimation of actual scores caused by technical error or biological variability between validation and cross-validation samples; constant error.

biaxial joint—Joint allowing movement in two planes; condyloid and saddle joints.

bioelectrical impedance analysis (BIA)—Field method for estimating the total body water or fat-free mass using measures of impedance to current flowing through the body.

bioimpedance spectroscopy (BIS)—Type of bioimpedance analysis that combines upper body, lower body, and whole-body bioimpedance to estimate FFM and %BF; utilizes a range of electrical frequencies and allows for determination of extracellular water (low level frequencies) and intracellular water (high level frequencies).

Bland and Altman method—Statistical approach used to assess the degree of agreement between methods by calculating the 95% limits of agreement and confidence intervals; used to judge the accuracy of a prediction equation or method for estimating measured values of individuals in a group.

body composition—A component of physical fitness; absolute and relative amounts of muscle, bone, and fat tissues composing body mass.

body density (Db)—Overall density of fat, water, mineral, and protein components of the human body; total body mass expressed relative to total body volume.

body mass (BM)—Measure of the size of the body; body weight.

body mass index (BMI)—Crude index of obesity; body mass (kg) divided by height squared (m^2).

body surface area—Amount of surface area of the body estimated from the client's height and body weight.

body volume (BV)—Measure of body size estimated by water or air displacement.

body weight (BW)—Mass or size of the body; body mass.

bone strength—Function of mineral content and density of bone tissue; related to risk of bone fracture.

Boyle's law—Isothermal gas law stating that volume and pressure are inversely related.

bradycardia—Resting heart rate < 60 bpm.

bronchitis—Acute or chronic inflammation of the bronchi of the lungs.

caloric threshold—Method to estimate duration of exercise based on the caloric cost of the exercise and to estimate the total amount of exercise needed per week for health benefits.

cardiac arrest—Sudden loss of heart function usually caused by ventricular fibrillation.

cardiomyopathy—Any disease that affects the structure and function of the heart.

cardiorespiratory endurance—Ability of heart, lungs, and circulatory system to supply oxygen to working muscles efficiently.

cardiovascular disease (CVD)—Disease of the heart, blood vessels, or both; types of cardiovascular disease include atherosclerosis, hypertension, coronary heart disease, congestive heart failure, and stroke.

center of pressure—Vertical force applied to the supporting base or a force platform during sitting or standing.

chest leads—Six ECG leads (V_1 to V_6) used to measure voltage across specific areas of the chest.

cholesterol—Waxy, fatlike substance found in all animal products (e.g., meats, dairy products, and eggs).

chylomicron—Type of lipoprotein derived from intestinal absorption of triglycerides.

circumference (C)—Measure of the girth of body segments.

cirrhosis—Chronic, degenerative disease of the liver in which the lobes are covered with fibrous tissue; associated with chronic alcohol abuse.

claudication—Cramp-like pain in the calves due to poor circulation in leg muscle.

complex carbohydrates—Macronutrients found in plant-based foods, whole grains, and low-fat dairy products, for example, starch and cellulose.

compound sets—Advanced resistance training system in which two sets of exercises for the same muscle group are performed consecutively, with little or no rest between sets.

computerized dynamic posturography—Computer system designed to assess the individual and composite functioning of sensory, motor, and biomechanical components of balance.

concentric contraction—Type of dynamic muscle contraction in which muscle shortens as it exerts tension.

congestive heart failure—Impaired cardiac pumping caused by myocardial infarction, ischemic heart disease, or cardiomyopathy.

constant error (CE)—Average difference between measured and predicted values for cross-validation group; bias.

constant-resistance exercise—Type of exercise in which the external resistance remains the same throughout the range of motion (e.g., lifting free weights or dumbbells).

continuous exercise test—Type of graded exercise test that is performed with no rest between workload increments.

continuous training—One continuous, aerobic exercise bout performed at low-to-moderate intensity.

contract-relax agonist contract (CRAC) technique—Type of proprioceptive neuromuscular facilitation technique in which the target muscle is isometrically contracted and then stretched; stretching is assisted by a submaximal contraction of the agonistic muscle group.

contract-relax (CR) technique—Type of proprioceptive neuromuscular facilitation technique in which the target muscle is isometrically contracted and then stretched.

contracture—Shortening of resting muscle length caused by disuse or immobilization.

core stability—Ability to maintain ideal alignment of neck, spine, scapulae, and pelvis while exercising.

core strengthening—Strengthening core muscle groups (erector spinae and abdominal movers and stabilizers) used for core stability.

coronary heart disease (CHD)—Disease of the heart caused by a lack of blood flow to heart muscle, resulting from atherosclerosis.

counting talk test (CTT)—Method to monitor exercise intensity; measure of the client's ability to comfortably count out loud while exercising; based on the relationship between exercise intensity and pulmonary ventilation.

criterion method—Gold standard or reference method; typically a direct measure of a component used to validate other tests.

cross-training—Type of training in which the client participates in a variety of exercise modes to develop one or more components of physical fitness.

cuff hypertension—Overestimation of blood pressure caused by use of a bladder that is too small for the arm circumference.

cyanosis—Bluish discoloration of skin caused by lack of oxygenated hemoglobin in the blood.

damping technique—Technique used to reduce the motion of the underwater weighing scale arm during the total body submersion process.

decision-making theory—Theory stating that individuals decide whether or not to engage in a behavior by weighing the perceived benefits and costs of that behavior.

delayed-onset muscle soreness (DOMS)—Soreness in the muscle occurring 24 to 48 hr after exercise.

densitometry—Measurement of body volume leading to calculation of total body density; hydrodensitometry and air displacement plethysmography are densitometric methods.

diabetes—Complex disorder of carbohydrate, fat, and protein metabolism resulting from a lack of insulin secretion (type 1) or defective insulin receptors (type 2).

diastolic blood pressure (DBP)—Lowest pressure in the artery during the cardiac cycle.

dietary thermogenesis—Energy needed for digesting, absorbing, transporting, and metabolizing foods.

digital activity log—A handheld computer used to record the type and duration of physical activities performed during the day.

diminishing return principle—Training principle; as genetic ceiling is approached, rate of improvement slows or evens off.

discontinuous exercise test—Type of graded exercise test that is performed with 5 to 10 min of rest between increments in workload.

discontinuous training—Several intermittent, low- to high-intensity aerobic exercise bouts interspersed with rest or relief intervals.

dose-response relationship—The volume of physical activity is directly related to health benefits from that activity.

dual-energy X-ray absorptiometry (DXA)—Method used to measure total body bone mineral density, bone mineral content, as well as estimate fat and lean soft tissue mass.

dynamic balance—Ability to maintain an upright position while the center of gravity and base of support are moving.

dynamic contraction—Type of muscle contraction producing visible joint movement; concentric, eccentric, or isokinetic contraction.

dynamic flexibility—Measure of the rate of torque or resistance developed during stretching throughout the range of joint motion.

dynamic stretching—Type of stretching exercise that uses slow, controlled movements that are repeated several times to produce stretch and increase range of motion.

dynapenia—Age-related loss in muscle strength.

dyslipidemia—Abnormal blood lipid profile.

dyspnea—Shortness of breath or difficulty breathing caused by certain heart conditions, anxiety, or strenuous exercise.

eccentric contraction—Type of muscle contraction in which the muscle lengthens as it produces tension to resist gravity or decelerate a moving body segment.

edema—Accumulation of interstitial fluid in tissues such as pericardial sac and joint capsules.

elastic deformation—Deformation of the muscle-tendon unit that is proportional to the load or force applied during stretching.

electrocardiogram (ECG)—A composite record of the electrical events in the heart during the cardiac cycle.

embolism—Piece of tissue or thrombus that circulates in the blood until it lodges in a vessel.

emphysema—Pulmonary disease causing damage in alveoli and loss of lung elasticity.

exercise deficit disorder (EDD)—Term associated with children who do not engage in at least 60 min/day of moderate-to-vigorous intensity physical activity.

exercise-induced hypertrophy—Increase in size of muscle as a result of resistance training.

exercise-induced muscle damage (EIMD)—Skeletal muscle damage induced through exercise.

exergaming—Interactive digital games in which the player physically moves to score points.

factorial method—Method used to assess energy needs; the sum of the resting metabolic rate and the additional calories expended during work, household chores, personal daily activities, and exercise.

false negative—An error in which individuals are incorrectly identified as having no risk factors when in fact they do have risk factors.

false positive—An error in which individuals are incorrectly identified as having risk factors when they do not have risk factors.

fat-free body (FFB)—All residual, lipid-free chemicals and tissues in the body, including muscle, water, bone, connective tissue, and internal organs.

fat-free mass (FFM)—*See* fat-free body; weight or mass of the fat-free body.

fat mass (FM)—All extractable lipids from adipose and other tissues in the body.

FITT-VP principle (FITT-VP)—Describes six components of an exercise prescription: frequency, intensity, time, type, volume, and progression of activity.

flexibility—Ability to move joints fluidly through complete range of motion without injury.

flexibility training—Systematic program of stretching exercises that progressively increases the range of motion of joints over time.

flexometer—Device for measuring range of joint motion using a weighted 360° dial and pointer.

free-motion machines—Resistance exercise machines that have adjustable seats, lever arms, and cable pulleys for exercising muscle groups in multiple planes.

functional balance—Ability to perform daily activities requiring balance, for example, picking up an object from the floor.

functional fitness—Ability to perform everyday activities safely and independently without fatigue; requires aerobic endurance, flexibility, balance, agility, and muscular strength.

functional training—System of exercise progressions for specific muscle groups using a stepwise approach that increases the difficulty level (strength) and skill (balance and coordination) required for each exercise in the progression.

gait velocity—The speed of walking. Indirect measure of dynamic balance while walking used to detect mobility problems and risk of falling.

generalized prediction equations—Prediction equations that are applicable to a diverse, heterogeneous group of individuals.

geographical information system (GIS)—Computer system that stores latitude and longitude information about location and the surrounding environment.

global positioning system (GPS)—System that uses 24 satellites and ground stations to calculate geographic locations and accurately track a specific activity.

glucose intolerance—Inability of body to metabolize glucose.

glycemic index (GI)—Rating of the body's glycemic response to a food compared to the reference value (GI = 100 for white bread or glucose).

goniometer—Protractor-like device used to measure joint angle at the extremes of the range of motion.

graded exercise test (GXT)—A multistage submaximal or maximal exercise test requiring the client to exercise at gradually increasing workloads; may be continuous or discontinuous; used to estimate $\dot{V}O_2$max.

Graves' disease—Disease associated with an overactive thyroid gland that secretes greater than normal amounts of thyroid hormones; also known as hyperthyroidism or thyrotoxicosis.

gross $\dot{V}O_2$—Total rate of oxygen consumption, reflecting the caloric cost of both rest and exercise.

gynoid obesity—Type of obesity in which excess fat is localized in the lower body; lower body obesity; pear-shaped body.

HbA1c—An indicator of the average blood glucose over the past 2 to 3 months; glycolsylated hemoglobin.

HDL-cholesterol (HDL-C)—Cholesterol transported in the blood by high-density lipoproteins.

health belief model—Model suggesting that individuals will change a behavior because they perceive a threat of disease if they do not change.

healthy body weight—Body mass index from 18.5 to 25 kg/m^2.

heart block—Interference in the conduction of electrical impulses that control normal contraction of the heart muscle; may occur at sinoatrial node, atrioventricular node, bundle of HIS, or a combination of these sites.

heart rate monitor—Device used to assess heart rate and to monitor exercise intensity.

heart rate reserve (HRR)—Maximal heart rate minus the resting heart rate.

hemiscan procedure—Used for clients who are too wide for the DXA scan table; client is positioned off center on the DXA scan table so that one side of the body is completely within the scan field.

hepatitis—Inflammation of the liver characterized by jaundice and gastrointestinal discomfort.

high blood pressure—Hypertension; chronic elevation of blood pressure.

high CHD risk—One or more signs or symptoms of cardiovascular, pulmonary, renal, or metabolic disease; characterizing individuals with known cardiovascular, pulmonary, renal, or metabolic disease.

high-density lipoprotein (HDL)—Type of lipoprotein involved in the reverse transport of cholesterol to the liver.

high-intensity interval training—Style of cardiometabolic training based on repeated combinations of vigorous-intensity exertion followed by a rest or recovery period; commonly performed using an aerobic modality; combinations of exertion and rest can be manipulated so that training focuses on a specific metabolic pathway.

high intensity–low repetitions—Optimal training stimulus for strength development; 85% to 100% 1-RM or 1- to 6-RM.

high total cardiovascular risk—Category of CVD risk estimate along the risk continuum; identifies those in need of active risk factor management and those who have several CVD risk factors that, in combination, elevate the risk of a CV event.

hybrid sphygmomanometer—Device used to measure blood pressure that combines features of electronic and auscultatory devices.

hydrodensitometry—Method used to estimate body volume by measuring weight loss when the body is fully submerged; underwater weighing.

hydrostatic weighing (HW)—*See* hydrodensitometry.

hypercholesterolemia—Excess of total cholesterol, LDL-cholesterol, or both in blood.

hyperlipidemia—Excess lipids in blood.

hypermobility—Excessive range of motion at a joint.

hyperplasia—Increase in number of cells.

hypertension—High blood pressure; chronic elevation of blood pressure.

hyperthyroidism—Overactive thyroid gland that secretes greater than normal amounts of thyroid hormones; also known as thyrotoxicosis or Graves' disease.

hypertrophy—Increase in size of cells.

hypoglycemia—Low blood glucose level.

hypokalemia—Inadequate amount of potassium in the blood characterized by an abnormal ECG, weakness, and flaccid paralysis.

hypomagnesemia—Inadequate amount of magnesium in the blood resulting in nausea, vomiting, muscle weakness, and tremors.

hypothyroidism—Underactive thyroid gland that secretes lower than normal amounts of thyroid hormones; also known as myxedema.

hypoxia—Inadequate oxygen at the cellular level.

impedance (Z)—Measure of total amount of opposition to electrical current flowing through the body; function of resistance and reactance.

improvement stage—Stage of exercise program in which client improves most rapidly; frequency, intensity, duration are systematically increased; usually lasting 16 to 20 wk.

inclinometer—Gravity-dependent goniometer used to measure the angle between the long axis of the moving segment and the line of gravity.

initial conditioning stage—Stage of exercise program used as a primer to familiarize client with exercise training, usually lasting 4 wk.

initial values principle—Training principle; the lower the initial value of a component, the greater the relative gain and the faster the rate of improvement in that component; the higher the initial value, the slower the improvement rate.

insulin-dependent diabetes mellitus (IDDM)—Type 1 diabetes, caused by lack of insulin production by the pancreas.

interindividual variability principle—Training principle; individual responses to training stimulus are variable and depend on age, initial fitness level, and health status.

interval training—A repeated series of exercise work bouts interspersed with rest or relief periods.

ischemia—Decreased supply of oxygenated blood to body part or organ; due to occlusion or restriction of blood flow.

ischemic heart disease—Pathologic condition of the myocardium caused by lack of oxygen to the heart muscle.

isokinetic contraction—Maximal contraction of a muscle group at a constant velocity throughout entire range of motion.

isometric contraction—Type of muscle contraction in which there is no visible joint movement; static contraction.

isotonic contraction—Type of muscle contraction producing visible joint movement; dynamic contraction.

joint laxity—Looseness or instability of a joint, increasing risk of musculoskeletal injury.

Karvonen method—Method to prescribe exercise intensity as a percentage of the heart rate reserve added to the resting heart rate; percent heart rate reserve method.

kettlebell training—Type of resistance training that uses a cast-iron weight (resembling a cannonball with a handle) to perform ballistic exercises; improves strength, cardiovascular fitness, and flexibility.

kilocalorie (kcal)—Amount of heat needed to raise the temperature of 1 kg of water 1° C; measure of energy need and expenditure.

lactate threshold—Exercise intensity at which blood lactate production exceeds blood lactate removal; denoted by an increase of 1 $mmol{\cdot}L^{-1}$ between two consecutive stages; an indication of when the primary metabolic pathway switches from mitochondrial oxidation to glycolysis.

LDL-cholesterol (LDL-C)—Cholesterol transported in the blood by low-density lipoproteins.

limb leads—Three ECG leads (I, II, III) measuring the voltage differential between left and right arms (I) and between the left leg and right (II) and left (III) arms.

limits of agreement—Statistical method used to assess the extent of agreement between methods; also known as the Bland and Altman method.

limits of stability—Measure of the maximum excursion of the center of gravity during maintenance of balance over a fixed supporting base.

linear periodization (LP)—Strength training method that progressively increases training intensity as training volume decreases between microcycles.

line of best fit—Regression line depicting relationship between reference measure and predictor variables in an equation.

line of gravity—Vertical projection of the center of gravity of the body to the supporting base.

line of identity—Straight line with a slope equal to 1 and an intercept equal to 0; used in a scatter plot to illustrate the differences in the measured and predicted scores of a cross-validation sample.

lipoprotein—Molecule used to transport and exchange lipids among the liver, intestine, and peripheral tissues.

low back pain—Pain produced by muscular weakness or imbalance resulting from lack of physical activity.

low CHD risk—Characterizing young, asymptomatic individuals having no more than one net risk factor.

low-density lipoprotein (LDL)—Primary transporter of cholesterol in the blood; product of very low-density lipoprotein metabolism.

lower body obesity—Type of obesity in which excess body fat is localized in the lower body; gynoid obesity; pear-shaped body.

low intensity–high repetitions—Optimal training stimulus for development of muscular endurance; ≤60% 1-RM or 15- to 20-RM.

lumbar stabilization—Maintaining a static position of the lumbar spine by isometrically cocontracting the abdominal wall and low back muscles during exercise.

macrocycle—Phase of periodized resistance training program usually lasting 9 to 12 mo; comprised of mesocycles.

maintenance stage—Stage of exercise program designed to maintain level of fitness achieved by end of improvement stage; should be continued on a regular, long-term basis.

masked hypertension—Condition in which individuals exhibit elevated BP readings outside the physician's office but have normal BP values in the office.

masked obesity—Condition in which individuals have a normal body mass index but carry an excessive amount of body fat.

maximal exercise test—Graded exercise test in which exercise intensity increases gradually until the $\dot{V}O_2$ plateaus or fails to rise with a further increase in workload.

maximum oxygen consumption—Maximum rate of oxygen utilization by muscles during exercise; $\dot{V}O_2$max.

maximum oxygen uptake ($\dot{V}O_2$max)—Maximum rate of oxygen utilization of muscles during aerobic exercise.

maximum voluntary isometric contraction (MVIC)—Measure of the maximum force exerted in a single contraction against an immovable resistance.

McArdle's syndrome—Inherited metabolic disease characterized by inability to metabolize muscle glycogen, resulting in excessive amounts of glycogen stored in skeletal muscles.

mesocycle—Phase of a periodized resistance training program usually lasting 3 to 4 mo; comprised of microcycles.

metabolic equivalents (METs)—The ratio of the person's working (exercising) metabolic rate to the resting metabolic rate.

metabolic syndrome—A combination of cardiovascular disease risk factors associated with hypertension, dyslipidemia, insulin resistance, and abdominal obesity.

MET·min—Index of energy expenditure; product of exercise intensity (METs) and duration (min) of exercise.

microcycle—Phase of a periodized resistance training program usually lasting 1 to 4 wk.

miscuffing—Source of blood pressure measurement error caused by use of a blood pressure cuff that is not appropriately scaled for the client's arm circumference.

moderate CHD risk—Characterizing asymptomatic individuals having two or more net risk factors.

multicomponent model—Body composition model that takes into account interindividual variations in water, protein, and mineral content of the fat-free body.

multimodal exercise program—Type of exercise program that uses a variety of exercise modalities.

multiple correlation coefficient (Rmc)—Correlation between reference measure and predictor variables in a prediction equation.

murmur—Low-pitched fluttering or humming sound.

muscle balance—Ratio of strength between opposing muscle groups, contralateral muscle groups, and upper and lower body muscle groups.

muscular endurance—Ability of muscle to maintain submaximal force levels for extended periods.

muscular strength—Maximal force or tension level produced by a muscle or muscle group.

musculoskeletal fitness—Ability of skeletal and muscular systems to perform work.

myocardial infarction—Heart attack.

myocardial ischemia—Lack of blood flow to the heart muscle.

myocarditis—Inflammation of the heart muscle caused by viral, bacterial, or fungal infection.

myxedema—Disease associated with an underactive thyroid gland that secretes lower than normal amounts of thyroid hormones; also known as hypothyroidism.

near-infrared interactance (NIR)—Field method that estimates %BF based on optical density of tissues at the measurement site; presently, validity of this method is questionable.

negative energy balance—Excess of energy expenditure in relation to energy intake.

net $\dot{V}O_2$—Rate of oxygen consumption in excess of the resting $\dot{V}O_2$; used to describe the caloric cost of exercise.

neuromotor training—Exercises to improve balance, agility, gait, coordination, and proprioception; especially beneficial as part of comprehensive exercise programs for older adults.

nonaxial joint—Type of joint allowing only gliding, sliding, or twisting rather than movement about an axis of rotation; gliding joint.

non-insulin-dependent diabetes mellitus (NIDDM)—Type 2 diabetes; caused by decreased insulin receptor sensitivity.

normotensive—Referring to normal blood pressure, defined as values less than 120/80 mmHg.

obesity—Excessive amount of body fat relative to body mass; BMI of 30 kg/m^2 or more.

objectivity—Intertester reliability; ability of test to yield similar scores for a given individual when the same test is administered by different technicians.

objectivity coefficient—Correlation between pairs of test scores measured on the same individuals by two different technicians.

occlusion—Blockage or restriction of blood flow to body part or organ.

omnikinetic exercise—Type of accommodating-resistance exercise that adjusts for fluctuations in both muscle force and speed of joint rotation throughout range of motion.

one-repetition maximum (1-RM)—Maximal weight that can be lifted with good form for one complete repetition of a movement.

optical density—Measure of the amount of near-infrared light reflected by the body's tissues at specific wavelengths.

oscillometry—Method for measuring blood pressure that uses an automated electronic manometer to measure oscillations in pressure when the cuff is deflated.

osteoarthritis—Degenerative disease of the joints characterized by excessive amounts of bone and cartilage in the joint.

osteopenia—Low bone mineral mass; precursor to osteoporosis.

osteoporosis—Disorder characterized by low bone mineral and bone density; occurring most frequently in postmenopausal women and sedentary individuals.

overcuffing—Using a blood pressure cuff with a bladder too large for the arm circumference, leading to an underestimation of blood pressure.

overload principle—Training principle; physiological systems must be taxed beyond normal to stimulate improvement.

overweight—BMI between 25 and 29.9 kg/m^2 in adults; BMI greater than or equal to 95th percentile for age and sex in children.

pallor—Unnatural paleness or absence of skin color.

palpation—Method used to measure heart rate by feeling the pulse at specific anatomical sites.

palpitations—Racing or pounding of the heart.

passive stretching—Stretching technique that involves a body part being moved by an assistant as the client relaxes the target muscle group.

pedometer—A device used to count the number of steps taken throughout the day.

pelvic stabilization—Maintenance of a static position of the pelvis during performance of exercises for the low back extensor muscles.

percent body fat (%BF)—Fat mass expressed relative to body mass; relative body fat.

percent heart rate maximum (%HRmax)—Method used to prescribe exercise intensity as a percentage of the measured or age-predicted maximum heart rate.

percent heart rate reserve (%HRR)—Method used to prescribe exercise intensity as a percentage of the heart rate reserve (HRR = HRmax − HRrest) added to the resting heart rate; Karvonen method.

percent $\dot{V}O_2$ reserve (%$\dot{V}O_2R$)—Method used to prescribe exercise intensity as a percentage of $\dot{V}O_2$ reserve ($\dot{V}O_2R = \dot{V}O_2max - \dot{V}O_2rest$) added to the resting $\dot{V}O_2$.

pericarditis—Inflammation of the pericardium caused by trauma, infection, uremia, or heart attack.

periodization—Advanced form of training that systematically varies the volume and intensity of the training exercises.

persuasive technology—A computer system, device, or application that is intentionally designed to change a person's attitude or behavior.

physical activity level (PAL)—The ratio of total energy expenditure to basal metabolic rate; PAL = TEE / BMR.

physical fitness—Ability to perform occupational, recreational, and daily activities without undue fatigue.

population-specific equations—Prediction equations intended only for use with individuals from a specific homogeneous group.

positive energy balance—Excess of energy intake in relation to energy expenditure.

prediabetes—Medical condition identified by fasting blood glucose or glycated hemoglobin levels above normal values yet below the threshold for diagnosis of diabetes.

prehypertension—Systolic blood pressure of 120 to 139 mmHg or diastolic pressure of 80 to 89 mmHg.

PR interval—Part of ECG tracing that indicates delay in the impulse at the atrioventricular node.

progression principle—Training principle; training volume must be progressively increased to impose overload and stimulate further improvements.

proprioceptive neuromuscular facilitation (PNF)—Mode of stretching that increases range of joint motion through spinal reflex mechanisms such as reciprocal inhibition.

prosthesis—An artificial replacement of a missing body part, such as an artificial limb or joint.

pulmonary ventilation—Movement of air into and out of the lungs.

pulse pressure—Difference between the systolic and diastolic blood pressures.

P wave—Part of ECG tracing that reflects depolarization of the atria.

pyramiding—Advanced resistance training system in which a relatively light weight is lifted in the first set and progressively heavier weights are lifted in subsequent sets; light-to-heavy system.

QRS complex—Part of ECG tracing reflecting ventricular depolarization and contraction.

ramp protocols—Graded exercise tests that are individualized and that provide for continuous, frequent (every 10–20 sec) increments in work rate so that $\dot{V}O_2$ increases linearly.

range of motion (ROM)—Degree of movement at a joint; measure of static flexibility.

rating of perceived exertion (RPE)—A scale used to measure a client's subjective rating of exercise intensity.

reactance (Xc)—Measure of opposition to electrical current flowing through body due to the capacitance of cell membranes; a vector of impedance.

reactive balance—Ability to compensate and recover from perturbations while standing or walking.

reciprocal inhibition—Reflex that inhibits the contraction of antagonistic muscles when the prime mover is voluntarily contracted.

reference method—Gold standard or criterion method; typically a direct measure of a component used to validate other tests.

regression line—Line of best fit depicting relationship between reference measure and predictor variables.

relative body fat (%BF)—Fat mass expressed as a percentage of total body mass; percent body fat.

relative strength—Muscular strength expressed relative to the body mass or lean body mass; 1-RM/BM.

relative $\dot{V}O_2max$—Rate of oxygen consumption expressed relative to the body mass ($ml \cdot kg^{-1} \cdot min^{-1}$) or lean body mass ($ml \cdot kgFFM^{-1} \cdot min^{-1}$).

reliability—Ability of a test to yield consistent and stable scores across trials and over time.

reliability coefficient—Correlation depicting relationship between trial 1 and trial 2 scores or day 1 and day 2 scores of a test.

repetition maximum (RM)—Measure of intensity for resistance exercise expressed as maximum weight that can be lifted for a given number of repetitions.

repetitions—Number of times a specific exercise movement is performed in a set.

residual score—Difference between the actual and predicted scores (Y – Y').

residual volume (RV)—Volume of air remaining in lungs following a maximal expiration.

resistance (R)—Measure of pure opposition to electrical current flowing through body; a vector of impedance.

resistance index (ht2/R)—Predictor variable in some BIA regression equations that is calculated by dividing standing height squared by resistance.

respiratory exchange ratio (RER)—Ratio of expired CO_2 to inspired O_2.

resting energy expenditure (REE)—Energy required to maintain essential physiological processes at rest; resting metabolic rate.

resting metabolic rate (RMR)—Energy required to maintain essential physiological processes in a relaxed, awake, and reclined state; resting energy expenditure.

reverse linear periodization (RLP)—Strength training method that progressively decreases training intensity as training volume increases between microcycles.

reversibility principle—Training principle; physiological gains from training are lost when individual stops training (detraining).

rheumatic heart disease—Condition in which the heart valves are damaged by rheumatic fever, contracted from a streptococcal infection (strep throat).

rheumatoid arthritis—Chronic, destructive disease of the joints characterized by inflammation and thickening of the synovial membranes and swelling of the joints.

sagittal abdominal diameter (SAD)—Measure of the anteroposterior thickness of the abdomen at the umbilical level.

sarcopenia—Age-related loss in muscle mass.

self-determination theory—Theory describing how the presence or absence of specific psychological needs affects behavior.

self-efficacy—Individuals' perception of their ability to perform a task and their confidence in making a specific behavioral change.

sensitivity—Probability of a test correctly identifying individuals with risk factors for a specific disease.

set—Defines the number of times a specific number of repetitions of a given exercise is repeated; single or multiple sets.

simple carbohydrates—Simple sugars (e.g., glucose and fructose) found in fruits, berries, table sugar, honey, and some vegetables.

skeletal diameter (D)—Measure of the width of bones.

skinfold (SKF)—Measure of the thickness of two layers of skin and the underlying subcutaneous fat.

social cognitive model—Psychological theory of behavior change; based on concepts of self-efficacy and outcome expectation.

specificity—Measure of a test's ability to correctly identify individuals with no risk factors for a specific disease.

specificity principle—Training principle; physiological and metabolic responses and adaptations to exercise training are specific to type of exercise and muscle groups involved.

sphygmomanometer—Device used to measure blood pressure manually, consisting of a blood pressure cuff and a manometer.

spinning—Group-led exercise that involves stationary cycling at various cadences and resistances.

split routine—Advanced resistance training system in which different muscle groups are targeted on consecutive days to avoid overtraining.

sprint interval training (SIT) —Subclass of high-intensity interval training; based on repeated combinations of short (e.g. 30 sec) sprints and extended (e.g. 4 min) rest or recovery intervals.

stages of motivational readiness for change model—Psychological theory of behavior change; ability to make long-term behavioral change is based on client's emotional and intellectual readiness; stages of readiness are precontemplation, contemplation, preparation, action, and maintenance.

standard error of estimate (SEE)—Measure of error for prediction equation; quantifies the average deviation of individual data points around the line of best fit.

static balance—Ability to maintain the center of gravity within the supporting base during standing or sitting.

static contraction—Type of muscle contraction in which there is no visible joint movement; isometric contraction.

static flexibility—Measure of the total range of motion at a joint.

static stretching—Mode of exercise used to increase range of motion by placing the joint at the end of its range of motion and slowly applying torque to the muscle to stretch it further.

steep ramp cycling protocol (SRP)—Maximal exertion cycling protocol utilizing stage changes every 10 sec; magnitude of stage increments are determined by the rider's height.

stress relaxation—Decreased tension within musculotendinous unit when it is held at a fixed length during static stretching.

stretch tolerance—Measure of the amount of resistive force to stretch within target muscles that can be tolerated before experiencing pain.

stroke—Rupture or blockage of blood flow to the brain caused by an aneurysm, blood clot, or some other particle.

ST segment—Part of ECG tracing reflecting ventricular repolarization; used to detect coronary occlusion and myocardial infarct.

submaximal exercise test—Graded exercise test in which exercise is terminated at some predetermined submaximal heart rate or workload; used to estimate $\dot{V}O_2$max.

super circuit resistance training—Type of circuit resistance training that intersperses a short, aerobic exercise bout between each resistance training exercise station.

supersetting—Advanced resistance training system in which exercises for agonistic and antagonistic muscle groups are done consecutively without rest.

syncope—Brief lapse in consciousness caused by lack of oxygen to the brain.

systolic blood pressure (SBP)—Highest pressure in the arteries during systole of the heart.

tachycardia—Resting heart rate >100 bpm.

talk test—Method to monitor exercise intensity; measure of the client's ability to converse comfortably while exercising; based on the relationship between exercise intensity and pulmonary ventilation.

tare weight—Weight of chair or platform and its supporting equipment used in hydrostatic weighing.

telomeres—Repeated DNA sequences that determine structure and function of chromosomes.

terminal digit bias—Tendency of the technician to round BP values to the nearest 0 or 5 mmHg.

theory of planned behavior—An extension of the theory of reasoned action that takes into consideration the individual's perception of behavioral control.

theory of reasoned action—Theory that proposes a way to understand and predict an individual's behavior; intention is the most important determinant of behavior.

thoracic gas volume (TGV)—Volume of air in the lungs and thorax.

thrombus—Lump of cellular elements of the blood attached to inner walls of an artery or vein, sometimes blocking blood flow through the vessel.

thyrotoxicosis—Overactive thyroid gland that secretes greater than normal amounts of thyroid hormones; also known as Graves' disease or hyperthyroidism.

tonic vibration reflex—Reflex that activates muscle spindles and alpha motor neurons of muscles stimulated by vibration loading.

total cholesterol (TC)—Absolute amount of cholesterol in the blood.

total energy expenditure (TEE)—Sum of energy expenditures for resting metabolic rate, dietary thermogenesis, and physical activity.

total energy expenditure (TEE) method—Method for determining energy expenditure measured by doubly labeled water or predicted from equations.

total error (TE)—Average deviation of individual scores of the cross-validation sample from the line of identity.

training volume—Total amount of training as determined by the number of sets and exercises for a muscle group, intensity, and frequency of training.

transcranial magnetic stimulation (TMS)—Method used to study adaptations in the central nervous system in response to strength training.

transcriptome signature of resistance exercise—The approximately 660 genes that are affected by resistance training.

transtheoretical model—Model describing the process a client goes through when adopting a change in health behavior.

treading—Type of group-led interval training that involves walking, jogging, and running at various speeds and grades on a treadmill with relief intervals interspersed.

triaxial joint—Type of joint allowing movement in three planes; ball-and-socket joint.

tri-sets—Advanced resistance training system in which three different exercises for the same muscle group are performed consecutively with little or no rest between the exercises.

T wave—Part of ECG tracing corresponding to ventricular repolarization.

two-component model—Body composition model that divides the body into fat and fat-free body components.

type A activity—Endurance activity requiring minimal skill or fitness, for example walking.

type B activity—Endurance activity requiring minimal skill but average fitness, for example jogging.

type C activity—Physical activity requiring both skill and physical fitness, for example swimming.

type D activity—Recreational sports that may improve physical fitness, for example basketball.

type 1 diabetes—Insulin-dependent diabetes, caused by lack of insulin production by the pancreas.

type 2 diabetes—Non-insulin-dependent diabetes, caused by decreased insulin receptor sensitivity.

undercuffing—Using a blood pressure cuff with a bladder too small for the arm circumference, leading to an overestimation of blood pressure.

underwater weight (UWW)—Method used to estimate body volume by measuring weight loss when the body is fully submerged; hydrostatic weighing.

underweight—BMI < 18.5 kg/m^2.

undulating periodization (UP)—Strength training method that varies training intensity and volume weekly or even daily.

uniaxial joint—Type of joint allowing movement in one plane; hinge or pivot joint.

upper body obesity—Type of obesity in which excess fat is localized to the upper body; android obesity; apple-shaped body.

uremia—Excessive amounts of urea and other nitrogen waste products in the blood associated with kidney failure.

validity—Ability of a test to accurately measure, with minimal error, a specific component.

validity coefficient—Correlation between reference measure and predicted scores.

valvular heart disease—Congenital disorder of a heart valve characterized by obstructed blood flow, valvular degeneration, valvular stenosis, and regurgitation of blood.

variable-resistance exercise—Type of exercise in which resistance changes during the range of motion due to levers, pulleys, and cams.

ventilatory threshold—Point at which there is an exponential increase in pulmonary ventilation relative to exercise intensity and rate of oxygen consumption.

ventricular ectopy—Premature (out of sequence) contraction of the ventricles.

ventricular fibrillation—Cardiac dysrhythmia marked by rapid, uncoordinated, and unsynchronized contractions of the ventricles, so that no blood is pumped by the heart.

vertigo—Dizziness or inability to maintain normal balance in a standing or seated position.

very high risk—Category of CVD risk estimate along the risk continuum; criteria are documented CVD, diabetes mellitus (type 2 or type 1 with microalbuminuria), chronic kidney disease, and calculated 10 yr risk SCORE ≥10%.

very low-density lipoprotein (VLDL)—Lipoprotein made in the liver for transporting triglycerides.

viscoelastic creep—A small increase in joint angle during constant-torque stretching, due to elongation of the muscle-tendon unit.

viscoelastic properties—Tension within the muscle-tendon unit caused by the elastic and viscous deformation of the unit when force is applied during stretching.

viscous deformation—Deformation of the muscle-tendon unit that is proportional to the speed at which tension is applied during stretching.

volume of exercise—Quantity of exercise determined by frequency, intensity, and time of exercise.

$\dot{V}O_2$max—Maximum rate of oxygen utilization of muscles during exercise.

$\dot{V}O_2$peak—Measure of highest rate of oxygen consumption during an exercise test regardless of whether or not a $\dot{V}O_2$ plateau is reached.

$\dot{V}O_2$reserve—The $\dot{V}O_2$max minus the $\dot{V}O_2$rest.

waist-to-height ratio (WHTR)—Waist circumference divided by standing height; used as a measure of abdominal obesity.

waist-to-hip ratio (WHR)—Waist circumference divided by hip circumference; used as a measure of upper body or abdominal obesity.

white coat hypertension—Condition in which individuals have normal blood pressure but become hypertensive when blood pressure is measured by a health professional.

whole-body vibration training (WBV)—Training method that uses whole-body mechanical vibration to increase strength, balance, and bone integrity.

wireless body area network (WBAN)—Integrated data sensors, receivers, and transmitters that collect physiologic data and transmit it to a central data repository through a wireless type of technology.

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