LEARNING OBJECTIVES
1. Recognize the differences between muscular and cardiovascular endurance.
2. Define activities/exercises that are aerobic or anaerobic.
3. Describe benefits associated with cardiovascular fitness training.
5. Describe methods to measure exercise intensity.
7. Define the training parameters to improve muscular endurance.

KEY TERMS
Borg rating of perceived exertion  Karvonen method  Muscular endurance
Cardiovascular endurance  Maximal heart rate (MHR)  Oxidative system
Catabolism  Maximal oxygen uptake  Target heart rate (THR)

CHAPTER OUTLINE
Cardiovascular Training
   Energy Metabolism for Aerobic Training
   Benefits of Cardiovascular Fitness Training
Minimum Aerobic Exercise Guidelines for Americans
   Exercise Guidelines for Adults
   Exercise Guidelines for Children
Additional Methods to Measure Exercise Intensity
   Target Heart Rate and Estimated Maximum Heart Rate

Borg Rating of Perceived Exertion
Methods of Aerobic Training
Aerobic Exercise for Patients with an Orthopedic Injury
Muscular Endurance Training
Glossary
References
Review Questions
   Short Answer
   True/False
The ability to perform repetitive activities, participate in recreational pursuits, or to compete in sports requires adequate endurance capacity. The performance of an endurance activity (or exercise) may require involvement from one’s muscular system, cardiovascular system, or both. Muscular endurance describes the ability of a muscle, or muscles, to perform at a particular level for a prolonged period of time. Cardiovascular endurance describes the ability of one’s cardiovascular system to allow the performance of prolonged aerobic activities. Both the muscular and cardiovascular systems require training to improve and/or maintain endurance capacity. In addition, training both systems will help to improve one’s fitness level, reduce the risk of developing certain acute or chronic conditions, and help restore function after injury.

The purpose of this chapter is to define muscular and cardiovascular conditioning, review the metabolic pathways associated with each form of endurance training, discuss the physical and physiologic changes that occur when performing an endurance fitness program, present the recommended minimum training requirements, and address the functional role of endurance training for the rehabilitation client.

CARDIOVASCULAR TRAINING
Energy Metabolism for Aerobic Training

The catabolism of macronutrients (carbohydrates, proteins, and fats) creates energy for the human body. These fuel sources are ultimately converted into adenosine triphosphate (ATP), the main energy source for muscular function. Three metabolic pathways (Box 5-1) in the human body are responsible for the production of ATP. Energy metabolism may occur either with (aerobic metabolism) or without (anaerobic metabolism) the presence of oxygen.

When an endurance-based activity is initiated, the initial production of ATP is supplied by the ATP-creatine phosphate (ATP-CP) and the glycolysis systems. The ATP-CP system can only provide enough ATP for approximately 15 seconds of activity and the glycolysis system can only supply up to an additional 2 minutes worth of ATP. Continuation of an endurance-based activity requires the constant supply of oxygen for the body to continue to produce ATP.2,11,25 The oxidative system produces approximately 19 times the ATP (38 to 39 ATP, dependent upon the fuel substrate) as produced by the phosphagen energy system (2 ATP).11,25

Benefits of Cardiovascular Fitness Training

More than 60% of adults in the United States are considered either overweight or obese.16,21 Obesity is a leading risk factor for developing heart disease, diabetes, hypertension, and some cancers. Obesity may also contribute to the development of certain musculoskeletal injuries.15 An individual with a chronic disease who initiates an aerobic exercise program may experience a decrease in the severity of symptoms associated with their disease. Likewise, participating in a regular aerobic fitness program may help to reduce the risk of developing a chronic disease.

There are many positive physical and physiologic changes that occur when one participates in a cardiovascular fitness program. Individuals who perform a cardiovascular fitness program have a lower risk of developing many chronic diseases including cardiovascular disease, type 2 diabetes, and some cancers.5,5,12,17-19,26,29,32,33 Additional training benefits associated with regular participation in an aerobic exercise program include reduction/control of one’s weight, an increase in muscular strength, a reduction in the risk of falls, and a reduced mortality.9,13

The most notable physical and physiologic changes associated with regular participation in an aerobic exercise training are4,23,25:

- Increased size and number of mitochondria
- Increased myoglobin content
- Increased heart weight and size
- Increased cardiac output and stroke volume
- Improved mobilization and use of fat and carbohydrates
- Selective hypertrophy of type I slow twitch oxidative muscle fibers
- Decreased resting heart rate and submaximal heart rate
- Decrease in adipose tissue
- Increased blood volume and hemoglobin
- Reduced systolic and diastolic blood pressure
- Significantly improved oxygen extraction rates from the blood

MINIMUM AEROBIC EXERCISE GUIDELINES FOR AMERICANS

The Centers for Disease Control and Prevention (CDC) has provided physical activity guidelines for children, adults, healthy pregnant or postpartum women, and older adults.1,9 Table 5-1 presents the minimum aerobic exercise guidelines suggested to improve one’s aerobic fitness.1,9
Exercise Guidelines for Adults

The minimum exercises guidelines for adults, older adults, and healthy pregnant or postpartum women are based on the volume of moderate or vigorous intensity aerobic activity one performs. The CDC has provided both relative and absolute guidelines to help one appreciate the intensity of his or her exercise session. The talk test may be used to determine the relative intensity of an exercise session. If one is able to talk during exercise, that exercise is of moderate-intensity. If one is unable to speak more than a few words before needing to pause for a breath, then they are likely performing a vigorous intensity exercise. The absolute intensity guidelines are based on the amount of energy one typically uses during 1 minute of exercise. Examples of moderate intensity exercises include walking briskly, water aerobics, doubles tennis, and cycling at a pace less than 10 miles per hour. Running, swimming laps, singles tennis, cycling faster than 10 miles per hour, and hiking are all examples of vigorous intensity exercises.

The CDC recommends that as adults’ fitness level improves, they should increase their level of either moderate intensity aerobic activity to 5 hours a week, or to 2 1/2 hours of vigorous intensity aerobic activity each week, or to an equal mix of both types.

Exercise Guidelines for Children

The number of children and adolescents who are considered overweight or obese has at least doubled during the past twenty years. Recent studies have demonstrated that the likelihood that one will be obese as an adult increases if he or she was obese as a child. To combat pediatric obesity, children and adolescents need to participate in daily physical activity. A lack of physical education in many school districts limits the opportunities during the day for a child to exercise.

The CDC recommends that children perform at least 60 minutes of moderate intensity exercises each day. In addition, children should perform vigorous intensity exercises at least 3 times a week. The physical therapy team may play a crucial role in educating a family as to the importance of daily physical activity for a child as well as developing and implementing a fitness program for the child.

ADDITIONAL METHODS TO MEASURE EXERCISE INTENSITY

In a clinical exercise physiology setting the efficiency of one’s aerobic fitness may be determined by measuring the maximum volume of oxygen consumed during exercise. This measure has been termed the maximal oxygen uptake or the \( \text{VO}_2 \text{ MAX} \). Using this number, a clinician can prescribe a particular exercise intensity based on a percentage of one’s \( \text{VO}_2 \text{ MAX} \).

Most physical therapy clinics do not possess the necessary equipment required to record a patient’s maximal oxygen uptake. Several methods have been developed that allow clinicians to measure and prescribe a particular exercise intensity without needing high-tech equipment.

The aforementioned talk test (previous section) is one manner to determine a client’s aerobic exercise intensity. Two other methods used to measure aerobic intensity are the target heart rate/estimated maximum heart rate method and the perceived exertion method.

Target Heart Rate and Estimated Maximum Heart Rate

The CDC recommends that an individual who is performing moderate intensity exercise should do so at a target heart rate range of 50% to 70% of one’s maximum heart rate (beats per minute). When an individual performs vigorous intensity exercise, their target heart rate (THR) should be 70% to 85% of their maximal heart rate.

Table 5-1: Minimum Weekly Aerobic Exercise Guidelines for Adults

<table>
<thead>
<tr>
<th>Intensity Level</th>
<th>Adults</th>
<th>Older Adults (65 years of age or older)</th>
<th>Healthy Pregnant or Postpartum Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate intensity aerobic activity</td>
<td>2 hours and 30 minutes weekly</td>
<td>2 hours and 30 minutes weekly</td>
<td>2 hours and 30 minutes weekly</td>
</tr>
<tr>
<td>Vigorous intensity aerobic activity</td>
<td>1 hour and 15 minutes weekly</td>
<td>1 hour and 15 minutes weekly</td>
<td>May continue vigorous intensity activities, such as running, if performing these exercises before her pregnancy.</td>
</tr>
<tr>
<td>Combination</td>
<td>Equal amount of moderate and vigorous intensity aerobic activity</td>
<td>Equal amount of moderate and vigorous intensity aerobic activity</td>
<td>N/A</td>
</tr>
</tbody>
</table>

rate (MHR). How is the MHR measured? To calculate a client's/patient's MHR, the individual's age is subtracted from 220 (e.g., 220 – 30). To establish the THR, the MHR is multiplied by the desired intensities. These two calculations (Table 5-2) will provide the lower and upper limit target heart rates for someone who is performing moderate or vigorous intensity exercises.

The Karvonen method has been suggested as an alternative method of calculating THR. The Karvonen method differs from the aforementioned technique in that it accounts for one's resting heart rate. In the previous example (see Table 5-2), the THR for a 30-year-old individual performing moderate intensity exercise is 95 to 113 beats per minute. If this individual has a resting heart rate of 70 beats per minute, the THR range would be 130 to 154 beats per minute (Table 5-3).

### Borg Rating of Perceived Exertion

The Borg Rating of Perceived Exertion scale may be used to assess exercise intensity based on an individual's perception of exertion. While the client is exercising, ask him or her to rate how hard he or she is exercising based on the Borg scale. The Borg scale ranges from 6 to 20 points, with a 6 corresponding to "no exertion at all" and a 20 corresponding to "maximal exertion." The client/patient should be asked to view the scale each time when measuring perceived exertion. The Borg scale has also been found to correlate with one's heart rate. This is a helpful feature allowing the clinician to monitor exercise intensity level based on an estimate of heart rate. To determine heart rate from the Borg scale, multiply the perceived rating (e.g., 13) by a factor of 10 (e.g., 130 beats per minute).

### Methods of Aerobic Training

Aerobic conditioning programs are either continuous or discontinuous. Continuous aerobic activities provide no rest interval during the entire bout of exercise. Examples of continuous activities are jogging, walking, running, cycling, and stair climbing.

Discontinuous aerobic activities are also known as interval training activities. A discontinuous aerobic exercise routine may include similar exercises used during continuous aerobic programs; however, during interval training, repeated exercise bouts are interspersed with rest intervals. Discontinuous training routines may be beneficial for patients who have limited exercise tolerance.

### Aerobic Exercise for Patients with an Orthopedic Injury

Patients who have been diagnosed with an orthopedic injury will benefit from the inclusion of aerobic exercise as part of their rehabilitation program. The physical therapy team must consider tissue healing parameters when implementing an exercise. An acute injury or surgery may require a period of rest (or activity avoidance) in order to avoid additional injury or protect the surgical repair.

Evidence suggests that aerobic fitness activities should be included in a rehabilitation program for a patient recovering from a back injury. Riding a stationary bicycle or walking on a treadmill (Fig. 5-1, A-B) may help to facilitate initial aerobic training. However, sitting on the saddle seat of a stationary ergometer may be uncomfortable or provoke symptoms for many patients with back problems. A recumbent cycle, with its large bucket seat (Fig. 5-1, C) to provide lumbar support, may be preferred by many clients. Patients who are unable to tolerate land based aerobic exercises may benefit from walking on an underwater treadmill. Immersion in the water can provide enough buoyancy during walking, unloading the spine, allowing the patient to exercise without exacerbating symptoms (Fig. 5-1, D).

Patients who have sustained a lower extremity injury or are recovering after a lower extremity surgery can maintain or improve cardiorespiratory fitness using an upper body ergometer (UBE) (Fig. 5-2, A). The UBE is ideal for individuals who are contraindicated from either bearing weight or performing range of motion activities with their involved lower extremity. The single-leg stationary bicycle ergometer exercise (Fig. 5-2, B)
I BASIC CONCEPTS OF ORTHOPEDIC MANAGEMENT

may also be safely initiated by a patient before begin-
ning double-leg cycling.

Older patients with hip, knee, or ankle osteoarthri-
tis (degenerative joint disease) may also benefit from a
UBE training program. The vertical compressive loads
experienced during treadmill walking, stair climbing,
or even stationary cycling may cause or increase one’s
symptoms.

Patients with upper extremity conditions can use a
stationary cycle or treadmill for endurance training.
Patients also can be instructed to use one-arm cycling
on a UBE (Fig. 5-3) to maintain upper body aerobic
fitness.

Fig. 5-1 A, Seated stationary bicycle ergometer. B, Standard treadmill. C, Recumbent bicycle ergometer. Large bucket
seat used in a recumbent position may allow some patients to tolerate seated aerobic activities. D, Underwater treadmill.
The buoyancy of the water may allow early vertical loading and the initiation of normalized gait mechanics.

Fig. 5-1  A, Seated stationary bicycle ergometer.  B, Standard treadmill.  C, Recumbent bicycle ergometer. Large bucket
seat used in a recumbent position may allow some patients to tolerate seated aerobic activities.  D, Underwater treadmill.
The buoyancy of the water may allow early vertical loading and the initiation of normalized gait mechanics.
a complete pedal stroke and keep the ankle joint in neutral (Fig. 5-4).

Stair climbing, seated rowing, and cross-country ski machines are popular aerobic tools but must be used judiciously. Stair climbers require the patient to be correctly positioned vertically and maintain balance (holding the hand rails) to perform the exercise correctly. Therefore stair climbers are inappropriate or unsafe for many patients during the acute stage or immediate postorthopedic surgery period. Rowing machines require both a pulling motion with the arms and hip and knee flexion and extension. These simultaneous motions make modifications for use with specific orthopedic problems quite difficult. Cross-country ski machines require bilateral, reciprocal leg and arm motions and are also difficult to modify for orthopedic patients with acute disorders. However, stair climbers, rowing machines, and cross-country ski machines can be effective tools in aerobic conditioning programs after the acute phase of recovery from injury or surgery.

**MUSCULAR ENDURANCE TRAINING**

Even though they share the term *endurance*, muscular endurance and cardiovascular endurance are not one and the same. One can demonstrate functional muscular endurance but not possess functional cardiovascular endurance. What is the difference? As mentioned earlier in the chapter, cardiovascular endurance involves one’s cardiovascular system to perform an aerobic activity. For an activity to be considered aerobic, the oxidative energy system is used.

On the other hand, muscular endurance exercises typically only use the ATP-CP and glycolysis energy systems.

The key variables that define how a muscle(s) is(are) being trained are: the number of repetitions performed during a set, the amount of weight lifted during the set, and the period of rest between sets.

To increase muscular endurance, sets of high repetitions should be performed. At least 15 repetitions
should be performed per set.\textsuperscript{2,10} Each repetition should be performed at or below 67\% of one’s 1 RM (repetition maximum). A period of 1 to 2 minutes should be allowed for rest in between each set. Table 5-4 compares variables associated with the four main types of muscular training: power, strength, hypertrophy, and endurance.

Muscular endurance training plays a key role when rehabilitating patients with an orthopedic injury.\textsuperscript{14,22,24,27,28} Using the muscular endurance training principles allows the physical therapy team to prescribe strengthening exercises during the subacute phase of healing (see Chapter 11) while reducing the risk of over-stressing the healing tissue.

<table>
<thead>
<tr>
<th>Training Goal</th>
<th>Repetitions Goal</th>
<th>Load (% of 1 RM)</th>
<th>Rest Interval Between Sets (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>1-2</td>
<td>80-90</td>
<td>2-3</td>
</tr>
<tr>
<td>Strength</td>
<td>≤6</td>
<td>≥85</td>
<td>2-3</td>
</tr>
<tr>
<td>Hypertrophy</td>
<td>6-12</td>
<td>67-85</td>
<td>2-3</td>
</tr>
<tr>
<td>Endurance</td>
<td>15+</td>
<td>≤67</td>
<td>1-2</td>
</tr>
</tbody>
</table>

Maximal oxygen uptake (V\textsubscript{O\textsuperscript{2}} MAX): The maximum volume of oxygen consumed during exercise. This measurement shows the patient’s level of aerobic fitness.

Muscular endurance: The ability of muscle(s) to perform at a particular level for prolonged period of time.

Oxidative system: An energy system known as the aerobic system because its operation requires a constant supply of O\textsubscript{2}.

Target heart rate (THR): The optimum number of beats per minute that the heart should pump during moderate or vigorous intensity exercise. THR is calculated by multiplying the patient’s MHR by either 0.70 (for moderate intensity) or 0.85 (for vigorous intensity).

**GLOSSARY**

Borg rating of perceived exertion: A scale used to assess exercise intensity based on an individual’s perception of exertion.

Cardiovascular endurance: The ability of one’s cardiovascular system to allow the performance of prolonged aerobic activities.

Catabolism: A metabolic process that breaks down compounds, such as degradation of glucose to CO\textsubscript{2} and H\textsubscript{2}O, causing the release of energy.

Karvonen method: An alternative (to the Borg) method of calculating target heart rate.

Maximal heart rate (MHR): The maximum number of beats per minute that the heart is able to pump. MHR is measured by subtracting the patient’s age from 220.
REFERENCES

REVIEW QUESTIONS
Short Answer
1. According to the CDC what is the minimum number of hours a week that an adult should perform moderate intensity aerobic exercises?
2. Calculate the MHR for a 40-year-old male.
3. The Borg scale has a range of numbers starting at _______ and ending at _______.
4. A 25-year-old football player has fractured his right fibula. The orthopedic surgeon believes that he can return to competition in 3 to 4 weeks. At this moment, the football player is not allowed to bear weight on his right lower extremity. Which exercises would be most appropriate for him to maintain cardiovascular fitness?

True/False
5. Cardiovascular endurance and muscular endurance are one and the same.
6. A distance runner primarily uses the glycolytic pathway to produce ATP.