Chapter 3: Cardiorespiratory Endurance

LEARNING OBJECTIVES

After reading this chapter, the student will be able to:

• Describe how the body produces the energy it needs for exercise.
• List the major effects and benefits of cardiorespiratory endurance exercise.
• Explain how cardiorespiratory endurance is measured and assessed.
• Describe how frequency, intensity, time (duration), and type of exercise affect the development of cardiorespiratory endurance.
• Explain the best ways to prevent and treat common exercise injuries.

KEY TERMS AND DEFINITIONS

cardiorespiratory system The system that circulates blood through the body; consists of the heart, blood vessels, and respiratory system.
pulmonary circulation The part of the circulatory system that moves blood between the heart and the lungs; controlled by the right side of the heart.

systemic circulation The part of the circulatory system that moves blood between the heart and the rest of the body; controlled by the left side of the heart.

venae cavae The large veins through which blood is returned to the right atrium of the heart.

atrium One of the two upper chambers of the heart in which blood collects before passing to the ventricles (pl. atria).

ventricle One of the two lower chambers of the heart from which blood flows through arteries to the lungs and other parts of the body.
aorta The body’s large artery; receives blood from the left ventricle and distributes it to the body.
systole Contraction of the heart.
diastole Relaxation of the heart.

blood pressure The force exerted by the blood on the walls of the blood vessels; created by the pumping action of the heart.

veins Vessels that carry blood to the heart.
arteries Vessels that carry blood away from the heart.
capillaries Very small blood vessels that distribute blood to all parts of the body.
coronary arteries A pair of large blood vessels that branch off the aorta and supply the heart muscle with oxygenated blood.

respiratory system The lungs, air passages, and breathing muscles; supplies oxygen to the body and removes carbon dioxide.
alveoli Tiny air sacs in the lungs that allow the exchange of oxygen and carbon dioxide between the lungs and blood.

stroke volume The amount of blood the heart pumps with each beat.
cardiac output The amount of blood pumped by the heart each minute; a function of heart rate and stroke volume.

metabolic rate The rate at which the body uses energy.
glucose A simple sugar that circulates in the blood and can be used by cells to fuel adenosine triphosphate (ATP) production.
glycogen  A complex carbohydrate stored principally in the liver and skeletal muscles; the major fuel source during most forms of intense exercise. Glycogen is the storage form of glucose.

adenosine triphosphate (ATP)  The energy source for cellular processes.

immediate (“explosive”) energy system  The system that supplies energy to muscle cells through the breakdown of cellular stores of ATP and creatine phosphate (CP).

nonoxidative (anaerobic) energy system  The system that supplies energy to muscle cells through the breakdown of muscle stores of glucose and glycogen; also called the anaerobic system or the lactic acid system, because chemical reactions take place without oxygen and produce lactic acid.

anaerobic  Occurring in the absence of oxygen.

lactic acid  A metabolic acid resulting from the metabolism of glucose and glycogen.

oxidative (aerobic) energy system  The system that supplies energy to cells through the breakdown of glucose, glycogen, and fats; also called the aerobic system because its chemical reactions require oxygen.

aerobic  Dependent on the presence of oxygen.

mitochondria  Cell structures that convert the energy in food to a form the body can use.

maximal oxygen consumption (VO$_{2\text{max}}$)  The highest rate of oxygen consumption an individual is capable of during maximum physical effort, reflecting the body’s ability to transport and use oxygen; measured in milliliters of oxygen used per minute per kilogram of body weight.

target heart rate zone  The range of heart rates that should be reached and maintained during cardiorespiratory endurance exercise to obtain training effects.

heart rate reserve  The difference between maximum heart rate and resting heart rate; used in one method for calculating target heart rate range.

MET  A unit of measure that represents the body’s resting metabolic rate—that is, the energy requirement of the body at rest.

ratings of perceived exertion (RPE)  A system of monitoring exercise intensity based on assigning a number to the subjective perception of target intensity.

cross-training  Alternating two or more activities to improve a single component of fitness.

dehydration  Excessive loss of body fluid.

heat cramps  Sudden muscle spasms and pain associated with intense exercise in hot weather.

heat exhaustion  Heat illness resulting from exertion in hot weather.

heatstroke  A severe and often fatal heat illness characterized by significantly elevated core body temperature.

hypothermia  Low body temperature due to exposure to cold conditions.

frostbite  Freezing of body tissues characterized by pallor, numbness, and a loss of cold sensation.

wind chill  A measure of how cold it feels based on the rate of heat loss from exposed skin caused by cold and wind; the temperature that would have the same cooling effect on a person as a given combination of temperature and wind speed.

EXTENDED LECTURE OUTLINE

Introduction
Cardiorespiratory endurance is the ability of the body to perform prolonged, large-muscle, dynamic exercise at moderate-to-high levels of intensity. This chapter describes the numerous benefits of cardiorespiratory fitness and provides guidelines for creating, maintaining, or building individualized cardiorespiratory endurance programs.

I. Basic Physiology of Cardiorespiratory Endurance Exercise

   A. The cardiorespiratory system picks up and transports oxygen, nutrients, and other key substances to the organs and tissues that need them as well as carrying waste away.

   B. The cardiorespiratory system consists of the heart, the blood vessels, and the respiratory system.

      1. The Heart
         a. The heart is a fist-sized muscle with four chambers located just beneath the sternum. It pumps deoxygenated blood to the lungs and delivers oxygenated blood to the rest of the body.
         b. The right side of the heart pumps blood to the lungs in what is called pulmonary circulation, and the left side pumps blood through the rest of the body in systemic circulation.
         b. Waste-laden, oxygen-poor blood travels through large vessels, called venae cavae, into the heart’s right upper changer, or atrium. After the right atrium fills, it contracts and pumps blood into the heart’s right lower chamber, or ventricle. When the right ventricle is full, it contracts and pumps blood through the pulmonary artery into the lungs. In the lungs, blood picks up oxygen and discards carbon dioxide. The cleaned, oxygenated blood flows from the lungs through the pulmonary veins into the heart’s left atrium. After the left atrium fills, it contracts and pumps blood into the left ventricle. When the left ventricle is full, it pumps blood though the aorta – the body’s largest artery for distribution to the rest of the body’s blood vessels.
         c. The period of the heart’s contraction is called systole, and the period of relaxation is called diastole.
         d. Blood pressure is the amount of force exerted by blood on the walls of the blood vessels based on the force created by the heart. The average person has about five quarts of blood circulated about once every minute at rest.
         e. The heartbeat is controlled by nerve impulses. The signals originate at the SA node (sinoatrial) and spreads throughout the heart which assists with the rate and flow of blood.

      2. Blood Vessels
         a. Veins have thin walls and carry blood to the heart.
         b. Arteries have thick elastic walls and carry blood away from the heart.
         c. Capillaries are the smallest vessels that deliver nutrient-rich blood and oxygen to the tissues and carry waste-laden blood away from the tissues.
         d. The heart has its own network of arteries, veins, and capillaries. The coronary arteries supply the heart with nutrients. Blockage of these arteries can lead to a heart attack.

      3. The Respiratory System
a. The respiratory system supplies oxygen to the body, carries off carbon dioxide – a waste product of body processes – and helps regulate acid produced during metabolism. Air passes in and out of the lungs based on pressure changes brought about by the contractions and relaxation of the diaphragm and rib muscles.

b. The exchange of oxygen and carbon dioxide occurs in the lungs between alveoli and capillaries.

c. The proper functioning of this system is crucial for the body to work properly.

4. The Cardiorespiratory System at Rest and During Exercise

a. At rest and during light activity, the cardiorespiratory system functions at a fairly steady pace.

b. The heart rate increases during exercise up to 170 to 210 beats per minute; the heart’s stroke volume increases; the heart pumps and circulates more blood per minute as a result of the faster heart rate and greater stroke volume; blood flow changes; systolic blood pressure increase, while diastolic blood pressure holds steady or declines slightly; you take deeper breaths and breathe faster.

C. Energy Production

Energy is required to fuel all body functions.

1. Metabolism is the sum of all the chemical processes necessary to maintain the body. The rate at which your body uses energy, or its metabolic rate, depends on your level of activity.

2. Energy from Food — The body converts chemical energy from food into substances that cells can use as fuel.

3. The three classes of energy-containing nutrients in food are carbohydrates, fats, and proteins.

   a. Carbohydrates are broken down into glucose so that they can be used; if not used, they are stored as glycogen or as fat.

   b. Excess energy from dietary fat is stored as body fat.

   c. Protein can be used for energy; however, its use is tissue building.

4. ATP (adenosine triphosphate): The Energy “Currency” of Cells — ATP is the basic form of energy used by the cells. When the body needs energy, it converts stored fuels (glucose, glycogen, fat) into ATP.

D. Exercise and the Three Energy Systems

Muscles use three energy systems to create ATP and provide fuel cellular activity.

1. The immediate (“explosive”) energy system fuels activities that last ten seconds or fewer. For fuel, this system uses cellular stores of ATP and creatine phosphate. Maximum levels are depleted during exercise within a few seconds.

2. The nonoxidative (anaerobic) energy system is used at the start of an exercise session and for high-intensity activities that last from ten seconds to two minutes. This system (sometimes referred as the anaerobic system) does not require oxygen and creates energy by breaking down glucose and glycogen.

   a. The body’s supply of glucose and glycogen is limited, and when it is depleted, fatigue sets in.
b. Lactic acid is produced, causing the release of hydrogen ions that interfere with metabolism and muscle contractions, thereby causing fatigue during intense activity.

3. The oxidative (aerobic) energy system is used during activities that last longer than about two minutes. Oxygen is required for ATP generation, so this is considered an aerobic system.
   a. The aerobic system can supply energy for a long period of time by producing ATP in the mitochondria of a cell. For fuel, mitochondria can use carbohydrates or fats to produce ATP.
   b. The optimal fuel for intense exercise is carbohydrates; for lower intensity exercise, it is fats.
   c. Fat utilization increases over time, and more-fit individuals use a greater proportion of fat as fuel.
   d. The body is limited in how much it can improve its ability to transport and use oxygen; this limit is known as $\text{VO}_{2\text{max}}$, or maximal oxygen consumption. $\text{VO}_{2\text{max}}$ is the best overall assessment of the cardiorespiratory system.

E. The Energy System in Combination and Physical Fitness and Energy Production
   1. Although the body uses all three systems during exercise, the intensity and duration of exercise determines which energy system predominates.
   2. Regular physical exercise improves the body’s ability to produce energy and adapt to physical activity.
   3. In designing a fitness program, it is important to target the energy system that is most important to your goals and to remember that improving the function of the cardiorespiratory system is key to overall fitness. Improving the functioning of the cardiorespiratory system is important to overall wellness; performing activities at moderate to high levels of intensity for a prolonged duration is key to any health-related fitness program.

II. Benefits of Cardiorespiratory Endurance Exercise
   Cardiorespiratory endurance exercise helps the body to become more efficient, better cope with physical challenges, and better resists chronic diseases.
   A. Improved Cardiorespiratory Functioning
      Endurance exercise enhances the heart’s health by:
      1. Maintaining or increasing the heart’s own blood and oxygen supply.
      2. Increasing the heart muscle’s function, so it pumps more blood per beat.
      3. Strengthening the heart’s contraction.
      4. Increasing the heart’s cavity size (in young adults).
      5. Increasing blood volume so the heart pushes more blood into the circulatory system during each contraction.
      6. Reducing blood pressure.
   B. Improved Cellular Metabolism
      Regular endurance exercise improves metabolism, down to the cellular level, enhancing your ability to produce and use energy efficiently.
1. Increases the number of capillaries in the muscles.
2. Allows training muscles to make the most of oxygen and fuel, so they work more efficiently.
3. Increases the number and size of mitochondria which increases energy capacity.
4. Prevents glycogen depletion and increasing the muscles’ ability to use lactic acid and fat as fuels.

C. Reduced Risk of Chronic Disease

Regular endurance exercise reduces your risk of many chronic, disabling diseases.

1. Cardiovascular Disease
   A sedentary lifestyle is a key contributor to cardiovascular disease. Cardiorespiratory endurance exercise lowers your risk of CVD by doing the following:
   a. Promoting a healthy balance of fats in the blood. Exercise increases high-density lipoproteins (HDL) and may decreases low-density lipoproteins (LDL).
   b. Reducing high blood pressure, which is a contributing factor in several kinds of CVD.
   c. Enhancing the function of the cells that line the arteries (endothelial cells).
   d. Reducing inflammation.
   e. Preventing obesity and type 2 diabetes, both of which contribute to CVD.

2. Cancer
   Exercise may be related to a reduction in risk of all types of cancer. There is strong evidence that it can reduce the risk of colon and breast and other reproductive cancers.

3. Diabetes
   Regular exercise can help prevent development of Type II diabetes by burning excess sugar, making cells more sensitive to the hormone insulin, and keeping body fat at healthy levels.

4. Osteoporosis
   Osteoporosis is a disease that results in loss of bone density and strength; it is especially common in women. Exercise throughout life helps people build and maintain bone mass and avoid falls and fractures.

5. Deaths from All Causes
   Physically fit people have a reduced risk of dying prematurely from all causes.

D. Better Control of Body Fat

1. Regular exercise increases daily calorie expenditure, so that a healthy diet is less likely to lead to weight gain.

2. Exercise can also increase resting metabolic rate, and as muscle is built, a higher metabolic rate is maintained.

E. Improved Immune Function
   Moderate endurance exercise appears to boost immune function, but over-training depresses it.

F. Improved Psychological and Emotional Well-Being
1. Most people who participate in regular endurance exercise experience social, psychological, and emotional benefits.

2. Performing physical activities provides proof of skill mastery and self-control, thus enhancing self-image.

3. Endurance exercises lessen anxiety, depression, stress, anger, and hostility, while improving sleep.

III. Assessing Cardiorespiratory Fitness

The best quantitative measure of cardiorespiratory endurance is maximal oxygen consumption.

A. Cardiorespiratory fitness is determined by the body’s ability to take up, distribute, and use oxygen during physical activity.

B. The best quantitative measure of cardiorespiratory endurance is maximal oxygen consumption, expressed as VO\textsubscript{2max}, the amount of oxygen your body uses when you reach your maximum ability to supply oxygen during exercise. This is measured through an analysis of gas exchange while exercising to a level of exhaustion. This procedure is expensive and time-consuming.

C. Three simple assessment tests provide good estimates of MOC; choice of assessment method should be based on access to equipment, current physical condition, and personal preference. Tests should not be taken if a person is ill or at risk; a physician should be consulted if there is any question.

1. The 1-Mile Walk Test
   This test estimates the level of maximal oxygen consumption based on the amount of time it takes to complete one mile of brisk walking and the heart rate at the end of the walk. A fast time and low heart rate indicate high endurance.

2. The 3-Minute Step Test
   This test measures how long it takes the pulse to return to normal after three minutes of stepping exercise. Quick recovery indicates high endurance.

3. The 1.5-Mile Run-Walk Test
   Oxygen consumption increases with speed, and so a fast time indicates high MOC. Recommended for people who are healthy and physically active.

D. Monitoring your heart rate is a key part of most fitness assessment tests.

1. The two most common sites for monitoring heart rate are the carotid artery (side of neck near Adam’s apple) or the radial artery (thumb side of wrist). Monitor your heart rate by placing your index and middle fingers gently on the carotid artery in your neck or the radial artery in your wrist.

2. Heart rates are usually assessed in beats per minute, but to estimate your heart’s beats per minute, count your pulse for ten seconds and multiply by six.

E. To interpret your score, use Lab 3.1 to determine your level of cardiorespiratory fitness. These assessments can be used to monitor your progress by retesting yourself from time to time. Always compare scores for the same test.

IV. Developing a Cardiorespiratory Endurance Program

Cardiorespiratory fitness programs are best for developing the type of fitness associated with good health.
A. Setting Goals.
Using the results of your cardiorespiratory fitness tests, set an oxygen consumption goal high enough to ensure a healthy cardiorespiratory system but not impossible for you to achieve.

B. Applying the FITT Equation
1. Frequency of Training.
   Beginners should start with three days per week and work up to five.
2. Determining Intensity of Training.
Choose one of these two methods to determine the level of exercise intensity necessary to improve your fitness:
   a. Target Heart Rate Zone (training between 65-90% of your max heart rate)
   b. Alternative Heart Rate Reserve Method (differences between max heart rate and resting heart rate). Both methods provide reasonable estimates of an appropriate target heart rate zone for cardiorespiratory fitness.

METs
Represent the body’s resting metabolic rate. Scientists use this value to measure metabolic costs of an exercise. One MET is equivalent of 3.5 ml of oxygen/kg/minute (at rest) compared to jogging which can elevate to 8-12 METS.

-Ratings of Perceived Exertion
   Based on how you feel during exercise, this method can be used to determine intensity compared to checking your pulse periodically. A level of 14-15 is close to corresponding to your target heart rate.

3. Time (Duration) of Training
   a. The length of time you spend on a workout depends on its intensity. Total duration of 20–60 minutes is recommended. Exercise can take place in a single session or in multiple sessions lasting 30 or more minutes.
   b. For low- to moderate-intensity exercise 45–60 minutes is necessary, and for high-intensity exercise for a duration of 20 minutes is sufficient. Although some studies have shown that 5–10 minutes of extremely intense exercise improves cardiorespiratory endurance, it also increases the risk of injury and your prolongs your level of discomfort.

4. Type of Activity
   a. Cardiorespiratory activity includes the rhythmic use of large muscle groups for an extended period of time such as jogging, walking, cycling, and swimming.
   b. Start and stop sports qualify if you have enough skill to play continuously and intensely enough to raise your heart rate to target levels.

C. Warming Up and Cooling Down
1. Muscles work better at a temperature slightly above resting level, so warming up your body enhances performance and decreases chance of injury. Warm up with low-intensity movements specific to your exercise.
2. Cool-down should consist of 5–10 minutes of reduced activity to return your body to its resting state. A rule of thumb is to cool down at least until your heart rate drops below 100 beats per minute.

3. Do not use stretching as part of your pre-exercise warm up. Warm up stretches do not prevent injury and have little or no effect on post-exercise muscle soreness. It is best to stretch after your workout, while your muscles are still warm and your joints are lubricated.

E. Building Cardiorespiratory Fitness
Your rate of progress will depend on your age, health status initial level of fitness, and motivation. Remember, fitness improves when you overload your body. Start initially with a threshold of the lower end of your target heart rate zone, 3-4 times per week. As you improve, increase your time and intensity. Be cautious of overloading too quickly by paying attention to your body’s response to the overload.

F. Maintaining Cardiorespiratory Fitness
1. Although initially your fitness level should improve quickly, after 4–6 weeks your rate of fitness progress will probably slow down.

2. You will need to increase intensity and duration to improve, until you reach an acceptable level of fitness, and then you should maintain the same intensity and duration of activity at least 3 nonconsecutive days a week. If you stop exercising, you will lose your gains rapidly.

3. Cross-training can help prevent injuries and improve enjoyment. Set new goals and make adjustments to your overall program.

V. Exercise Safety and Injury Prevention
Exercise safety and injury prevention are two important factors to consider when partaking in cardiorespiratory exercises.

A. Hot Weather and Heat Stress
1. A change of just a few degrees in body temperature can quickly lead to distress and even death.

2. Problems associated with heat stress can include dehydration, heat cramps, heat exhaustion, and life-threatening heat stroke.

3. Dehydration increases body temperature and decreases sweat rate, plasma volume, cardiac output, maximal oxygen consumption, exercise capacity, muscular strength, and stores of liver glycogen. Drinking fluids before (2 cups of fluid) and during exercise is important to prevent this. Drink 1 cup of fluids every 20 to 30 minutes of exercise as a general rule.

4. While depletion of sodium and potassium from the muscles is involved with heat cramps, the primary cause of cramps is muscle fatigue. The best treatment for this is electrolyte fluid replacement, gentle stretching, and rest.

5. Heat exhaustion includes a rapid and weak pulse, low blood pressure, faintness, profuse sweating, and, in some cases psychological disorientation; core body temperature may be normal or slightly elevated. This occurs when venous return is low, based on blood being used by the muscles during the activity and skin for cooling. Treatment is usually rest in a cool environment.
6. Heat stroke is a major medical emergency involving the failure of the brain’s temperature regulatory center. The body does not sweat enough, and body temperature rises to dangerous levels. The person who is suffering from heat stroke should be cooled as rapidly as possible and taken to the hospital.

B. Cold Weather

1. Hypothermia depresses the central nervous system, resulting in sleepiness and a lower metabolic rate. This can result in a coma and eventually death.

2. Frostbite is the freezing of body tissues, which is a potential danger of exercise in extremely cold conditions. This requires immediate medical treatment. Prevent frostbite by dressing appropriately to prevent heat loss and exposure to the elements by protecting the areas of the body such as the fingers, toes, ears, nose, and cheeks.

C. Poor Air Quality

Air pollution can decrease exercise performance and negatively affect health, particularly for those with respiratory problems such as asthma, bronchitis, or emphysema.

1. Do not exercise when outdoors during a smog alert or if air quality is poor. Air quality is better during the early mornings or late evenings.

D. Exercise Injuries

1. Consult a physician for head and eye injuries; possible ligament injuries; broken bones; internal disorders such as chest pain, fainting, and heat intolerance; and injuries that do not improve in a reasonable amount of time.

2. Managing Minor Exercise Injuries
   a. For cuts and scrapes, stop the bleeding and clean the wound.
   b. For injuries to muscles and joints, rest, apply ice packs, elevate the limb, and compress the injured area with an elastic bandage to reduce swelling. Continue to apply ice for 36–48 hours or until the swelling is gone. The acronym RICE—rest, ice, compression, elevation—makes this easy to remember. Use over-the-counter medications to decrease inflammation.

3. Preventing Injuries
   a. The best means of dealing with injuries is to prevent them.
   b. Choose activities that suit your body and level of fitness, and carefully follow the guidelines for that activity.
   c. Guidelines for preventing athletic injuries include the following: train regularly; increase intensity, duration, or frequency gradually; avoid or minimize high-impact activities; get proper rest; drink plenty of fluids; warm up and cool down consistently; maintain flexibility; use proper body mechanics; don’t exercise when ill or overtrained; use proper equipment, particularly shoes, and exercise on an appropriate surface; don’t exercise until any injuries have healed.
Chapter 4: Muscular Strength and Endurance

LEARNING OBJECTIVES

After reading this chapter, the student will be able to:

• Describe the basic physiology of muscles and explain how strength training affects muscles.
• Define muscular strength and endurance and describe how they relate to wellness.
• Assess muscular strength and endurance.
• Apply the FITT principle to create a safe and successful strength training program.
• Describe the effects of supplements and drugs that are marketed to active people and athletes.
• Explain how to safely perform common strength training exercises using free weights and machines.

KEY TERMS AND DEFINITIONS

**muscle fiber** A single muscle cell, usually classified according to strength, speed of contraction, and energy source.
**myofibrils** Protein structures that make up muscle fibers.
**hypertrophy** An increase in the size of a muscle fiber, usually stimulated by muscular overload as occurs during strength training.
**atrophy** A decrease in the size of muscle fibers.
**hyperplasia** An increase in the number of muscle fibers.
**slow-twitch fibers** Red muscle fibers that are fatigue-resistant but have a slow contraction speed and a lower capacity for tension; usually recruited for endurance activities.
**fast-twitch fibers** White muscle fibers that contract rapidly and forcefully but fatigue quickly; usually recruited for actions requiring strength and power.
**power** The ability to exert force rapidly.
**motor unit** A motor nerve (one that initiates movement) connected to one or more muscle fibers.
**muscle learning** The improvement in the body’s ability to recruit motor units brought about through strength training.
**tendon** A tough band of fibrous tissue that connects a muscle to a bone or other body part and transmits the force exerted by the muscle.
**ligament** A tough band of tissue that connects the ends of bones to other bones or supports organs in place.
**cartilage** Tough, resilient tissue that acts as a cushion between the bones in a joint.
**testosterone** The principal male hormone responsible for the development of secondary sex characteristics and important in increasing muscle size.
**repetition maximum (RM)** The maximum amount of resistance that can be moved a specified number of times.
**repetitions** The number of times an exercise is performed during one set.
**static (isometric) exercise** Exercise involving a muscle contraction without a change in the muscle length
**dynamic (isotonic) exercise** Exercise involving a muscle contraction with a change in the muscle length
**concentric muscle contraction** A dynamic contraction in which the muscle gets shorter as it contracts.
**eccentric muscle contraction** A dynamic contraction in which the muscle lengthens as it contracts; also called a *pliometric contraction*.

**constant resistance exercise** A type of dynamic exercise that uses a constant load throughout a joint’s entire range of motion.

**variable resistance exercise** A type of dynamic exercise that uses a changing load, providing a maximum load throughout the joint’s entire range of motion.

**eccentric (pliometric) loading** Loading the muscle while it is lengthening; sometimes called *negatives*.

**plyometrics** Rapid stretching of a muscle group that is undergoing eccentric stress (the muscle is exerting force while it lengthens), followed by a rapid concentric contraction.

**speed loading** Moving a load as rapidly as possible.

**kettlebell** A large iron weight with a connected handle; used for ballistic weight training exercises such as swings and one-arm snatches.

**isokinetic** The application of force at a constant speed against an equal force.

**spotter** A person who assists with a weight training exercise done with free weights.

**set** A group of repetitions followed by a rest period.

**agonist** A muscle in a state of contraction, opposed by the action of another muscle, its *antagonist*.

**antagonist** A muscle that opposes the action of another muscle, its *agonist*.

**EXTENDED LECTURE OUTLINE**

**Introduction**

Muscles make up more than 40% of your body mass. Muscular strength and endurance are vital to health, wellness, and overall quality of life. This chapter explains the benefits of strength training and describes tests used to assess muscular strength and endurance. It describes the basics of weight training and provides guidelines for establishing a weight training program.

I. **Basic Muscle Physiology and the Effects of Strength Training**

   A. *Muscles consist of individuals’ muscle cells, or muscle fibers, connected in bundles which enables the body to move.*

      1. Muscle fibers are bundles made up of smaller units called myofibrils.
      2. Strength training causes the size of individual muscle fibers to increase by increasing the number of myofibrils known as *hypertrophy*. Inactivity causes the opposite effect, known as *atrophy*.

   B. *Muscle fibers are classified according to their strength, speed of contraction, and energy source.*

      1. Slow-twitch fibers are relatively fatigue resistant and do not contract as rapidly or strongly as fast-twitch fibers.
      2. Fast-twitch fibers contract more rapidly and forcefully than slow-twitch fibers but fatigue more quickly.
3. Most muscles contain a mixture of both fiber types, the composition of which is based on genetics. Endurance activities tend to use slow twitch fibers, whereas strength and power activities require fast twitch fibers.

C. To exert force, the body recruits one or more motor units to contract.
   1. A motor unit is made up of a nerve connected to a number of muscle fibers.
   2. When a motor nerve calls on its fibers to contract, all fibers contract to their full capacity.
   3. The number of motor units is dependent upon the amount of strength required.

D. Strength training improves the body’s ability to recruit motor units—muscle learning—which increases strength even before muscle size increases.

II. Benefits of Muscular Strength and Endurance

Enhanced muscular strength and endurance can lead to improvements in the areas of performance, injury prevention, body composition, self-image, lifetime muscle and bone health, and metabolic health.

A. Improved Performance of Physical Activities
   Increased muscular strength and endurance helps with performance of everyday tasks and recreational activities and leads to the enjoyment that accompanies higher levels of achievement.

B. Injury Prevention
   Muscular strength and endurance help protect you from injury in two key ways:
   • By enabling you to maintain good posture.
   • By encouraging proper body mechanics during daily activities such as walking or lifting.

C. Improved Body Composition
   Muscular strength and endurance exercise increases fat-free mass which raises metabolism.

D. Enhanced Self-Image and Quality of Life
   Strength training offers the benefit of readily recognizable results: Your body will become noticeably stronger and firmer, and you can easily monitor your progress in terms of amount of weight lifted and number of repetitions, leading to greater self-confidence and self-worth.

E. Improved Muscle and Bone Health with Aging
   Strength training can prevent muscle and nerve degeneration brought about by aging and inactivity.
   1. After age 30, people begin to lose muscle mass (sarcopenia) which leads to loss of strength and eventual mobility.
   2. Aging and inactivity can cause motor nerves to disconnect from the portion of muscle they control and allow muscles to become slower—less able to perform quick, powerful movements.
   3. Risk of bone loss, or osteoporosis, can be lessened with strength training, and increases in muscle strength can also help prevent falls.
F. Metabolic Health
Regular strength training helps prevent and manage both CVD and diabetes by:

- Improving glucose metabolism.
- Increasing maximal oxygen consumption.
- Reducing blood pressure.
- Increasing HDL cholesterol and reducing LDL cholesterol (in some people).
- Improving blood vessel health.

III. Assessing Muscular Strength and Endurance

A. Muscular strength is usually assessed by measuring the maximum amount of weight a person can lift one time. This single maximum effort is called a repetition maximum (RM). You can measure 1 RM directly or estimate it by doing multiple repetitions with a submaximal (lighter) weight.

B. Muscular endurance is usually assessed by counting the maximum number of repetitions a person can do (as in a push-up or sit-up test) or the maximum time a muscle contraction can be held (as in a flexed-arm hang).

IV. Creating a Successful Strength Training Program

When muscles are stressed by a greater load than they are used to, they adapt and improve their function. The type of adaptation depends on the type of stress applied.

A. Static Versus Dynamic Strength Training Exercises

Weight training exercises are generally classified as static or dynamic.

1. Static Exercise (Isometric)
   In this exercise, the length of the muscle does not change nor does the angle in the joint on which the muscle acts (e.g., pushing against a wall).
   a. These exercises can be performed with an immobile object (such as a wall) for resistance or simply by tightening a muscle. The contraction should be held for six seconds, and 5-10 repetitions should be done.
   b. They develop strength only at a specific point in the joint range of motion.

2. Dynamic Exercise (Isotonic)
   In this exercise, the length of the muscle changes (e.g., with weight machines or free weights). Dynamic exercise involves applying force with movement, using either weights or a person’s own body weight (as in push-ups).
   a. There are two types of dynamic muscle contractions:
      (1) A concentric contraction occurs when the muscle applies enough force to overcome resistance and shortens as it contracts.
      (2) An eccentric contraction (plyometric contraction) occurs when the resistance is greater than the force applied by the muscle and the muscle lengthens as it contracts.
   b. The two most common dynamic exercise techniques are constant resistance exercise, which uses a constant load (weight) throughout a joint’s entire range of motion, and variable resistance exercise, in which the load is changed to provide maximum load throughout the range of motion.
c. A problem with constant resistance exercise with free weights is that, because of differences in leverage, some points in a joint’s range of motion are weaker than others. Variable resistance exercise uses machines that place more stress on muscles at the end of the range of motion, where a person has better leverage and can exert more force.

d. Other kinds of isotonic \( (\text{dynamic exercise}) \) techniques include:

1. Eccentric \( (\text{pliometric}) \) loading, placing a load on a muscle as it lengthens.
2. Plyometrics, the sudden eccentric loading and stretching of muscles followed by a forceful concentric contraction. This type of exercise is used to develop explosive strength; it also helps build and maintain bone density.
3. Speed loading involves moving a weight as rapidly as possible in an attempt to approach the speeds used in movements like throwing a softball or sprinting.
4. Kettlebell training is a type of speed loading. It is highly ballistic and involves fast, pendulum-type motions, extreme decelerations, and high-speed eccentric muscle contractions.
5. Isokinetic exercise, exerting force at a constant speed against an equal force exerted by a special strength training machine.

3. Comparison Static and Dynamic Exercise

a. Static exercises require no equipment, build strength rapidly, and are useful for rehabilitating joints. However, they have a short, specific range of motion, and so they have to be performed at several different angles for each joint.

b. Dynamic exercises can be performed with or without equipment. They are excellent at building endurance and strength throughout a joint’s range of motion.

c. The type of exercise will be dependent upon individual goals, preferences, and access to equipment.

B. Weight Machines versus Free Weights

1. Muscles will get stronger if you make them work against a resistance.

2. Weight machines are preferred by some, because they are safe, convenient, and easy to use. They make it easy to isolate and work a specific muscle, and a spotter isn’t always necessary.

3. Free weights require more care, balance, and coordination, but they strengthen the body in ways that are more adaptable to real life and sports.

C. Other Training Methods and Types of Equipment

This includes resistance bands, exercise (stability) balls, Pilates, medicine balls, suspension training, stones or carrying exercises, and no-equipment calisthenics.

V. Applying the FITT Principle: Selecting Exercises and Putting Together a Program

A complete program uses the FITT Principle to maximize fitness benefits and obtain a full body workout by performing 8-10 different exercises of all major muscle groups.

A. Frequency of Exercise
1. For general fitness, the ACSM recommends 2–3 nonconsecutive days per week for weight training.

2. Allow muscles at least one day of rest between workouts.

B. Intensity of Exercise: Amount of Resistance

1. The amount of weight lifted determines the way the body will adapt and how quickly it will adapt.

2. To build strength rapidly, lift weights as heavy as 80% of your maximum capacity (1 RM). For endurance, choose 40–60% of your maximum 1 RM to perform more reps.

3. Assess maximum capacity by applying a base weight on the number of repetitions you can perform with a given resistance for time purposes.

C. Time of Exercise: Repetitions and Sets

1. To improve fitness, you must perform enough repetitions to fatigue your muscles.
   a. A heavy weight and a low number of repetitions (1–5) builds strength.
   b. A light weight and a high number of repetitions (15–20) builds endurance.
   c. For general fitness, do 8–12 repetitions of each exercise. For older and more frail people (50–60 years of age and above), 10–15 repetitions with a lighter weight is appropriate.

2. A set is a group of repetitions of an exercise followed by a rest period.
   a. For general fitness, one set is sufficient if muscular fatigue is present. Most serious weight trainers perform three or more sets of each exercise.
   b. The length of your rest interval depends on the amount of resistance: If you are training to develop strength and endurance for wellness, rest 1–3 minutes between sets. If you are training to develop maximum strength (and are lifting heavier loads), rest 3–5 minutes between sets. Possible signs of overtraining include a lack of progress, chronic fatigue, decreased coordination, and chronic muscle soreness. The best remedy is to rest by adding more days between workouts.

D. Type or Mode of Exercise

1. A complete weight training program works all the major muscle groups including neck, upper back, shoulders, arms, chest, abdomen, lower back, thighs, buttocks, and calves.

2. Usually, 8–10 different exercises are required in order to work all major muscle groups.

3. A balanced program includes exercises for both agonist and antagonist muscle groups.

4. Exercise the large-muscle groups first and then the small-muscle groups.

E. The Warm-Up and Cool-Down

1. You should do both a general warm-up (such as walking) and a specific warm-up for the exercises. You will perform ten reps with lighter weights.
2. For cool-down, relax for 5–10 minutes after exercising. Post-exercise stretching may prevent post-exercise soreness.

**F. Getting Started and Making Progress**

1. To begin training, choose a weight you can easily move through 8–12 repetitions for one set.

2. Gradually add weight and (if you want) sets until you can perform 1–3 sets of 8–12 repetitions for each exercise.

3. As you progress, add weight according to the “two-for-two” rule: When you can perform two additional repetitions with a given weight on two consecutive training sessions, increase the load.

4. You can expect to improve rapidly during the first 6–10 weeks of training; after that, gains come more slowly.

5. After you have achieved the strength and muscularity you want, you can maintain your gains by training 2–3 times per week.

**G. More Advanced Strength Training Programs**

1. If you desire to achieve greater increases in strength, increase the load and the number of sets and decrease the number of reps.

2. **Periodization** or **cycle training**, in which the sets, reps, and intensity of exercise vary, may be useful for making greater gains in strength.

**H. Weight Training safety**

1. Use proper lifting technique.
   a. Perform exercises smoothly and with control and good form through the full range of motion.
   b. Ask an instructor or weight room attendant if you have questions.

2. Use spotters and collars with free weights.
   a. Use spotters when performing a potentially dangerous exercise.
   b. Always use collars on bars to prevent weights from slipping off.

3. Be alert for injuries. Do not continue to train an injured joint or muscle.
   a. Report injuries to your instructor or physician, and use the R-I-C-E principle for treatment.
   b. Consult a physician if you have unusual symptoms during exercise.

**I. A Caution About Supplements and Drugs**

Most of these substances are ineffective, and many are dangerous. Ask yourself the following questions:

- Do you really need a supplement at all?
- Is the product safe and effective?
- Can you be sure that the product is of high quality?

Performance Aids Marketed to Weight Trainers:
1. Dehydroepiandrosterone (DHEA) and androstenedione are two relatively weak male hormones produced in the adrenal glands of both men and women. Both are broken down into testosterone. People take these drugs to stimulate muscle growth and aid in weight control. These substances have side effects similar to those of anabolic steroids.

2. Amphetamines stimulate the nervous system and mask fatigue. Amphetamines can cause severe neural and psychological effects.

3. Anabolic steroids are synthetic derivatives of testosterone. They increase protein synthesis, which enhances fat-free weight, muscle mass, and strength. Steroids are controlled substances and have many side effects including liver damage, heart disease, psychological disturbances, and increased risk of cancer.

4. Beta-agonists are a type of medication used to treat asthma. Some athletes take beta-agonists in an attempt to enhance performance.

5. Chromium picolinate has been shown to have no significant effect on fat-free mass or body fat. Its actual efficacy is unclear, and long-term effects are unknown.

6. Creatine monohydrate has been shown to increase muscle mass and performance in some types of high-intensity exercise. Although there are minimal side effects, long-term effects are unknown.

7. Diuretics promote loss of body fluid to accentuate muscle definition. It causes muscle cell destruction, low blood pressure, blood chemistry abnormalities, and heart problems.

8. Energy drinks can increase energy and strength but cause increased blood pressure and heart palpitations.

9. Ephedra has been shown to decrease appetite. It also causes abnormal heart rhythms, nervousness, headache, gastrointestinal distress and heatstroke; banned by the FDA.

10. Erythropoietin has been shown to stimulate growth of red blood cells; enhancing oxygen uptake and endurance. It increases blood viscosity (thickness), and can cause potentially fatal blood clots.

11. Ginseng has been shown to have no effect on performance. No serious side effects; high doses can cause high blood pressure, nervousness, and insomnia.

12. Green tea extract is used to decrease body fat; however, it can cause headaches, nausea, and heart palpitations.

13. Growth hormone is used to increase muscle mass and strength. It has serious side effects including heart enlargement, high insulin levels, and diseases of the nerves, bones, and joints.

14. Human chorionic gonadotropin (HCG) is used by steroid users to boost natural testosterone production. It interferes with normal testosterone regulation and is banned in most sports.

15. Beta-hydroxy beta-methyl butyrate (HMB) has been shown in some studies to increase fat-free mass and decrease fat. There are no reported side effects, however, long-term effects are unknown and more research is needed.
16. Insulin’s effectiveness in stimulating muscle growth is unknown. Insulin supplementation is an extremely dangerous practice.

17. Insulin-like growth factor (IGF-1) is produced by the pituitary gland and is a powerful anabolic agent. Actual effects in healthy, active people are unknown. Its long-term use is known to promote cancer.

18. Metabolic-optimizing meals for athletes have no proven effects beyond those of balanced meals. There are no reported side effects; extremely expensive.

19. Over the counter stimulants such as caffeine, and phenylpropanolamine (PPA) may improve endurance. There is an increased risk of heart attack and stroke in some people; increased incidence of abnormal heart rhythm and insomnia; caffeine is addictive.

20. Prescription appetite suppressants are usually prescribed for short-term use. They cause a large variety of side effects and can be habit-forming.

21. Protein, amino acids, polypeptide supplements have been shown to have no effects if dietary protein intake is adequate. Can be dangerous for people with liver or kidney disease. Substituting amino acid or polypeptide supplements for protein-rich food can cause nutrient deficiencies.

J. Weight Training Exercises

1. Labs 4.2 and 4.3 are designed to help assess current levels of muscular endurance and help design a personal weight training program.

2. If strength for a particular activity is the goal – the program should contain exercises for general fitness, exercises for the muscle groups most important for the activity, and exercises for muscle groups most often injured.