Which is most important for an athlete—muscular strength, power, or endurance?

Muscle is the only human tissue capable of shortening, or contracting. This unique ability is what makes body movements possible.

Without muscle the powerful movements required in athletic performances would be impossible, as would the finely tuned, graceful movements needed to send a text message or play a musical instrument. Muscles also control the movements of our eyes, the movement of food through our digestive systems, and the beating of our hearts.

What enables muscle to be so versatile? In this chapter we will look at the different types, properties, and structures of muscle, and examine the effects of different kinds of physical training on skeletal muscle. We will also discuss some of the common injuries and disorders of muscles, how these problems tend to occur, and how their likelihood, in some cases, can be reduced.
Lesson 5.1
Muscle Tissue Categories and Functions

Before You Read
Try to answer the following questions before you read this lesson.
Why are some muscles controlled involuntarily?
When a skeletal muscle is stimulated to contract, what three types of actions can occur?
Are muscles irritable?

Lesson Objectives
1. Discuss the structural and functional characteristics of each of the three categories of muscle.
2. Describe the four behavioral characteristics of all muscle tissue.
3. Explain the roles of agonist and antagonist muscles.

Muscle Categories
The three major categories of muscle fibers are skeletal, smooth, and cardiac. In this section we will examine the important structural and functional differences among these three types of muscle fibers.

Skeletal Muscle
The skeletal muscles attach to bones and are largely responsible for body movements. Skeletal muscle is also known as striated muscle due to the prominent cross-stripes, or striations, which can be seen when examining this tissue under a microscope (Figure 5.1A). A third name, voluntary muscle, is an appropriate name because this type of muscle is stimulated by consciously directed nerve activity.

An individual skeletal muscle cell is referred to as a muscle fiber because of its thread-like shape. Muscle fibers include many nuclei and vary considerably in length and diameter. Some fibers run the entire length of a muscle; others are much shorter.

The number of muscle fibers in a given person is genetically determined, and does not change as we age, except for occasional loss of fibers resulting from injury. Although fiber number doesn’t change, the skeletal muscle fibers grow in length and diameter from birth to adulthood. Adults can increase their fiber diameter, and strength, by resistance training with just a few repetitions of heavy loads on a regular basis over a period of time.

As Figure 5.2 shows, skeletal muscle is highly organized. The cell membrane of the muscle fiber is called the sarcolemma (SAR-koh-LEHM-a). Over the sarcolemma of each muscle fiber is a fine, protective sheath of connective tissue called the endomysium (EHN-doh-MIZ-ee-um). Groups of muscle fibers are bundled together by a strong fibrous membrane called a perimysium (PER-i-MIZ-ee-um) into a unit known as a fascicle (FAS-i-kuhl).

All of the fascicles in a muscle are enclosed by a thick, tough connective tissue called an epimysium (EHP-i-MIZ-ee-um). The epimysium connects at both ends of the muscle with either a cordlike tendon composed of extremely strong connective tissue or with a flat, sheetlike aponeurosis (AP-oh-noo-ROH-sis).

Tendons differ from ligaments in that ligaments connect bone to bone.

Smooth Muscle
In contrast to skeletal muscle fibers, smooth muscle cells are small, spindle-shaped, and nonstriated. They are involuntary (not under conscious control), and they have a single nucleus (Figure 5.1B). Also known as visceral muscle, this type of muscle is found in the walls of many internal organs such as the stomach, intestines, urinary bladder, and respiratory passages.

Smooth muscle cells are arranged in layers, with one layer running lengthwise and the other...
surrounding the organ in which the muscles are contained. The coordinated, alternate contracting and relaxing of these layers changes the size and shape of the organ ... is called peristalsis, which you will learn more about in chapter 13.

Cardiac Muscle

As the name suggests, cardiac muscle is located solely in the walls of the heart. Cardiac muscle cells are branched, cross-striated, and involuntary—under the control of the autonomic nervous system (Figure 5.1C). Cardiac cells are arranged in an interconnected network of figure-eight or spiral-shaped bundles that join together at structures called intercalated (in-TER-kah-lay-tehd) discs. This arrangement enables simultaneous contraction of neighboring cells to produce the heartbeat.

The table in Figure 5.3 summarizes the major features of the three categories of muscle tissue. Although all three types are important and, in fact, essential for human life, we will focus primarily on the skeletal muscles in this chapter.

Muscle Functions

Despite the different properties of the three types of muscle, certain behavioral characteristics are common to all muscle tissue. In the case of skeletal muscles, there are also certain functional roles that muscles can play in contributing to different movements of the body.

Behavioral Properties

All muscle tissues have four behavioral characteristics in common: irritability, extensibility, elasticity, and contractility. Two of these—extensibility, the ability to be stretched, and elasticity, the ability to return to normal length after a stretch—are common not just to muscle, but to many types of biological tissues. For example, when a muscle group such as the hamstrings (on the posterior side of the thigh) is stretched over a period of time, the muscles lengthen, and the range of motion at the hip increases, making it easier to touch the toes. The stretched muscles do not return to resting length immediately, but shorten over a period of time.

Tension and Types of Skeletal Muscle Contraction

Although we commonly use the term contraction (which implies shortening) to mean that tension has developed in a muscle, muscles do not always shorten when they develop tension. When a skeletal muscle develops tension, one of three actions can happen: the muscle can shorten, remain the same length, or actually lengthen. Let’s look at the familiar large muscle groups, the biceps and triceps, on the anterior and posterior sides of your upper arm, to see examples of these three different types of tension.

Check Your Understanding

1. What is the difference between voluntary and involuntary muscles?
2. Categorize each muscle type as voluntary or involuntary.
3. What are the three layers of tissue that run the length of a skeletal muscle?
6. Compare and contrast the three types of contractions during a typical day.

5. Give three examples of how you use isometric contractions.

4. What is the difference between extensibility and contractility?

3. Explain the difference between irritability and elasticity?

2. Describe the role of each type of muscle tissue surrounding each striated muscle fiber.

1. Explain contractility and how it creates movement.

Check Your Understanding
1. Explain contractility and how it creates movement.
2. When you are in the process of moving from a standing to a sitting position, what type of contraction are your quadriceps (page 180) muscles experiencing?
3. What chemical substance in the body provides energy for muscles?

Lesson 5.1 Review and Assessment

Mini Glossary
- agonist: role played by a skeletal muscle to cause a movement
- antagonist: role played by a skeletal muscle acting to slow or stop a movement
- aponeurosis: a flat sheetlike fibrous tissue that connects muscle or bone to other tissues
- eccentric: a type of contraction that results in shortening of a muscle
- isometric: a type of contraction that involves no change in muscle length
- extensibility: the ability to be stretched
- irritability: the ability to respond to a stimulus
- fascicule: a bundle of muscle fibers

Know and Understand
1. Starting with a muscle fiber and working from the inside out, name each part of the skeletal muscle structure.
2. Describe the role of each type of muscle tissue (cardiac, smooth, and skeletal).
3. Explain the difference between irritability and contractility.
4. What is the difference between extensibility and elasticity?

Analyze and Apply
5. Give three examples of how you use isometric contractions during a typical day.
6. Compare and contrast the three types of muscles.

But even when we are not exercising, the muscles, typically comprising at least 40% of body mass, generate heat, and this heat helps maintain normal body temperature.

How does this happen? Muscles require energy in the form of adenosine triphosphate (ATP) to function. You may recall from your study of chapter 2 that ATP is generated within muscle cells. The ATP is then released to provide energy when the muscle is stimulated, generating heat in the process.

When the biceps muscle develops tension and shortens, your hand moves up toward your shoulder (Figure 5.4A). This is called a concentric (kon-SEHN-trik) contraction, or shortening, contraction of the biceps.

In the example just described, the biceps is performing the role of agonist (AG-un-ist), or prime mover, and the opposing muscle group, the triceps, is playing the role of antagonist (an-TAG-un-ist). The antagonist muscles may be completely relaxed or may develop a slight amount of tension, depending on the requirements of the movement.

You might wonder if a muscle can lengthen while developing tension, and if so, how it can lengthen. Suppose someone were to place in your hands a very heavy weight that was too heavy for you to hold in position. At first, your biceps would develop tension in an effort to hold the weight in place. But if the weight were too heavy to manage, causing you to lower the weight, your biceps would lengthen. This type of action is known as an eccentric (ehk-SEHN-trik) contraction (Figure 5.4B). In this case the force of gravity (not the triceps) acting on the weight causes the weight to lower.

In a third scenario (Figure 5.4C) you “flex” the muscles in your arm, developing tension in both the biceps and triceps, but there is no movement. This is called an isometric (IGH-soh-MEH-rik) contraction of both the biceps and triceps. With an isometric contraction no change in muscle length occurs.

It is the versatility of the arrangements of human muscles in agonist and antagonist pairs around joints that enables the different movements of the human body. These versatile arrangements also help to stabilize joints and maintain body posture.

The Production of Heat

We all know that vigorous exercise is typically accompanied by an increase in body temperature and sweating. Do you know why this happens? It happens because the working muscles generate heat.
Lesson 5.2

Skeletal Muscle Actions

Before You Read

Try to answer the following questions before you read this lesson.

1. Do sprinters and distance runners have different types of skeletal muscle fibers?
2. What factors influence how rapidly a muscle fatigues?

Lesson Objectives

1. Describe a motor unit and explain the functional differences between motor units that contain large and small numbers of muscle fibers.
2. Explain how a nerve impulse generates an action potential in a muscle fiber.
3. Explain how muscle contraction occurs at the level of the sarcomere.
4. Describe the differences between slow-twitch and fast-twitch skeletal muscle fibers.
5. Discuss the concepts of muscular strength, power, and endurance.

Key Terms

- acetylcholine
- action potential
- all-or-none law
- axon
- axon terminals
- cross bridges
- fast-twitch
- motor neuron
- motor unit
- neuromuscular junction
- parallel
- pennate
- sarcomere
- slow-twitch
- synaptic cleft
- tetanus

The development of tension in a skeletal muscle is influenced by a number of variables. Among these variables are signals from the nervous system, the properties of the muscle fibers, and the arrangement of fibers within the muscle. This lesson describes the effects of these influences. You will also learn in this lesson how muscle actions contribute to muscular strength, power, and endurance.

The Motor Unit

Muscle tissue is not able to develop tension unless stimulated by one or more nerves. Because of the dependent relationship of the muscular system on the nervous system, the two are often referred to collectively as the neuromuscular system.

A nerve that stimulates skeletal muscle, which is under voluntary control, is known as a motor neuron. A single motor neuron and all of the muscle cells that it stimulates is known as a motor unit (Figure 5.5). The motor unit is considered to be the functional unit of the neuromuscular system.

One motor neuron supplying impulses to a muscle may connect to anywhere between 100 to nearly 2,000 skeletal muscle fibers, depending on the size and function of the muscle. The small muscles responsible for finely tuned movements, such as those in the eyes and fingers, have small motor units with very few fibers per motor unit. Large, powerful muscles, such as those surrounding the hips, have large motor units with many fibers. Motor units are typically contained within a portion of a muscle, but may also be dispersed with the muscle cells of other motor units.

Generating Action Potentials

How does the motor neuron communicate with the muscle cells in the motor unit to stimulate them? As Figure 5.5 shows, a long, thin fiber called an axon connects the motor neuron cell body with the muscle fibers included in the motor unit. Close to the fibers, the axon branches into axon terminals which in turn branch out to individual muscle fibers. The link between each axon terminal and muscle fiber is called the neuromuscular junction. The axon terminal and fiber are separated by a tiny gap known as the synaptic cleft, which is filled with interstitial fluid (Figure 5.6 on the next page).

When a nerve impulse reaches the end of an axon terminal, a chemical called a neurotransmitter is released and diffuses across the synaptic cleft to attach receptors on the muscle fiber sarcolemma. The neurotransmitter that stimulates muscle is called acetylcholine (a-SEE-till-KOH-leen).

The effect of acetylcholine is to make the sarcolemma temporarily permeable. Channels open that allow positive sodium ions (Na+) to rapidly invade the fiber at the same time that positive potassium ions (K+) rush out of the fiber. Because more Na+ enters than K+ exits, the net effect is the creation of a positive charge inside the muscle fiber. This reversal of electrical charge is known as depolarization. Depolarization triggers the opening of additional channels in the fiber membrane that allow entry of additional Na+. This flood of positive ions into the fiber generates an electrical charge called an action potential.

Contractions of the Sarcomeres

Glucose stored in the form of glycogen within the muscle cell provides the energy for creating the action potential. Phosphocreatine within the cell enables the transfer of energy to the protein filaments actin and myosin. Actin and myosin are contractile proteins that reside in functional units called sarcomeres (SAR-koh-mairz) inside the muscle fiber. The release of calcium ions (Ca++) triggers the sliding of
the actin filaments over the myosin filaments, resulting in a contraction of the sarcomere (Figure 5.7). What causes the actin filaments to slide over the myosin filaments? Notice in Figure 5.7 that the myosin filaments are encircled by small protrusions called heads. When the sarcomere is activated by an action potential, these heads attach to receptor sites on the actin filaments, forming cross bridges. The cross bridges contract, pulling the actin filaments toward the center of the sarcomere. During the process of sarcomere contraction, these cross bridges attach, pull, and release multiple times. The Ca++ ions released with the arrival of the action potential enable the attachments of the myosin heads to the actin filaments.

The neuromuscular system has the ability to produce slow, gentle movements as well as fast, forceful movements. This ability to produce different kinds of movements and force variance is accomplished by regulating the number and frequency of action potentials. Only a small number of action potentials are needed for slow, gentle movements, while fast or forceful movements require a large number of action potentials, released rapidly.

Maximum Tension and Return to Relaxation

When receiving an action potential, a given motor unit always develops maximum tension, a physiological principle known as the all-or-none law. But because each whole muscle includes multiple motor units, simultaneous activation of many motor units is required for the muscle to develop maximum tension. The diagram in Figure 5.8 displays the relationship between number and frequency of action potentials and the development of tension in the muscle. With high-frequency stimulation, the muscle develops a sustained, maximal level of tension called tetanus.

Almost all skeletal motor units develop tension in a twitch-like fashion, generating maximum tension very briefly and then immediately relaxing. After the action potential has traveled the length of the muscle fiber, chemical processes return the fiber to its resting state. Sodium ions diffuse back out of the cell into the interstitial fluid, and calcium ions return to storage sites within the cell. The actin filaments slide back to their original positions as the cross bridges release them, and the muscle fiber returns to a state of relaxation.

Skeletal Fiber Types

Why are some athletes especially good at events or tasks that require endurance, whereas others excel at activities that require explosive strength or speed? The answer may have something to do with the ways in which these individuals train, but that is only a small part of the explanation. In fact, a big part of why certain people are better at particular activities and sports may relate to the characteristics of their skeletal muscle fibers.

Skeletal muscle fibers may be divided into two umbrella categories—slow-twitch (Type I) and fast-twitch (Type II). As the names suggest,
the fast-twitch fibers contract much faster than slow-twitch fibers. Because sufficient variation exists among the fast-twitch fibers, they too have been divided into two categories—Type Ila and Type Iib. The Type Ila fibers are intermediate in contraction speed between the slow-twitch fibers and the classic fast-twitch fibers, which are Type Iib. The Type Iib fibers contract very rapidly, in about one-seventh the time required for slow-twitch fibers to contract. As a result, the Type Iib fibers also fatigue rapidly. Although all of the muscle fibers in a motor unit are of the same type, most skeletal muscles include motor units of both fast-twitch and slow-twitch fibers. The fast-twitch/slow-twitch ratio varies from muscle to muscle and from person to person.

**Fiber Architecture**

Another factor that affects the ways in which skeletal muscles function is fiber architecture. Fiber architecture refers to the ways in which fibers are arranged within the muscle. The two major categories of muscle fiber arrangement are **parallel** and **pennate**.

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**WHAT RESEARCH TELLS US**

*about Fast- and Slow-Twitch Muscles*

Researchers have taken muscle biopsies (small, needle-sized plugs of muscle tissue) from elite athletes in a variety of sports. They have found that individuals specializing in events that require explosive strength or speed have unusually high proportions of fast-twitch (FT) fibers, and that elite endurance athletes tend to have very high proportions of slow-twitch (ST) fibers.

It may be the case that many of those who are able to achieve athletic success at the highest levels are simply born with high percentages of either FT or ST fibers. Once these individuals have experienced success in a particular sport or event, it is likely that they gravitate toward that sport or event (Figure 5.9).

Of course, certain individuals within the general population of untrained people also have high percentages of FT or ST muscles. The distribution of FT/ST ratios among the general population is represented in the normal, bell-shaped curve (Figure 5.10). We also know from research that FT-fiber types can change over time. FT fibers can be converted to ST fibers with years of endurance training. No evidence exists, however, that any form of training can convert ST fibers to FT fibers. We do know that a progressive loss of FT motor units and fibers occurs as we age, although this loss can be minimized by regular, high-intensity exercise throughout life.

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**Parallel Fiber Architecture**

With parallel fiber architecture, the fibers run largely parallel to each other along the length of the muscle. As Figure 5.11 shows, these parallel fiber arrangements may result in muscle shapes that are fusiform (wide in the middle and tapering on both ends), bundled, or triangular. Examples of muscles with this type of architecture are the biceps brachii (fusiform), rectus abdominis (bundled), and pectoralis major (triangular).

- **Fibers that attach to a central tendon are unipennate**;
- **fibers that attach to a central tendon are bipennate**; and
- **fibers that attach to a central tendon in more than two directions are referred to as multipennate**.

The individual fibers in the parallel architecture typically do not run the entire length of the muscle. Instead, the individual parallel fibers have interconnections with neighboring fibers. These interconnections promote contraction when the muscle is stimulated. This fiber arrangement enables shortening of the muscle and the ability to move body segments through large ranges of motion.

**Check Your Understanding**

1. What is the difference between fast-twitch and slow-twitch fibers?
2. Which fiber type helps a sprinter get out of the blocks fast?
3. Why can pennate-arranged fibers generate more force than parallel-arranged fibers?

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**Pennate Fiber Architecture**

In a pennate fiber arrangement, each fiber attaches obliquely to a central tendon, and sometimes attaches to more than one tendon. As Figure 5.11 shows, pennate fiber arrangements are characterized by having fibers that are:

- **unipennate** if fibers are arranged within the muscle. The two major categories of muscle fiber arrangement are parallel and pennate.
Muscular Strength

It may be tempting to think that muscular strength is the amount of force a given muscle can produce. It is impossible, however, to measure muscle force directly without penetrating the body. So to avoid invasive procedures, we use external measures (such as the amount of resistance a person can move) to establish an indirect measure of muscle strength.

Remember that most joints in the human body are crossed by more than just one muscle. Additionally, many exercises involve more than one joint. This means that an index-of-strength measure such as maximum bench press actually assesses the collective work of several muscles that cross the shoulder and elbow (Figure 5.12). The main muscles that work during execution of a bench press include the pectoralis major, pectoralis minor, anterior deltoid, and triceps brachii.

A more precise assessment of the strength of a muscle group at a given joint is the amount of torque (TORK), or rotary force, that the muscles can generate. Torque is the product of the size of a force and the perpendicular distance of that force from an axis of rotation. For the joint shown in Figure 5.13, the torque produced by a muscle is the product of muscle force and the perpendicular distance from the muscle attachment to the center of rotation at the joint.

The more torque a muscle generates at a joint, the greater the tendency for movement of the bones at the joint. Machines called dynamometers measure joint torques. Measures of joint torque, which we use as a measure of strength, are based solely on the resistance moved or matched. The speed with which a resistance is moved is not relevant to the strength measurement.

Muscular Power

The variable that does involve speed is muscular power. Mechanical power is defined as force multiplied by velocity (force \( \times \) velocity). Muscular power, then, has been defined specifically as muscle force multiplied by muscle-shortening velocity during contraction. Notice, however, that neither muscle force nor shortening velocity can be measured from outside the body. Research dynamometers have the ability to generate estimates of muscular power based on the resistance moved and movement speed.

Like muscular strength, muscular power is typically generated by several different muscles working collectively. Sprinting, along with the jumping and throwing events in track and field, are good examples of activities that require muscular power. Because force production and movement speed contribute equally to muscular power, the sprinter with the greatest leg strength may not necessarily be the fastest.

Muscular Endurance

Muscular endurance is the ability of a muscle to produce tension over a period of time. The tension may be constant (for example, when a gymnast holds a motionless handstand), or it may vary cyclically (for example, during running, cycling, or rowing). Generally, the longer the physical activity is maintained, the greater the required muscular endurance. Because the force and speed requirements of different movements can vary significantly, the
6. What would happen if you had no Na+ in your endurance? Explain your reasoning.

4. Describe parallel and pennate fiber patterns.

3. Discuss the differences between a large and slow-twitch muscle fibers?

2. Describe the parts of a motor unit.

1. Explain the role of acetylcholine in muscle contractions.

Know and Understand

1. Explain the role of acetylcholine in muscle contractions.
2. Describe the parts of a motor unit.
3. Discuss the differences between a large and small motor unit and their functions.
4. Describe parallel and pennate fiber patterns.

Analyze and Apply

5. Which fiber types do you think contribute to each of the following: muscular strength, power, and endurance? Explain your reasoning.

6. What would happen if you had no Na+ in your body? No Ca2+?

Check Your Understanding

1. What is measured to determine muscular strength?
2. What is measured to determine muscular power?
3. Is the strongest athlete the fastest? Why or why not?
4. What is muscular endurance?
5. What influences muscular endurance?

Build vocabulary with e-flash cards and games

_mini_glossary_

- acetylcholine: a neurotransmitter chemical that stimulates muscle action potential, the electric charge produced in nerve or muscle fiber by stimulation.
- all-or-none law: the rule stating that fibers in a given motor unit always develop maximum tension when stimulated.
- axon: a long, thin fiber connected to the motor neuron cell body.
- axon terminals: offshoots of the axon that branch out to connect with individual muscle fibers.
- cross bridges: connections between the heads of myosin filaments and receptor sites on the actin filaments.
- fast-twitch: type of muscle that contracts quickly.
- motor neuron: a nerve that stimulates skeletal muscle tissue.
- motor unit: a single motor neuron and all of the muscle fibers that it stimulates.
- neuromuscular junction: the link between an axon terminal and a muscle fiber.
- parallel: a type of muscle fiber arrangement in which fibers run largely parallel to each other along the length of the muscle.
- pennate: a type of muscle fiber arrangement in which each fiber attaches obliquely to a central tendon.
- sarcomeres: units composed of actin and myosin that contract inside the muscle fiber.
- slow-twitch: type of muscle that contracts slowly and is fatigue resistant.
- synaptic cleft: the tiny gap that separates the axon terminal and muscle fiber.
- tetanus: a sustained, maximal level of muscle tension that occurs with high-frequency stimulation.

Directional Motions

To understand the functional movement of muscles, you need to learn a new concept about muscle attachments. It will also be helpful to review some directional terms that you learned in chapter 1.

Skeletal muscles attach at either end of the muscle; the most common attachments are tendon connections to bone. The end of a muscle that attaches to a relatively fixed structure is called the origin. The end of a muscle that attaches to a bone that typically moves when the muscle contracts is called the insertion.

For an example of origin and insertion, let’s look at the brachialis muscle, which crosses the anterior side of the elbow. Its origin is on the humerus, and its insertion is on the ulna in the forearm. When the brachialis contract, the forearm (ulna) is pulled toward the upper arm, while the upper arm (humerus) remains stationary.

Remember—when stimulated to develop tension, muscles can only pull. They are incapable of pushing.

In addition, remember from chapter 1 that to describe the human body and its movements, we refer to three major planes that pass through the center of the body:

- The sagittal plane is in line with forward and backward motions;
- The frontal plane is in line with sideways movement; and
• Rotational movements occur in the transverse plane.
  
  As we learned in chapter 1, the frame of reference for all movement is the anatomical position. In this position the human body is erect with the hands at the sides and the palms facing forward.

**Sagittal Plane Movements**

The primary sagittal plane (forward/backward) movements are flexion (FLEHK-shun), extension, and hyperextension (Figure 5.14). Flexion describes forward-bending motion of the head, trunk, upper arm, forearm, hand, and hip; and backward motion of the lower leg at the knee. In flexion movements, body surfaces are coming together. Extension returns body segments from a position of flexion to anatomical position. Hyperextension continues the extension motion past anatomical position. Two movements of the foot also occur primarily in the sagittal (SAJ-i-tal) plane. Bringing the top of the foot toward the lower leg is called dorsiflexion (DOR-si-FLEHK-shun), and moving the foot in the opposite direction away from the lower leg is called plantar flexion (Figure 5.14).

**Memory Tip**

Placing the ball of the foot is the motion involved in plantar flexion.

**Frontal Plane Movements**

Common movements in the frontal plane include abduction and adduction (Figure 5.14). Movements at the shoulder and hip that take the arm and leg away from the midline of the body are called abduction. Oppositely directed movements that bring the arm and leg closer to the midline of the body are called adduction.

**Memory Tip**

Just as abduct means “to take away,” abduction takes a body segment away from the body. Just as add means “to bring back,” adduction returns a body segment closer to the body.

 Movements of the foot that occur mainly in the frontal plane are inversion and eversion. Rolling the sole of the foot inward is inversion, while rolling the sole of the foot outward is eversion (Figure 5.14).

Frontal plane movements of the hand at the wrist are called radial deviation and ulnar deviation. Recall from chapter 4 that the forearm has two bones—the radius and the ulna. The radius is on the thumb side of the hand, and the ulna is on the “little finger” side of the arm. From anatomical position, with the palms facing forward, abduction of the hand toward the thumb is called radial deviation, and adduction of the hand toward the little finger is called ulnar deviation (Figure 5.14).

Trunk and neck motions away from anatomical position in the frontal plane are called lateral flexion and side bending. Return from a position of lateral flexion to anatomical position is called lateral extension.

**Transverse Plane Movements**

Transverse plane movements mostly involve rotation around the long axis of a body segment. When the head or trunk rotate from side to side, the movement is simply called left or right rotation. Rotation of an arm or a leg in the transverse plane is called medial rotation if the rotation is directed medially, or inward, and lateral rotation if the movement is directed laterally, or outward (Figure 5.14). The special terms used for rotation of the forearm are pronation for medial (palm down) rotation and supination (SOO-pee-NAY-shun) for lateral (palm up) rotation (Figure 5.14).
Multiplanar Movements

A few movements of body segments do not fall within a single plane. If you have ever purchased running shoes, you may have heard the terms *pronation* and *supination* used to describe motions of the foot occurring specifically at the subtalar joint (where the heel and ankle bones meet). Pronation at the subtalar joint is a combination of eversion, abduction, and dorsiflexion. Supination at this joint includes inversion, adduction, and plantar flexion. Moving a finger, arm, or leg in a rotational manner such that the end of the segment traces a circle is called *circumduction* (SER-kum-DUK-shun), which you can see in Figure 5.14. And, finally, touching any of your four fingers to the thumb is known as *opposition*. Having an opposable thumb gives us the all-important ability to grasp objects.

Check Your Understanding

1. In what direction are movements guided on the sagittal plane?
2. What special movements occur on the frontal plane at the hand? the foot?
3. What is the difference between pronation and supination of the hand and the foot?
4. Describe circumduction.
5. Define medial and lateral rotation.

Head and Neck Muscles

The muscles of the head and neck can be divided into three groups: facial muscles, chewing muscles, and neck muscles. The difference between facial muscles and most other muscles is that facial muscle insertions connect them to other muscles or skin. When these muscles contract, pulling on the skin, they produce an array of facial expressions.

With the exception of the orbicularis oris, which encircles the mouth, and the sheetlike platysma on the front and sides of the neck, all of the other head and neck muscles are paired—one on the right and one on the left. The head and neck muscles are displayed in Figure 5.15, and their locations and functions are summarized in Figure 5.16.

Trunk Muscles

The trunk muscles provide stability for the vertebral column. They are also responsible for maintaining upright posture. American football players train to strengthen the neck and trunk muscles in an effort to maximize spinal stability and minimize risk of injury to the delicate spinal cord and internal organs (Figure 5.17). Conversely, female gymnasts train to enhance the flexibility of the spine and are capable of extraordinary spinal hyperextension, especially during balance-beam and floor-exercise routines. Collectively, the trunk muscles enable flexion, extension, hyperextension, lateral flexion, and rotation of the head and trunk. From a functional perspective, the anterior abdominal muscles also assist with urination, defecation, forced expiration during breathing, and childbirth. The all-important diaphragm muscle regulates breathing. The trunk muscles also

![Figure 5.16 Muscles of the Head and Neck](image)

**Figure 5.16** Muscles of the Head and Neck

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Location</th>
<th>Primary Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Facial Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frontalis</td>
<td>forehead; connects cranium to skin above eyebrows</td>
<td>raises eyebrows, wrinkles forehead</td>
</tr>
<tr>
<td>Orbicularis oculi</td>
<td>encircles the eyes</td>
<td>closes eyes, enables squinting</td>
</tr>
<tr>
<td>Nasalis</td>
<td>nose</td>
<td>modifies size of nostrils</td>
</tr>
<tr>
<td>Orbicularis oris</td>
<td>encircles mouth</td>
<td>closes lips, produces kissing motion</td>
</tr>
<tr>
<td>Zygomaticus</td>
<td>connects cheekbones to corners of mouth</td>
<td>the “smiling” muscle</td>
</tr>
<tr>
<td>Platysma</td>
<td>front and sides of neck</td>
<td>pulls corners of mouth down, opens mouth wide</td>
</tr>
<tr>
<td><strong>Chewing Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Masseter</td>
<td>connects zygomatic bone to mandible</td>
<td>closes the jaw</td>
</tr>
<tr>
<td>Temporalis</td>
<td>fan-shaped muscle over temporal bone</td>
<td>assists masseter with closing jaw</td>
</tr>
<tr>
<td><strong>Neck Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sternocleidomastoid</td>
<td>sides of neck</td>
<td>flexion of head, rotation of head toward opposite side of contraction</td>
</tr>
</tbody>
</table>
serve as a protective sheath for the organs of the thoracic and abdominal cavities. The locations and primary functions of the major muscles of the anterior and posterior trunk are summarized in the table in Figure 5.18. These muscles are shown in Figure 5.19.

### Upper Limb Muscles

Because the shoulder is a ball-and-socket joint and the most freely movable joint in the human body, the movement capabilities of the upper limb are impressive. This large range of motion is achieved because the bone structure of the glenohumeral (GLEH-noh-HYOO-mer-al) joint provides little to no stability, rendering it susceptible to dislocation. Therefore, it is up to the large, powerful muscles surrounding the shoulder to maintain the stability and integrity of the joint.

The arm muscles enable strong, controlled movements in sports such as gymnastics, rowing, and archery, as well as fast, powerful movements in weightlifting, boxing, and throwing. The dexterity of the finger muscles enables precise movements, such as typing, texting, knitting, and playing musical instruments.

The joints of the upper limb include those of the shoulder, elbow, wrist, and fingers. In this lesson we include information about the major muscles that cross the shoulder and elbow joints. Because there are nine muscles that cross the wrist and ten muscles within the hand (some

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**Figure 5.18 Muscles of the Trunk**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Location</th>
<th>Primary Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Anterior Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pectoralis major</td>
<td>upper chest; connects sternum, shoulder girdle, and upper ribs to proximal humerus</td>
<td>adduction and flexion of arm</td>
</tr>
<tr>
<td>Rectus abdominis</td>
<td>center front of abdomen; connects ribs to pubic crest</td>
<td>flexion and lateral flexion of trunk</td>
</tr>
<tr>
<td>External oblique</td>
<td>front of abdomen; connects lower eight ribs to anterior iliac crest</td>
<td>flexion, lateral flexion, and rotation to opposite side of trunk</td>
</tr>
<tr>
<td>Internal oblique</td>
<td>front of abdomen beneath the external oblique; connects lower four ribs to the iliac crest</td>
<td>flexion, lateral flexion, and rotation to same side of trunk</td>
</tr>
<tr>
<td><strong>Posterior Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trapezius</td>
<td>upper back and neck; connects skull and thoracic vertebrae to clavicle and scapula</td>
<td>extension and hyperextension of head</td>
</tr>
<tr>
<td>Erector spinae</td>
<td>length of vertebral column; connects adjacent vertebrae</td>
<td>extension, lateral flexion, and rotation to opposite side of vertebral column</td>
</tr>
</tbody>
</table>

**Muscles for Breathing**

- **Diaphragm**: dome-shaped muscle separating thoracic and abdominal cavities; enlarges thoracic cavity for inhalation
- **Internal intercostals**: connect the ribs; located between them; decrease thoracic cavity during forced expiration
- **External intercostals**: connect the ribs; located between them; help enlarge thoracic cavity for inhalation

---

**Figure 5.19 Major muscles of the trunk. What are some basic functions that the muscles of the trunk assist with, in addition to movement of the trunk and the head and protection of the organs?**
of which branch out to several of the fingers) these are not discussed. Figure 5.20 lists the major muscles of the upper limb, and Figure 5.21 summarizes their locations and functions.

**Lower Limb Muscles**

While the structure of the upper limb lends itself well to activities that involve large ranges of motion, the lower limb is well designed for its primary jobs of standing and walking. Running, jumping, kicking, climbing, skipping, hopping, and dancing are just a few of the additional capabilities of the lower limb.

The lower limb includes the joints of the hip, knee, and ankle, along with numerous joints in the foot. In this lesson we include the major muscles of the hip, knee, and ankle, but we omit a number of small muscles that play assistive roles. The table in Figure 5.22 outlines the locations and primary functions of the major muscles of the lower limb. Figure 5.23 on the next page shows these muscles.

Notice in Figures 5.22 and 5.23 the two muscle groups on the anterior side and posterior side of the thigh. The anterior group, the quadriceps, includes the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius, which lies under the rectus femoris. These four muscles are often referred to as a group because they all attach to the patellar tendon.

### Table: Muscles of the Lower Limb

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Location</th>
<th>Primary Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hip Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gluteus maximus</td>
<td>external buttocks; connects pelvis to femur</td>
<td>extension and lateral rotation of leg</td>
</tr>
<tr>
<td>Gluteus medius</td>
<td>directly under maximus; connects ilium of pelvis to femur</td>
<td>abduction and medial rotation of leg</td>
</tr>
<tr>
<td>Iliopsoas</td>
<td>anterior groin; connects ilium and lower vertebrae to femur</td>
<td>flexion of leg at hip</td>
</tr>
<tr>
<td>Adductor muscles</td>
<td>anterior-medial thigh</td>
<td>adduction and medial rotation of leg</td>
</tr>
<tr>
<td><strong>Knee Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Quadriceps</td>
<td>anterior thigh; connects ilium and proximal femur to tibia</td>
<td>extension of leg at knee</td>
</tr>
<tr>
<td>Hamstrings</td>
<td>posterior thigh; connect ischium to tibia and fibula</td>
<td>flexion of leg at knee</td>
</tr>
<tr>
<td>Sartorius</td>
<td>long, straplike muscle that crosses anterior thigh obliquely; connects ilium to proximal tibia</td>
<td>assists with flexion, abduction, and lateral rotation of thigh</td>
</tr>
</tbody>
</table>

**Figure 5.22 Muscles of the Lower Limb**

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Location</th>
<th>Primary Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elbow Muscles</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biceps brachii</td>
<td>anterior arm; connects scapula to radius</td>
<td>flexion, and assists with supination of forearm</td>
</tr>
<tr>
<td>Brachialis</td>
<td>connects upper arm to forearm (humerus to ulna)</td>
<td>flexion of forearm</td>
</tr>
<tr>
<td>Brachioradialis</td>
<td>connects upper arm to forearm (humerus to radius)</td>
<td>flexion of forearm</td>
</tr>
<tr>
<td>Triceps brachii</td>
<td>posterior arm; connects scapula and humerus to ulna</td>
<td>extension of forearm</td>
</tr>
</tbody>
</table>

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The posterior group, the hamstrings, includes the biceps femoris, semimembranosus (SEHM-ee-MEHM-bray-NOH-suhs), and semitendinosus (SEHM-ee-TEHN-di-NOH-suhs). What these muscles have in common, besides their general location, is strong, stringlike tendons that can be felt on either side of the back of the knee. The name hamstrings comes from the fact that hams consist of thigh and hip muscles, and butchers use the tendons of these muscles to hang the hams for smoking.

**Check Your Understanding**

1. How do the attachments for facial muscles differ from the attachments for other muscles?
2. Which muscles help with posture?
3. What is sacrificed at the shoulder to allow greater range of motion?
4. For which two primary functions is the lower limb designed?

**Lesson 5.3 Review and Assessment**

**Mini Glossary**

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>abduction</td>
<td>movement of a body segment away from the body in the frontal plane</td>
</tr>
<tr>
<td>adduction</td>
<td>movement of a body segment closer to the body in the frontal plane</td>
</tr>
<tr>
<td>circumduction</td>
<td>rotational movement of a body segment such that the end of the segment traces a circle</td>
</tr>
<tr>
<td>dorsiflexion</td>
<td>movement of the top of the foot toward the lower leg</td>
</tr>
<tr>
<td>eversion</td>
<td>movement in which the sole of the foot is rolled outward</td>
</tr>
<tr>
<td>extension</td>
<td>movement that returns a body segment to anatomical position in the sagittal plane</td>
</tr>
<tr>
<td>flexion</td>
<td>forward movement of a body segment away from anatomical position in the sagittal plane</td>
</tr>
<tr>
<td>hyperextension</td>
<td>backward movement of a body segment past anatomical position in the sagittal plane</td>
</tr>
<tr>
<td>insertion</td>
<td>muscle attachment to a bone that tends to move when the muscle contracts</td>
</tr>
<tr>
<td>inversion</td>
<td>movement in which the sole of the foot is rolled inward</td>
</tr>
<tr>
<td>lateral rotation</td>
<td>outward (lateral) movement of a body segment in the transverse plane</td>
</tr>
<tr>
<td>medial rotation</td>
<td>inward (medial) movement of a body segment in the transverse plane</td>
</tr>
<tr>
<td>opposition</td>
<td>touching any of your four fingers to your thumb; this movement enables grasping of objects</td>
</tr>
<tr>
<td>origin</td>
<td>muscle attachment to a relatively fixed structure</td>
</tr>
<tr>
<td>planar flexion</td>
<td>downward motion of the foot away from the lower leg</td>
</tr>
<tr>
<td>pronation</td>
<td>medial rotation of the forearm (palm down)</td>
</tr>
<tr>
<td>radial deviation</td>
<td>rotation of the hand toward the thumb</td>
</tr>
<tr>
<td>supination</td>
<td>lateral rotation of the forearm (palm up)</td>
</tr>
<tr>
<td>ulnar deviation</td>
<td>rotation of the hand toward the little finger</td>
</tr>
</tbody>
</table>

**Know and Understand**

1. What are the directions of movement for the sagittal, frontal, and transverse planes?
2. Describe hyperextension.
3. Describe the difference between abduction and adduction.
4. Using the drawings and tables in this lesson, identify the agonist/antagonist pairs for abduction/adduction of the hip and plantar flexion/dorsiflexion of the ankle.

**Analyze and Apply**

5. What type of motor units do you think the forearm and hands have? Why?
6. Compare and contrast inversion and eversion of the foot and supination and pronation of the hand.
5.4 Common Injuries and Disorders of Muscles

Before You Read
Try to answer the following questions before you read this lesson.

What causes muscle cramps?
Which individuals are at greatest risk for developing low back pain?

Lesson Objectives
1. Explain the differences between a muscle sprain, a contusion, and a cramp.
2. Discuss the differences between tendinitis and tendinosis.
3. Explain the causes of common muscular injuries that occur during participation in different sports.
4. Describe the causes and symptoms of whiplash injuries and hernias.
5. Describe the risk factors for low back pain and explain what strategies can be used to avoid it.

Key Terms
contusion delayed-onset muscle soreness (DOMS) hernia muscle cramps muscle strain
muscular dystrophy (MD) myositis ossificans shin splints tendinitis tendinosis

Although common, most muscle injuries are relatively minor. Fortunately, the healthy human body has considerable ability to self-repair a variety of injuries, such as those to muscles. In this lesson you will learn about some of the common muscle injuries and disorders.

Strains
A muscle strain happens when a muscle is stretched beyond its usual limits. Someone who has a large degree of flexibility at a particular joint is at much lower risk of straining those muscles than someone with extremely "tight" muscles crossing that same joint.

Another factor in muscle strains is the speed with which the muscles are stretched. Many strains to the hamstrings, for example, result from participating in activities in which the individual is running, accelerating, and changing direction all at the same time. When the muscle group is overstretched, a strain results.

Strains are classified as Grade I, II, or III:
- With a Grade I (mild) strain, you would feel a tightness in the muscle the day after the injury, but nothing more.
- Grade II (moderate) strains produce pain caused by a partial tear in the muscle. Associated weakness and temporary loss of function may also occur.
- With a Grade III (severe) strain, the damage and symptoms are significantly greater than those accompanying grades I and II strains. Grade III strains involve a tearing of the muscle, loss of function, internal bleeding, and swelling.

Strains of the hamstrings are a frequent problem for athletes because these injuries are slow to heal and tend to recur. One-third of all hamstring strains will recur within the first year of returning to a sport or an activity.

Contusions
A contusion is a bruise or bleeding within a muscle, resulting from an impact. When an already injured muscle is repeatedly struck, a more serious condition, called myositis ossificans (migh-oh-SIGH-tis ah-SIF-i-kanz), can develop.

Myositis ossificans involves the formation of a calcium mass within the muscle over a period of three to four weeks. After six or seven weeks the mass usually begins to dissolve and is resorbed by the body. In some cases a bony lesion can remain in the muscle.

Cramps
Muscle cramps involve moderate to severe muscle spasms that cause pain. The cause of cramps is unknown; in fact, there may be numerous causes. Some of the possible causes include an electrolyte imbalance; deficiency in calcium, magnesium, or potassium; and dehydration.

Delayed-Onset Muscle Soreness
Muscle soreness is common and typically arises shortly after unaccustomed activity. Delayed-onset muscle soreness (DOMS) follows participation in a particularly long or strenuous activity, with the soreness beginning 24 to 72 hours after the activity. DOMS involves multiple, microscopic tears in the muscle tissue and causes inflammation, pain, swelling, and stiffness.

Tendinitis and Tendinosis
Tendons are the bands of tough, fibrous connective tissue that connect muscles to bones. Tendinitis is inflammation of a tendon, usually accompanied by pain and swelling. Both acute and overuse injuries can cause tendinitis. The condition can also occur with aging, as the tendon wears and elasticity decreases. Diseases such as diabetes and rheumatoid arthritis can also promote the development of tendinitis. Tendinitis can occur in any part of the body, but common sites involving injury include the shoulder, elbow, wrist, and the Achilles tendon of the heel.

Treatment of tendinitis involves rest and application of heat or cold. Pain relievers such as aspirin and ibuprofen can reduce pain and inflammation. In severe cases, steroid injections into the tendon can help control pain. Once the pain is reduced, physical therapy to stretch and strengthen both muscle and tendon promotes healing and can help prevent reinjury.

If untreated, chronic tendinitis can progress to tendinosis. Tendinosis, or degeneration of a tendon, is believed to be caused by microtears in the tendon connective tissue that decrease the tendon’s strength. This weakened condition increases the likelihood that the tendon will rupture.

Although the condition is painful, no inflammation is present, unlike with tendinitis. Once tendinosis has developed, recovery takes months to years of minimal use. In many cases physical therapy can help.
Rotational Injuries of the Shoulder

Repetition of forceful overhead motions at the shoulder (as in throwing and spiking in volleyball and serving in tennis) can lead to inflammation or tears of the muscles and muscle tendons surrounding the shoulder (Figure 5.24). A similar condition among competitive swimmers is known as swimmer’s shoulder.

Improper motion mechanics increases the likelihood of these types of shoulder injuries. The symptoms are pain and stiffness with overhead or rapid movements. If not treated, the pain can become constant. Treatment includes application of ice, rest, and, when necessary, surgical repair.

Overuse Injuries of the Elbow

Epicondylitis (EHP-th-kahn-di-LIGHT-iss) involves inflammation and sometimes microtearing of the muscle tendons that cross the lateral and medial sides of the elbow. If unchecked, the condition can worsen, leading to swelling and then scarring of the tendons near the elbow. Lateral epicondylitis, which is reported in 30%–40% of tennis players, is known as tennis elbow, although it also occurs in activities such as swimming, fencing, and repetitious hammering. Medial epicondylitis, known as Little Leaguer’s elbow, can result from repeated throwing, especially with improper pitching mechanics. Both lateral and medial epicondylitis commonly occur among amateur golfers.

Shin Splints

The term shin splint is often used to describe pain localized to the medial lower leg. The condition is an overuse injury that typically arises from running or dancing—particularly running on a hard surface or uphill. The cause of the pain is believed to be microdamage to the muscle tendons that attach to the tibia or inflammation of the periosteum of the tibia. The muscles potentially involved include the soleus, tibialis anterior, and extensor digitorum.

Whiplash Injuries

Whiplash injuries to the neck are fairly common, often resulting from automobile accidents in which the victim’s car was rear-ended. Such injuries result from abnormal motion of the cervical vertebrae, accompanied by rapid, forceful contractions of the neck muscles as the neuromuscular system attempts to stabilize and protect the spine. Symptoms can include neck muscle pain; pain or numbness extending down to the shoulders, arms, and even the hands; as well as headache.
Muscular Dystrophy

Muscular dystrophy (MD) is a group of similar, inherited disorders characterized by progressively worsening muscle weakness and loss of muscle tissue. Depending on the specific type, the onset of MD may occur during either childhood or adulthood, and the symptoms vary. Some forms of MD affect only certain muscle groups, whereas other forms affect all of the muscles. The more severe types of MD begin in childhood; symptoms may include intellectual disability, delayed development of motor skills, frequent falling, drooling, and drooping of the eyelids. Some forms of MD also affect the heart muscle, resulting in an irregular heartbeat. There are no known cures for the various muscular dystrophies; the goal of treatment is to control symptoms. Some types of muscular dystrophy lead to a shortened life; others cause little disability, allowing for a normal lifespan.

Hernia

A hernia is a balloon-like section of the abdominal cavity lining that protrudes through a hole or weakened section of the muscles in the abdomen. A hernia can be caused by heavy lifting or by any activity or medical problem that increases pressure inside the abdominal cavity. In most cases, however, no specific cause is evident. Some hernias are present at birth, and some occur in infants and children. A hernia that is present at birth may not become noticeable until later in life. Most hernias produce no symptoms, although some are accompanied by discomfort or pain that intensifies with heavy lifting or other activities that produce abdominal strain. A large hernia may “strangulate,” or cut off the blood supply to the tissue inside the hernia. A strangulated hernia requires immediate surgery. Small hernias that cause no symptoms do not necessarily require treatment. Larger hernias and those that cause discomfort can be permanently remedied with surgery.

Lesson 5.4 Review and Assessment

Check Your Understanding

1. What is the role of the neuromuscular system in whiplash injuries?
2. What causes swimmer’s shoulder?
3. What is the difference between tennis elbow and Little Leaguer’s elbow?
4. What are the characteristics of MD?
5. What are the different forms that MD may take?

Hernia

A hernia is a balloon-like section of the abdominal cavity lining that protrudes through a hole or weakened section of the muscles in the abdomen. A hernia can be caused by heavy lifting or by any activity or medical problem that increases pressure inside the abdominal cavity. In most cases, however, no specific cause is evident. Some hernias are present at birth, and some occur in infants and children. A hernia that is present at birth may not become noticeable until later in life. Most hernias produce no symptoms, although some are accompanied by discomfort or pain that intensifies with heavy lifting or other activities that produce abdominal strain. A large hernia may “strangulate,” or cut off the blood supply to the tissue inside the hernia. A strangulated hernia requires immediate surgery. Small hernias that cause no symptoms do not necessarily require treatment. Larger hernias and those that cause discomfort can be permanently remedied with surgery.

Lesson 5.4 Review and Assessment

Mini Glossary

- **contusion**: the bruises or bleeding within a muscle that result from an impact
- **delayed-onset muscle soreness (DOMS)**: muscle pain that follows participation in a particularly long or strenuous activity, begins 24–72 hours later, and involves multiple, microscopic tears in the muscle tissue that cause inflammation, pain, swelling, and stiffness
- **hernia**: a balloon-like section of the lining of the abdominal cavity that protrudes through a hole or weakened section of the muscles in the abdomen
- **muscle strain**: moderate to severe muscle pain that follows an injury that occurs when a muscle is stretched beyond the limits to which it is accustomed
- **muscle cramps**: a group of similar, inherited disorders characterized by progressively worsening muscle weakness and loss of muscle tissue
- **tendinitis**: inflammation of a tendon, usually accompanied by pain and swelling
- **tendinosis**: degeneration of a tendon believed to be caused by microtears in the tendon connective tissue

Know and Understand

1. What causes a muscle strain?
2. What can you do to increase your chances of avoiding muscle strains?
3. What is myositis ossificans? What problems can it cause?
4. What do shoulder, elbow, and shin injuries have in common?
5. What is the main cause of DOMS?
6. Why is it important to treat chronic tendinitis?
7. What is believed to be the main cause of shin splints?
8. Name an activity often associated with hernias.

Analyze and Apply

9. If obesity is a major cause of LBP, why would gymnasts experience this health problem?
10. How do poor mechanics contribute to overuse injuries such as swimmer’s shoulder and tennis elbow? Describe and analyze the effect of torque in these injuries.

In the Lab

11. What types of muscle can be affected by muscular dystrophy?
12. Interview a physical therapist or an athletic trainer. Ask the person to describe a typical day at work. Here are some questions you might ask:
   - What is the work environment like?
   - What are the job duties?
   - What kinds of injuries are dealt with?
   - What other types of professionals does he or she work with?
   Report your findings to the class, giving reasons why you would or would not want to pursue a career similar to that of the person you interviewed. You may want to incorporate additional research from the Career Corner activity on the next two pages into your report.
13. Research shin-splint taping. Determine its purpose and how it helps the athlete.
Many challenging and rewarding careers involve treating and rehabilitating the muscles of the body. We will discuss two career options below.

**Physical Therapist**

Physicians often prescribe physical therapy for patients with muscle injuries. Frequently employed in physical therapy clinics, physical therapists and related professionals treat each patient’s condition with appropriate exercise, stretching, and other therapeutic protocols (Figure 5.27). Treatment at a physical therapy clinic can last from a few visits to a series of visits over a period of months, depending on the severity of the condition being treated.

Prescribed exercise and stretching regimens are typically progressive in nature, beginning with a relatively easy routine that grows increasingly challenging. All patient activity in the clinic is closely supervised by a physical therapist to ensure that all movements are carried out in the correct directions and through appropriate ranges of motion.

The academic degree that physical therapists must earn is the DPT, or Doctor of Physical Therapy. Nationwide, entry into DPT programs is highly competitive. To become a physical therapist, students must complete a bachelor’s degree in a health-related field and then pass a national certification examination. Programs of study in physical therapy include a number of basic science courses, human anatomy and physiology, and in-depth lecture/laboratory courses that cover prevention and treatment of athletic injuries to all parts of the body. Athletic trainers are employed in high schools, colleges and universities, hospitals, and clinics.

**Planning for a Health-Related Career**

Do some research on career opportunities for physical therapists or athletic trainers. Keep in mind the different levels of education and certifications that are required. You may want to select a profession from the list of Related Career Options. Using the Internet or resources at your local library, find answers to the following questions:

1. What are the main tasks and responsibilities of an athletic trainer or a physical therapist?
2. What is the outlook for these careers? Are workers in demand, or are jobs dwindling? For complete information, consult the current edition of the Occupational Outlook Handbook, published by the US Department of Labor. This handbook is available online or at your local library.
3. What special skills or talents are required? For example, do you need to be capable of lifting? Are you comfortable looking at injuries that may be severe?
4. What personality traits do you think are needed to be successful in these jobs? For instance, both athletic trainers and physical therapists must work closely with their patients. Do you enjoy working with others?
5. Do these careers involve a great deal of routine, or are the day-to-day responsibilities varied?
6. Does the work require long hours, or are these standard, “9-to-5” jobs?
7. What is the salary range for these jobs?
8. What do you think you would like about each career? Is there anything about them that you might dislike?

**Related Career Options**

- Athletic Trainer
- Massage Therapist
- Occupational Therapist
- Physical Therapist Assistant
- Recreational Therapist
- Rehabilitation Counselor

Figure 5.27 A physical therapist works with a patient to rehabilitate her knee after surgery. Why do all physical-therapy patient activities need to be closely monitored by the physical therapist?

**Athletic Trainer**

If an injury is related to a sport played at the high school or collegiate level, the first professional to examine the patient will likely be an expert in athletic training (Figure 5.28). Athletic trainers are knowledgeable first responders who are trained to apply advanced first aid, as well as to know when immediate referral to emergency care, a physician, or a specialist is necessary.

Athletic trainers are also well qualified to administer rehabilitative treatments when appropriate, typically after the injured athlete has been seen by a physician. Athletic trainers work with active individuals of all ages and physical abilities in industrial settings, gyms, fitness centers, youth athletic leagues, the Special Olympics, and anywhere that people are active.

To become an ATC, or Certified Athletic Trainer, students must complete a bachelor’s degree in athletic training and then pass a national certification examination. Programs of study in athletic training include a number of basic science courses, human anatomy and physiology, and in-depth lecture/laboratory courses that cover prevention and treatment of athletic injuries to all parts of the body. Athletic trainers are employed in high schools, colleges and universities, hospitals, and clinics.

Figure 5.28 Athletic trainers work with student athletes to prevent, treat, and rehabilitate injuries.
Chapter 5

Review and Assessment

Chapter Summaries

Lesson 5.1 Muscle Tissue Categories and Functions

Key Points
- The three major categories of muscle fibers are smooth, cardiac, and skeletal (striated), each with a different function.
- Muscles are either voluntary or involuntary.
- Muscles have four common behavioral characteristics: extensibility, elasticity, irritability, and contractility.
- Skeletal muscles work in an agonist/antagonist relationship and can experience concentric, eccentric, or isometric contractions.

Key Terms
- agonist
- antagonist
- aponeurosis
- concentric
- contractility
- eccentric
- endomysium
- epimysium

Lesson 5.2 Skeletal Muscle Actions

Key Points
- The muscular and nervous systems work together and are known as the neuromuscular system.
- The motor unit is the functional unit of the neuromuscular system and is made up of the neuron and the muscle fibers that the neuron stimulates. The location at which the neurons and the fibers come together is known as the neuromuscular junction.
- Skeletal muscle fibers are divided into fast-twitch fibers, which are powerful and fatigue quickly, or slow-twitch fibers, which are fatigue resistant.
- Muscular strength is determined by measuring torque. Muscular power is defined as force \( \times \) velocity, and muscular endurance is how long a muscle fiber can continuously contract before it fatigues.

Key Terms
- acetylcholine
- action potential
- all-or-none law
- axon
- axon terminals
- cross bridges
- fast-twitch
- motor neuron
- neuromuscular junction
- parallel
- sarcoplasm
- slow-twitch
- synaptic cleft
- tetanus

Lesson 5.3 The Major Skeletal Muscles

Key Points
- Muscles are attached to bone via the origin and insertion.
- The sagittal plane movements are forward and backward actions.
- The frontal plane movements take the body part toward or away from the midline of the body.

Key Terms
- adduction
- abdution
- circumduction
- dorsiflexion
- flexion
- inversion
- extension
- hyperextension
- lateral rotation
- medial rotation

Lesson 5.4 Common Injuries and Disorders of Muscles

Key Points
- Strains are injuries that occur when muscles are stretched beyond their limits.
- Contusions are caused by impact; severe contusions can result in myositis ossificans.
- Possible causes of cramps are dehydration, mineral deficiency, and electrolyte imbalance.
- Delayed-onset muscle soreness is brought on by long, strenuous activity resulting in inflammation, pain, swelling, and stiffness.
- Many muscle injuries, such as DOMS, strains, rotational injuries, and shin splints, result from muscle overuse.
- Low back pain (LBP) can be caused by obesity, muscle strain, muscle overuse, or an issue with the spinal column.
- Muscular dystrophy (MD) is a neuromuscular disease that results in progressively worsening muscle weakness and atrophy.

Key Terms
- contusion
- delayed-onset muscle soreness (DOMS)
- hernia
- muscle cramps
- muscle strain
- muscular dystrophy (MD)
- myositis ossificans
- shin splint
- tendinitis
- tendinosis

Thinking Critically
8. Discuss in depth the differences between concentric, isometric, and eccentric contractions and provide examples of how each one is used in daily life.
9. What do you think would be the pros and cons of body organs being made up exclusively of voluntary muscle (no involuntary muscle)? Provide specific examples and some pros and cons for each.
10. Describe the structure of skeletal muscle. What different parts make up what we typically think of as a muscle?
Lesson 5.3

The Major Skeletal Muscles

Instructions: Write the letter of the name of the muscle on your answer sheet next to the corresponding number.

13. A(n) _____ is an electrical charge that creates tension within a muscle fiber.

14. _____ twitch muscle fibers contract powerfully but fatigue quickly.

Thinking Critically

15. Discuss muscle fiber arrangements that contribute to the force a muscle can generate.

16. How do you think slow-twitch muscle fibers are usually arranged? Give reasons for your answer.

17. Who generates more power: an athletic weight lifter who must lift 400 pounds from the ground to a position over his head very rapidly, or a power lifter who must squat down and stand up with 800 pounds on his back? Defend your answer.

18. Discuss how torque is used to measure the strength of a muscle group at a specific joint.

Lesson 5.4

Common Injuries and Disorders of Muscles

Learning Key Terms and Concepts

30. A muscle strain is classified as _____, _____, or _____.

31. A(n) _____ is a bruise or bleeding within a muscle.

32. A complication that can arise from a contusion is _____.

33. Which of the following may be a cause of cramps?
   A. electrolyte imbalance
   B. dehydration
   C. deficiency in minerals such as calcium or potassium
   D. all of the above

34. The role of the neuromuscular system in a whiplash injury is _____.
   A. an inhibitory response that causes the muscles to relax and the head to move freely
   B. a strong, fast series of contractions that attempt to stabilize the head
   C. not present because the movement is so intense that muscles don’t have time to contract
   D. dependent upon whether the movement is medio/lateral or anteroposterior

35. Lateral epicondyliitis is also known as _____.
   A. Little League’s elbow
   B. Swimmer’s shoulder
   C. Jumper’s knee
   D. Tennis elbow

Thinking Critically

36. If being active is considered healthy, why do you think active people and athletes have a significantly higher incidence of LBP than inactive, sedentary people?

37. Compare and contrast the responsibilities of physical therapists and athletic trainers. How are they similar? How are they different? Which job seems more appealing to you and why?

Lab Investigations

45. Do a push-up starting in the “up” position. Go down. Which muscles are experiencing concentric contractions? Which muscles are experiencing eccentric contractions? Which muscles are experiencing isometric contractions? Which plane(s) is the shoulder moving through? What actions are occurring at the shoulder, elbow, and wrist? Record your observations and then compare them with those of your classmates in a class discussion.

46. Make a working model of a joint that includes both the agonist and the antagonist muscles. Write a brief explanation of how they work together to produce movement.

Building Skills and Connecting Concepts

Analyzing and Evaluating Data

Use the bar graph to answer the following questions.

38. Which sport involves the most muscle strains?

39. Which sport involves the most muscle contusions?

40. What percentage of swimming injuries is attributed to muscle strains?

41. What is the approximate ratio of muscle contusions in figure skating to muscle contusions in baseball?

42. Compare the total number of swimming injuries with the total number of figure skating injuries.

Communicating about Anatomy and Physiology

43. Listening In small groups discuss with your classmates—in basic, everyday language—your knowledge and awareness of your muscles as you go about your daily routine. Conduct this discussion as though you had never read this chapter. Take notes on the observations expressed. Then review the points discussed, factoring in your new knowledge of muscles.

44. Speaking Pick a figure in this chapter, such as Figure 5.1, 5.4, or 5.6. Working with a partner, tell and then retell the important information being conveyed by that figure. Through your collaboration, develop what you and your partner believe is the most interesting verbal description of the importance of the chosen figure. Present your narration to the class.

47. Try to switch the common (what we think of as normal) origin and insertion points of as many muscles as you can. Focus on the most frequent, everyday movements. Make a list and describe what you did to switch them. Hint: Compare origin and insertion points when doing straight-leg sit-ups and straight-leg leg lifts.

Expand your learning with additional online resources

• Supplemental Lab Activities
• Interactive Exercises
• Animations