Myology

Learning Objectives

After working through the material in this chapter, you should be able to:

- Compare and contrast the three types of muscle tissue in the human body.
- Discuss the five functions of skeletal muscle.
- Compare and contrast parallel and pennate fiber arrangements and give an example of each.
- Identify the six factors that make up muscle names. Give examples using each factor.
- Explain the contribution of each of the five properties of skeletal muscle tissue to human movement.
- Identify the major macroscopic and microscopic structures of muscle tissue and describe the function of each.
- List the events that lead to a skeletal muscle contraction and identify all chemicals necessary in the process.
- Discuss the factors that influence the amount of force produced by a muscle.

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Now that we have discussed osteology (the study of bones) and arthrology (the study of joints), we are ready to examine myology (the study of muscles). All movements, from blinking an eye to jumping a hurdle, require the participation of muscles. Although there are three types of muscle tissue in the human body, in this chapter we focus on one: skeletal muscle, the type that generates movement. We will look at its functions and unique properties, and then explore the relationship between its structure and its ability to contract to produce the force behind human movement.

Once myology has been explored, concepts from Chapters 1 through 3 will be fused to examine more complex components of human movement. We will examine levers, where they are found in the human body, and their purpose. Next, we will explore the structures of proprioception and how they work. The chapter will finish with an examination of range of motion: the types, purpose, and guidelines for performing range of motion assessment.

TYPES OF MUSCLE TISSUE

The three types of muscle tissue in the human body are smooth, cardiac, and skeletal. Each type is found in specific locations and serves individual functions (Fig. 3-1).

Smooth Muscle

Smooth muscle is present in the walls of hollow organs, vessels, and respiratory passageways, where it functions in digestion, reproduction, circulation, and breathing. This type of muscle is called involuntary because it is not under our conscious control. For example, we don’t have to think about pushing food through our digestive tract. Instead, in response to the presence of food, smooth muscle automatically generates the wavelike contractions (called peristalsis) that move digestion forward. Smooth muscle within blood vessels and bronchioles (found in the respiratory system) dilates and contracts these structures to increase or decrease the flow of blood or air. The pupil of the eye is also able to dilate and contract in response to changing light thanks to smooth muscle. Finally, smooth muscle surrounding hair follicles allows our hair to “stand on end,” trapping warm air close to the body when we are cold.

Smooth muscle is so named because it has no striations, visible alternating dark and light fibers within other types of muscle tissue. Striations are indicative of tightly arranged proteins responsible for strong muscle contractions. In smooth muscle, these contractile proteins are scattered rather than aligned, and thus it appears unstriated. True striations are not necessary because smooth muscle contractions are slow, steady, and somewhat weaker than the contractions produced by striated cardiac and skeletal muscles.

Cardiac Muscle

Cardiac muscle makes up the wall of the heart, creating the pulsing action necessary to circulate blood. As with smooth muscle, it is involuntary: we do not consciously in-
striated, producing very strong, rapid contractions when activated. However, its fibers fatigue more rapidly than those of smooth or cardiac muscle.

Skeletal muscle fibers are fragile, and thus vulnerable to damage, and they have a very limited ability to regenerate themselves following injury. Fortunately, they are bundled together and reinforced with connective tissue (discussed shortly), which protects them during strong muscle contractions. These connective tissue envelopes converge to form tendons, attaching skeletal muscles to the bones they move.

**SKELETAL MUSCLE FUNCTIONS**

Since our focus in this text is human movement, we will direct our attention primarily to skeletal muscle. Skeletal muscle has several functions in the body, including initiation of motion, maintenance of posture, protection, heat production, and fluid pumping.

**Motion**

The primary function of skeletal muscles is to exert a pull on the bones, creating motion. Contracting muscles lift the feet off the ground, swing the arms back and forth, and even purse the lips for whistling while you walk. Skeletal muscles also expand the ribcage when you take a deep breath and contract it when you exhale. All of these movements of the body are initiated, modified, and controlled by skeletal muscle contractions.

**Posture**

Skeletal muscles maintain upright posture against gravity. They keep your head up and centered, your trunk straight and erect, and your hips and knees aligned over your feet. Skeletal muscles also adjust and respond to changes in posture, as when you lean over or stand up from a chair. These postural muscles cannot rest as long as you are awake and upright.

**Protection**

Skeletal muscles protect underlying structures in areas where bones do not. For example, the abdomen is unprotected by the skeleton, making the underlying organs vulnerable. Strong abdominal muscles protect the deep structures while allowing free movement of the trunk.

**Thermogenesis**

As the skeletal muscles contract to create movement, they also produce body heat. This heat production is called thermogenesis. Approximately three-quarters of the energy created by muscle tissue is heat. We can see this function when it’s cold and the body begins to shiver. These involuntary muscle contractions produce heat and warm the body.

**Vascular Pump**

We know that cardiac muscle is responsible for driving the circulatory system, but the skeletal muscles also play a role. Specifically, contractions of skeletal muscles help propel the circulation of lymph and venous blood. The pumping of the heart keeps the pressure within arteries high, but both lymphatic vessels and veins have relatively low pressure. They require help from the contraction of surrounding muscles to keep their fluids moving forward. This is particularly important where these fluids must flow upward against gravity, as with venous blood returning to the heart from the lower limbs.

**FIBER DIRECTION AND NAMING MUSCLES**

Recall from our discussion about palpation of muscles (Chapter 1) that skeletal muscle cells, called muscle fibers, line up in parallel formations. On a larger scale, bundles of muscle fibers are arranged to achieve specific actions (Table 3-1). The two major divisions of fiber arrangements are parallel and pennate.

**Parallel Arrangements**

Parallel muscles have fibers equal in length that do not intersect. This arrangement enables the entire muscle to shorten equally and in the same direction. Parallel arrangement maximizes range of motion. Configurations include fusiform, circular, and triangular.

**Fusiform Muscles**

Fusiform fiber arrangements have a thick central belly with tapered ends. These tapered ends force production into specific bony landmarks. The *brachialis* and *biceps brachii* in the arm are examples of fusiform muscles. The biceps brachii in particular has very specific attachment points and a large range of motion.

**Circular Muscles**

Circular fiber arrangements surround an opening to form a sphincter. These muscles are designed to contract and close passages or relax and open them. The *orbicularis oris* around the mouth and the *sphincter ani* of the anus are both circular muscles. Each of these muscles regulates what passes in and out of the digestive system.

**Triangular Muscles**

Triangular fiber arrangements start at a broad base then converge to a single point. This fan-shaped arrangement allows them to diversify their actions, creating multiple movement possibilities. Both the *pectoralis major* and *trapezius* are triangular muscles with multiple, sometimes opposing, actions. These muscles can pull in different directions depending upon which fibers are recruited.
### TABLE 3-1. FIBER ARRANGEMENTS

<table>
<thead>
<tr>
<th>Appearance</th>
<th>Purpose</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Parallel Arrangements</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fusiform</td>
<td>Shorten equally and in the same direction to maximize range of motion.</td>
<td>Brachialis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biceps brachii</td>
</tr>
<tr>
<td>Circular</td>
<td>Focus force production into specific bony landmarks.</td>
<td>Orbicularis oris</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sphincter ani</td>
</tr>
<tr>
<td>Triangular</td>
<td>Contract and close passages or relax and open them.</td>
<td>Pectoralis major</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trapezius</td>
</tr>
<tr>
<td><strong>Pennate Arrangements</strong></td>
<td>Maximize the number of fibers in an area for greater force production.</td>
<td></td>
</tr>
<tr>
<td>Unipennate</td>
<td>Strong force production from one direction.</td>
<td>Tibialis posterior</td>
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<tr>
<td></td>
<td></td>
<td>Biceps femoris</td>
</tr>
<tr>
<td>Bipennate</td>
<td>Strong force production from two directions.</td>
<td>Rectus femoris</td>
</tr>
<tr>
<td>Multipennate</td>
<td>Weaker force production from many directions.</td>
<td>Deltoid</td>
</tr>
</tbody>
</table>
Pennate Arrangements

Pennate muscles are feather-shaped (*penna* means feather) with shorter muscle fibers intersecting a central tendon. This arrangement maximizes the number of fibers in an area. More muscle fibers mean greater cross-sectional area and greater force production by these types of muscles. Pennate muscles, like parallel ones, come in several different types including unipennate, bipennate, and multipennate.

Unipennate Muscles

Unipennate muscle fibers run obliquely from one side of a central tendon. These muscles look like half of a feather. This arrangement allows strong force production from one direction. The *tibialis posterior* and *biceps femoris* are examples of unipennate muscles.

Bipennate Muscles

Bipennate muscle fibers run obliquely along both sides of a central tendon. These muscles look like a full feather. Very strong muscle contractions are possible from bipennate muscles as the central tendon is pulled from two directions. The *rectus femoris* is an example of a bipennate muscle.

Multipennate Muscles

Multiple tendons with oblique muscle fibers on both sides characterize multipennate muscles. The muscle fibers connect the tendons and pull from many directions. Of the three types of pennate muscles, this type produces the least amount of force. The multipennate design of the *deltoid* allows it to wrap around the outside of the shoulder and perform many different actions.

Naming Muscles

A muscle’s name can reflect any of several characteristics, including its fiber direction, location, action, size, shape, and number of heads.

Fiber Direction

We have already discussed muscle fiber direction as the configuration of muscle fibers relative to their tendon (see above). Terms such as *oblique* (slanting) and *rectus* (straight) identify a muscle’s fiber direction. The external *oblique* and *rectus abdominus* are both abdominal muscles, but are distinguished by their fiber direction.

Location

Often a muscle name will include its location or relative position in the body to differentiate it from a similar-looking muscle in a different area. Terms such as *brachii* (arm), *femoris* (thigh), *pectoralis* (chest), and *abdominus* (abdomen) identify regional location. We utilize this strategy when identifying the *biceps brachii* and *triceps brachii*, the *rectus femoris* and *rectus abdominus*, and the *pectoralis major*.

The location of muscle attachments is also reflected in muscle names. We see this with the *coracobrachialis*, which attaches to the coracoid process of the scapula, and the *iliacus*, which attaches to the iliac fossa of the pelvis. Similarly, the *spinalis* group of muscles attaches to the spinous processes of the vertebrae. In contrast, *supraspinatus* has no attachment to the vertebrae. Instead, it attaches to the supraspinous fossa of the scapula. *Supra* means above, and here *spina* refers to the spine of the scapula.

Action

Sometimes it’s useful to identify a muscle’s action or movement in its name. Terms such as *flexor*, *extensor*, *adductor*, and *abductor* give insight into a muscle’s purpose. Muscles named by their action include the *flexor carpi radialis*, *extensor digitorum*, and *pronator teres*.

Size

When muscles of similar shape and function reside in the same location, it is useful to distinguish them by size or bulk. The following muscles are all differentiated by size:

- *pectoralis major* and *minor*
- *gluteus maximus*, *medius*, and *minimus*
- *peroneus longus*, *brevis*, and *tertius*
- *adductor magnus*, *longus*, and *brevis*.

Shape

Sometimes a muscle has a unique shape or appearance, which reminded early anatomists of certain objects. For example, the kite-shaped *trapezius* is reminiscent of a geometric trapezoid. The triangular-shaped *deltoid* looks like the Greek letter *delta*. And jagged-edged *serratus anterior* has a shape that corresponds to a saw (*serratus* is Latin for saw-shaped).

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**Box 3-1** CHARACTERISTICS USED TO NAME MUSCLES

- Fiber direction (*oblique, rectus, transverse*)
- Location (*brachii, femoris, pectoralis, abdominus*)
- Action (*flexor, extensor, adductor, abductor, pronator, supinator*)
- Size (*major, minor, maximus, medius, minimus, magnus, longus, brevis*)
- Shape (*trapezius, rhomboid, deltoid, serratus, quadratus*)
- Number of heads (*biceps, triceps, quadriceps*)
Number of Heads

Finally, a muscle may have more than one division or head. Using the suffix –ceps, which means “head,” anatomists identify such muscles as biceps (two heads), triceps (three heads), and quadriceps (four heads). Examples include the biceps brachii and triceps brachii of the upper extremity. Four anterior thigh muscles that extend the knee are typically grouped together as the quadriceps. Three posterior lower leg muscles that share the Achilles tendon are sometimes referred to as the triceps surae (literally translated, “three-headed calf muscle”).

By putting together certain qualities, we can glean information from a muscle’s name. We know, for example, that the pectoralis major is a large chest muscle. We can guess that there is a smaller muscle in the same region (pectoralis minor). From its name we can tell that the latissimus dorsi is a broad muscle on the back of the body (lati means broad and dorsi means back). A flexor carpi ulnaris is a muscle that attaches to the ulna and flexes the wrist. We can discover all of this just from a muscle’s name!

SKELETAL MUSCLE PROPERTIES

Now that we have a clearer idea of why we need skeletal muscles, how they are arranged, and how to name them, let’s look more closely at how they work. Muscle tissue is one of the four primary tissue types in the body (see Chapter 1). It is different from the others (nervous, epithelial, and connective) in that it possesses the properties of extensibility, elasticity, excitability, conductivity, and contractility. Together, these properties enable a skeletal muscle to generate movement.

Extensibility

Extensibility is the ability to stretch without sustaining damage. This property allows muscles to lengthen when relaxed. This is important because muscles usually work in opposite directions as they produce movement while maintaining stability and balance at joints. If one muscle is shortening, its opposite must relax and lengthen to allow the joint to move in the intended direction. For example, when the anterior muscles of your upper arm (flexors) shorten, the posterior muscles of your upper arm (extensors) must relax and lengthen. Without extensibility, the lengthening muscles would be damaged.

Elasticity

Elasticity is the ability to return to original shape after lengthening or shortening. As muscle tissue performs its various functions, its shape changes or deforms. Once its work is completed, the muscle tissue can rest and resume its original form. This property maintains a specific shape and geometry in muscles despite their malleable nature. Using our previous example, once the flexors of the arm have finished contracting and the corresponding lengthening has occurred in the extensors, both will return to a resting length. This return to original length is possible because of elasticity.

Excitability

Excitability (also called irritability) means muscle tissue can respond to a stimulus by producing electrical signals. In response to an event such as a touch or a decision to move, nerves at their junction with muscles release specialized chemicals called neurotransmitters. The neurotransmitters prompt propagation (spread) of an electrical signal called an action potential that in turn triggers a series of events that lead to muscle contraction (see Sliding Filament Mechanism). Without this ability to respond to the nervous system, muscles would not be able to contract and function.

Conductivity

Conductivity describes muscle tissue’s ability to propagate electrical signals, including action potentials. Once muscle tissue is “excited” by the nervous system, it must carry the electrical signal to the inner cell structures. Conductivity allows the action potential to be transmitted along the muscle cell, activating the tissue, and initiating a muscle contraction.

Contractility

Contractility is the ability to shorten and thicken—thus producing force—in response to a specific stimulus. Here, that stimulus is an action potential initiated by the nervous system. This ability to shorten is a unique feature of muscle tissue and responsible for its force-production ability. Specialized proteins within muscle tissue interact to shorten and thicken muscles, generating force. The human body depends on this force to move.
ANATOMY OF SKELETAL MUSCLE TISSUE

In order to understand how muscles generate force and produce movement, we must look at their macroscopic and microscopic anatomy.

Macroscopic Anatomy

Connective tissue wrappings support, protect, and separate portions of muscle and whole muscles (Fig. 3-2). Individual muscle cells, called fibers, are each wrapped in a sheath of connective tissue called the endomysium (endo- means within). Many muscle fibers group into bundles called fascicles, which are held together and encircled by a layer of connective tissue called the perimysium (peri- means around). Finally, these “bundles of bundles” are enveloped by the epimysium (epi- signifies a covering), part of the network of deep fascia (discussed in Chapter 1). All of these connective tissue layers work together to help transmit force while protecting the muscle fibers from damage during muscle contraction.

As shown in Figure 3-2, the epimysium surrounding a whole muscle converges to form a tendon that connects the muscle to bone. The musculotendinous junction describes the point at which this connective tissue convergence begins. The portion of the muscle between tendons is called the muscle belly. Larger blood vessels and nerves are enclosed within the epimysium, and capillaries and nerve fiber endings are wrapped within the endomysium where they interact with individual muscle fibers.

Microscopic Anatomy

If we were to look at muscle fibers under the microscope, we would see several specialized structures (see Fig. 3-2). The entire fiber is surrounded by the sarcolemma, which serves as the cell membrane and regulates chemical transport into and out of the fiber. Surrounding the structures within the fiber is a gelatinous substance called the sarcoplasm, the cytoplasm of muscle cells.

Important structures within the muscle fiber are the nuclei and the myofibrils. Most cells in the human body have a single nucleus, but muscle fibers have multiple nuclei that contain the functional information for the cell and control its operations. The myofibrils are the specialized contractile proteins that make skeletal muscle tissue appear striated. The stripes of the myofibrils reflect two types of filaments: Thin filaments (seen in light blue in Fig. 3-2) occur alone at the lighter I band. The darker A band is where thin and thick filaments (seen in red) overlap. The lighter I bands are interrupted by a zigzag line called the Z line. This line marks the borders of the functional units of the muscle fiber, called sarcomeres; that is, a sarcomere includes structures from one Z line to the next. As we’ll explain in more detail shortly, sarcomeres are considered the functional units of muscle fibers because it is the shortening of sarcomeres that produces muscle contraction.

Other functional structures contained within the sarcolemma include mitochondria, which produce adenosine triphosphate (ATP), a compound that stores the energy needed for muscle contraction. A network of tubules is also present: these transverse tubules run at right angles to the sarcomeres and transmit nerve impulses from the sarcolemma to the cell interior. The sarcoplasmic reticulum is a network of fluid-filled chambers that covers each myofibril like a lacy sleeve. Its channels store calcium ions, an electrically charged form of the mineral calcium, which you learned in Chapter 2 helps trigger muscle contractions.

PHYSIOLOGY OF MUSCLE CONTRACTION

Remember that one of the properties of muscle tissue is excitability. Muscle cells must respond to stimuli from the nervous system in order to function. So before we can examine the events that cause a muscle to contract, we must first learn how nerves and muscles communicate.

Events at the Neuromuscular Junction

Figure 3-3 shows the connection between neurons and muscle fibers. It is called the neuromuscular junction.

Recall from Chapter 1 that neurons have a thin axon that reaches out from the cell body to transmit an action potential through its terminal branches toward other cells—in this case skeletal muscle fibers. Unlike other types of electrical signals, action potentials are strong, invariant, and capable of traveling long distances in the body—from a neuron in your brain that decides to turn a page of this book to the muscle fibers in your fingers that do the turning. The axon branches nearly touch the muscle fibers they innervate, but a gap called a synapse (or synaptic cleft) prevents the signal from crossing to the muscle on its own. The signal can jump this gap only with the help of acetylcholine (abbreviated Ach), which is a type of neurotransmitter. Ach is stored in little sacs called synaptic vesicles at the ends of axon branches, and is released when an action potential reaches the neuromuscular junction. Once across the synaptic cleft, Ach binds to receptors within the muscle fiber’s sarcolemma. This stimulates chemical changes that initiate a new action potential, this time on the muscle fiber “side” of the neuromuscular junction. This new action potential in turn initiates the chemical processes of muscle contraction. As we noted earlier in the chapter, transmission of action potentials in skeletal muscles fibers is possible because of their property of conductivity.

To review the steps involved in initiating muscle contraction:

1. A neuron sends an electrical signal called an action potential down its axon.
2. The signal reaches the ends of the axon branches, where it stimulates synaptic vesicles to release the neurotransmitter acetylcholine (ACh).
3-2. **Macroscopic anatomy of skeletal muscle.** Muscle fibers are organized into muscles by successive layers of connective tissue, including the epimysium, perimysium, and endomysium. This arrangement separates and protects fragile muscle fibers while directing forces toward the bone. The sarcolemma envelops the nucleus, mitochondria, and myofibrils. Myofibrils contain well-organized proteins that overlap and form Z lines, I bands, and A bands. The sarcoplasmic reticulum houses calcium and the transverse tubules transmit electrical signal from the sarcolemma inside the cell, both critical to muscle function.
3. Acetylcholine molecules cross the synaptic cleft and bind with receptors in the sarcolemma.
4. A muscle action potential travels along the sarcolemma and down the transverse tubules.

The remaining question is: How does the muscle action potential lead to muscle contraction?

**Sliding Filament Theory**

The events that follow production of the muscle action potential are described by the sliding filament theory. It explains how contractile proteins within the thin and thick filaments of the myofibrils bind and release to produce shortening in the sarcomere—that is, a muscle contraction. Four contractile proteins are involved (Fig. 3-4):

- Thin filaments are made up of strands of a globular protein called actin. Notice in Figure 3-4 that actin “beads” are assembled in long strands.
- The actin beads are covered with threads of tropomyosin, a protein that—as long as the muscle is relaxed—covers binding sites on the actin molecules, preventing them from participating in muscle contraction.
- The tropomyosin threads are in turn studded with and controlled by clusters of troponin. This protein keeps tropomyosin in place over actin’s binding sites in relaxed muscle, and moves it out of the way to allow muscle contraction.
- Thick filaments are composed of a protein called myosin that forms shorter, thicker ropes with bulbous heads (see Fig. 3-4). These heads must bind with actin for muscle contraction to occur.

Now let’s see how these four proteins contribute to muscle contraction.

After the action potential crosses the neuromuscular junction, it travels to the sarcoplasmic reticulum. From here, stored calcium ions are released into the sarcoplasm. The calcium ions bind with the studs of troponin on the thin filaments, thereby “moving aside” the tropomyosin protein strands covering the binding sites on the actin filament. With the binding sites of actin revealed, the thin filament is ready for contraction.

Meanwhile, the myosin heads on the thick filament are charged with energy from the breakdown of adenosine triphosphate (ATP). (Recall that the mitochondria in the muscle fibers synthesize ATP.) This energy is used to bind the myosin heads to the active receptor sites on the actin filament, making connections called cross-bridges.

Once cross-bridges are formed, a ratcheting action called the power stroke can occur as the myosin heads, bound to actin, pull the sarcomere together. Like a line of rowers in a long boat simultaneously pulling their oars against the water, myosin heads along the thick filaments pull and slide the thin filaments toward the center of the sarcomere, shortening the strand (Fig. 3-5).
3-4. The events of muscle contraction. 

A. At rest, strands of tropomyosin proteins cover binding sites on actin and prevent interaction between actin and myosin. 

B. Action potentials release calcium into the sarcoplasm, which bind to troponin. The bound calcium deforms the tropomyosin protein, exposing actin binding sites and allowing cross-bridges to form between the myosin heads and actin.

3-5. Sliding filament mechanism. 

A. Prior to transmission of the action potential, no cross-bridges connect actin and myosin. 

B. Once the active sites are revealed and myosin heads bind to actin, the power stroke occurs. Synchronized movement of the myosin heads pulls the ends of the sarcomere together, shortening the muscle. 

C. Energy from ATP releases the myosin heads and positions them for another power stroke.
As the myosin heads complete their power stroke, they bind more ATP. This provides the energy necessary for them to release their hold on the actin strand. The cross-bridges detach. This process is repeated by alternating myosin heads on both sides of the thin filament along the length of the muscle fiber, creating muscle contractions.

Once the sliding thick and thin filaments have accomplished muscle contraction, the nerve action potential stops. Any acetylcholine remaining in the synaptic cleft is broken down and deactivated. Calcium ions are released from troponin and actively pumped back into the sarcoplasmic reticulum (using additional energy from ATP). The tropomyosin threads realign with the actin binding sites, preventing further cross-bridge formation. The muscle then passively returns to its resting length.

Factors Affecting Force Production

All muscles generate force by the sliding filament mechanism, but how do the same muscles generate different amounts of force? How can we lift something light, like a piece of paper, and something heavy, like a paperweight, using the same muscle? Moreover, why are some muscles able to generate a much greater maximal force than others? The factors affecting force production include motor unit recruitment, cross-sectional area, fiber arrangement, and muscle length.

Motor Unit Recruitment

The relationship between neurons and muscle fibers is important in determining force production. Neurons responsible for initiating motion, called motor neurons, communicate with a specific number of muscle fibers. A motor neuron and all of the fibers it controls is called a motor unit (Fig. 3-6). Some motor units, like those in the thigh, have thousands of muscle fibers, and therefore can produce powerful movements, but they lack fine control.

One muscle is typically composed of multiple motor units. The body can control the amount of force produced by a given muscle by varying the number and size of motor units recruited. Stimulation of a few motor units generates a small amount of force, whereas activating all motor units in a muscle generates maximal force. The process of recruiting more and more motor units is called summation. The larger the motor units and the more motor units recruited, the greater the potential force production.

Some motor units remain activated all the time, creating a minimal amount of tension in resting muscles that keeps them firm and in a state of readiness to contract. This tension from continual motor unit activation is called muscle tone, and indicates the strength of the connection between the nervous system and skeletal muscles. If muscles are utilized frequently, as with exercise, increased tone may result. Indeed, overworked muscles sometimes develop excessive tone, termed hypertonicity. Decreased use or injury can create less tone, or flaccid muscles. Muscle tone helps maintain posture and joint stability and decreases time needed for muscle force production.
Muscle cross-sectional area is a major factor influencing muscle force production. Indeed, force production correlates more closely with a muscle’s thickness than its total volume. Thus, shorter, thicker muscles generate more force than longer, thinner muscles. Cross-sectional area is related to the size of myofibrils. As myofibrils become larger through use (hypertrophy), muscles increase in cross-sectional area and are able to generate more force.

Fiber Arrangement

Pennate fiber arrangements generate more total force than their parallel counterparts. This fiber arrangement allows more muscle fibers to reside in a given area. More muscle fibers effectively increase the muscle’s cross-sectional area and ability to generate force. Pennate muscles sacrifice range of motion for increased strength and speed.

SKELETAL MUSCLE FIBER TYPES

Earlier we classified muscles by their fiber arrangement. We’re now ready to classify them by their fiber type, which is determined not only by their anatomy, but also by the way they produce energy from ATP. These factors in turn influence the contraction speed of the three types, as reflected in their names: slow twitch fibers, fast twitch fibers, and intermediate fibers.

Slow Twitch Fibers

Slow twitch fibers, also called slow oxidative fibers, contract (or twitch) slowly but are resistant to fatigue (Fig. 3-8A). This is possible because slow twitch fibers rely on aerobic energy production. Aerobic energy production utilizes oxygen in generating ATP, hence the name oxidative. Slow twitch fibers are utilized for long-duration activities (greater than 2 minutes) such as walking and jogging. Postural muscles that must remain contracted for extended periods are primarily composed of slow twitch fibers.

Fast Twitch Fibers

Fast twitch fibers, also called fast glycolytic fibers, generate fast, powerful contractions but quickly fatigue (Fig. 3-8B). These fibers are larger in diameter than their slow twitch

counterparts due to a greater number of myofilaments. More myofilaments produce greater amounts of force. Fast twitch fibers do not rely on oxygen for energy production. They utilize anaerobic energy production. Here, a form of fuel called glucose is converted to lactate in a process called glycolysis. These fibers are utilized for short-duration activities (less than 2 minutes) such as sprinting and lifting. Large, powerful muscles are composed primarily of fast twitch fibers.

Intermediate Fibers

Intermediate fibers, or fast oxidative glycolitic fibers, have characteristics of both the slow twitch and fast twitch fibers. Some evidence suggests that these fibers will adapt to the body’s demands. For example, as a distance runner trains, the intermediate fibers begin to behave like slow twitch fibers and produce energy aerobically. In someone training as a powerlifter, these fibers adapt and produce energy anaerobically, assisting the fast twitch fibers. Thus, you can think of intermediate fibers as reservists waiting to be called up when and where the need arises.

Distribution of Fiber Types

The distribution of slow-twitch, fast-twitch, and intermediate fibers is intermingled and genetically determined. Some people’s muscles have a high concentration of slow-twitch fibers. Their muscles tend to be long and lean. This predisposes them to excel at long-duration activities like marathons or distance biking. Others have high concentrations of fast-twitch fibers, making them great sprinters or body builders. Their muscles tend to be larger and thicker.

Fiber-type distribution is a continuum and varies greatly from one individual to the next.

**TYPES OF MUSCLE CONTRACTIONS**

Some muscle contractions initiate movement, others control movement, while still others stabilize joints and maintain position of the body. Isometric and isotonic contractions describe these different possibilities.

**Isometric Contractions**

Isometric contractions occur when tension is generated in a muscle, but the muscle length and joint angle don’t change (Fig. 3-9A). This type of contraction is used to stabilize joints rather than create movement. Pushing or pulling against an immovable object or holding an object in a fixed position requires effort by the muscles, but no motion in the joints.

**Isotonic Contractions**

Isotonic contractions describe muscle contractions that change the length of the muscle and create movement (Fig. 3-9B,C). There are two different types: concentric and eccentric.

**Concentric Contractions**

In concentric contractions, the muscle shortens. This type of contraction initiates or accelerates movement and overcomes some external resistance like gravity (Fig. 3-9B).
Lifting a book off a table or standing up requires concentric contractions.

**Eccentric Contractions**

Eccentric contractions involve muscle lengthening. These contractions decelerate and control movements and produce greatest force at high speed (Fig. 3-9C). Eccentric contractions are the most powerful, followed by isometric, then concentric. Slowly lowering your book and placing it on the table or lowering yourself into a chair involves eccentric contractions. Injuries occur with eccentric contractions when we try to prevent or control movements such as falling or dropping an object.

**Integrating Contraction Types in Human Movement**

Let’s see if we can clarify how the body uses isometric, concentric, and eccentric contractions to accomplish everyday tasks. First, let’s use the example of sitting in a chair. The quadriceps muscles on the front of your thighs play an important role in this activity. Imagine you are sitting and decide to stand up. The quadriceps muscles shorten to extend your knees, allowing you to rise from the chair. This is a concentric contraction of the quadriceps. The muscles of your trunk are keeping you steady as you rise. This is accomplished with isometric contractions of your trunk muscles. When you decide to sit back down, the quadriceps muscles must lengthen and slow your descent. This keeps you from flopping down in the chair.

Let’s look at another example: filling a pot with water. Imagine (or try) standing at the sink holding a pot in one hand and filling it with water from the tap. You feel the muscles on the front of your upper arm (elbow flexors) working harder as the pot fills. This is an isometric contraction as you hold the pot steady. Once the pot is full, you lift it out of the sink using a concentric contraction of those same elbow flexors. You carry the pot to the stove and carefully lower it to the burner trying not to spill the water or drop the pot. Eccentric contraction of the elbow flexors controls this lowering movement.

**MUSCLE RELATIONSHIPS**

As we have seen in our examples of standing from a chair and filling a pot with water, muscles work together to achieve certain activities. Muscles group themselves into those responsible for a motion, those assisting with a motion, and those working against a motion. We can look at specific muscles and muscle groups (Fig. 3-10A,B) to understand how they interact and create movement.

**Agonists**

Agonist muscles are those most involved in creating a joint movement. Also called prime movers, they are primarily responsible for moving a joint through a given action such as flexion or abduction. The agonist also serves as a point of reference when describing relationships with other muscles or muscle groups. For example, the deltoid is primarily responsible for shoulder abduction; thus, it is the agonist for this movement.

**Synergists**

Synergist muscles assist in some way with the function of its agonist (syn means same). These muscles assist by stabilizing, steering, or contributing to a particular joint movement. Muscles that have the same action or actions are considered synergists. For example, the supraspinatus assists the deltoid in performing shoulder abduction, making this pair synergists. Some muscles have all of their actions in common and thus are direct synergists, whereas others have only one or a few actions in common, making them relative synergists. Here, relationships are motion-specific.

**Antagonists**

Muscles that perform opposite actions to the agonist are called antagonists (anti means against or opposite). The latissimus dorsi is an antagonist to the deltoid and supraspinatus because it performs shoulder adduction, the opposite of shoulder abduction. Opposite actions include flexion and extension, abduction and adduction, and internal and external rotation. The synergist or antagonist relationship is joint specific, meaning that muscles of the shoulder can be synergists or antagonists to each other, but not to muscles of the hip or knee.

The agonist–antagonist relationship is critical for balanced posture as well as for slowing and controlling movements initiated by the body. For example, the erector spinae group (trunk extensors) is counterbalanced by the antagonist rectus abdominus (trunk flexor). Proper development of each is critical for maintaining normal, upright trunk posture. The serratus anterior (scapular abductor, depres-sor, upward rotator) and the rhomboids (scapular adductor, elevator, downward rotator) of the shoulder girdle are also a good example, as together they maintain the position of the scapula on the ribcage by performing opposite actions.

During a movement such as walking the hip flexors and knee extensors swing the leg anteriorly, thereby helping to propel the body forward. The hip extensors and knee flexors are required to slow and stop this movement. Without proper balance between these muscle groups, the body would not be able to control and finish movements it initiated. As we examine individual muscles and muscle groups in future chapters, we will explore these relationships further.
3-10. Muscles of the human body. A. Anterior view. (continues)
Adductor magnus m.
Gracilis m.
Iliotibial tract
Vastus lateralis m.
Biceps femoris m.

Adductor muscles
Minimus
Magnus
Vastus lateralis m.
Biceps femoris m.

Gastrocnemius muscle
Lateral head
Medial head

Peroneus longus m.
Peroneus brevis m.
Tibialis posterior t.
Flexor hallucis longus m.
Superior peroneal retinaculum

Gastrocnemius m.
Soleus m.

Peroneus longus m.
Aponeurosis of soleus m.
Tibialis posterior m.
Flexor digitorum longus mm.
Peroneus brevis m.
Tibialis posterior t.
Flexor hallucis longus m.
Superior peroneal retinaculum

B Posterior view

3-10. (continued) Muscles of the human body. B. Posterior view.
LEVERS IN THE HUMAN BODY

Now it’s time to put things together to understand how human movement happens. As you may recall from Chapter 2, our examination of the skeleton revealed that the bones are a system of levers, rigid devices that transmit or modify forces to create movement.

Components of a Lever

To understand lever systems, we must examine all components. Every lever system must have an axis (or fulcrum). This is the part that the lever itself turns around. For example, in a pair of scissors, the axis is the pivot point between the handles and the blades. A wrench is a lever that uses the center of the bolt you are turning as an axis. In the body, joints serve as the axis. For example, the elbow joint serves as the pivot point between the upper arm and forearm.

Next, we need two sources of mechanical energy. One of these is internal, and is generated by pulling muscles. It is identified simply as the force. An external source of mechanical energy, such as gravity or friction, is the second. This we call resistance. Using our scissor example, the effort you generate at the handles is the force and the resistance is provided by the item you are cutting. In our wrench example the effort you use to turn the wrench is the force and the resistance is provided by the threads of the bolt.

Types of Levers

Lever systems can be arranged in different configurations to accomplish different tasks. Three different configurations found in the body include: first-class levers, second-class levers, and third-class levers. Let’s examine each, using an everyday example (Fig. 3-11).

First-Class Levers

A first-class lever is characterized by a central axis with the force on one side and the resistance on the other. This type can be referred to as force–axis–resistance (FAR). If you have ever played on a teeter–totter (see–saw), you have experienced a first-class lever (see Fig. 3-11A). A plank is placed on a central stand and one person sits on each end. The two can balance on the central axis, or one can move skyward while the other moves down.

This type of lever is designed for balance. Moving the axis closer or farther away from the end can change the leverage or mechanical advantage. Range of motion and speed are increased as the axis moves toward the force (muscle). When the axis is close to the resistance, the lever can produce greater force.

First-class levers are utilized where the body needs balanced strength. Lifting your head up after looking down is a first-class lever at work. The weight of the head is forward relative to the vertebral column. This forms the resistance of the lever. The joint between the base of the skull and the first cervical vertebrae forms the axis. The trapezius muscle and its synergists that extend the head provide the force to move the lever. Resistance is on one side, the axis is in the middle, and the force is on the other side. This type of lever at this location allows your head to balance on your vertebral column.

Second-Class Levers

A second-class lever has the force on one end, the axis on the other end, and the resistance between the two (FRA). Wheelbarrows are a commonly used second-class lever (see Fig. 3-11B). Your body lifts the handles providing force on one end. The wheel serves as the axis. The bucket in the center is filled with dirt or other material providing resistance in the center. Second-class levers are very powerful, but at the cost of range of motion and speed.

A second-class lever is found in the ankle where power and propulsion is critical. The lever formed when you stand on your toes is an example. Here, the axis is the ball of the foot and strong calf muscles (plantar flexors) attaching to the heel provide the force. The resistance comes from the weight of the body compressing down through the tibia between the two. This powerful lever propels the body when walking, running, and jumping. It also helps explain why the calf muscles are so big compared to the smaller shin muscles. This lever is not meant to be balanced, just strong.

Third-Class Levers

Third-class levers are those with the resistance on one end, the axis on the other, and the force between the two (RFA). A shovel is a third-class lever (see Fig. 3-11C). The ground provides resistance when you dig the end in. Force is provided when you lift the middle of the handle. Your other hand provides the axis at the far end of the handle. These levers provide great speed and range of motion.

Third-class levers are the most common type of lever in the human body. Flexing the elbow to raise the hand toward the shoulder is a third-class lever at work. The elbow joint is the axis, the biceps brachii and brachialis muscles just distal provide the force. Resistance is the weight of the forearm and whatever is held in the hand.

PROPRIOCEPTION

We have seen how the motor neuron, part of the nervous system, initiates muscle contractions and contributes to force production. The nervous system also contributes to the health and function of muscles through proprioception. Proprioception is an overall awareness of body position. This awareness is independent of vision and critical in preventing injury and creating efficient movement. The nervous system communicates with muscles, tendons, and joints through different proprioceptors to sense and alter body position.
Try raising your arm over your head with your eyes closed or without looking at your arm. Can you tell when it’s raising and when it is fully overhead? How can you tell if you’re not looking at it? What sensations tell you where it is? Try standing on one foot. Get yourself settled, then close your eyes. Do you feel your body adjusting? How does this happen? This is the function of the proprioceptors (Table 3-2).

### Muscle Spindles

**Muscle spindles** are proprioceptors that are distributed throughout skeletal muscle tissue and monitor changes in tissue length. A muscle spindle includes specialized muscle fibers called *intrafusal fibers* surrounded by a coil of sensory nerve endings. The sensory nerves, or *afferent fibers*, monitor the rate and magnitude of stretch within the muscle.
<table>
<thead>
<tr>
<th>Structure</th>
<th>Location</th>
<th>Trigger</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle spindle</td>
<td>Parallel to skeletal muscle fibers</td>
<td>Rapid or excessive muscle lengthening</td>
<td>Target muscle contraction</td>
</tr>
<tr>
<td>Golgi tendon organ</td>
<td>Within connective tissue of tendons</td>
<td>Excessive muscle contraction or passive stretch</td>
<td>Inhibition of target muscle contraction and contraction of opposite muscles</td>
</tr>
<tr>
<td>Vestibular apparatus</td>
<td>Inner ear</td>
<td>Change in head position</td>
<td>Reestablishes equilibrium</td>
</tr>
<tr>
<td>Pacinian corpuscle</td>
<td>Skin, connective tissue, muscles, and tendons</td>
<td>Vibration and deep pressure</td>
<td>Indicates direction and speed of movement</td>
</tr>
<tr>
<td>Ruffini corpuscle</td>
<td>Joint capsules</td>
<td>Distortion of joint capsule</td>
<td>Indicates joint position</td>
</tr>
</tbody>
</table>
If a stretch is strong or fast enough to potentially cause tissue damage, the alpha motor neuron prompts the surrounding extrafusal fibers to contract and shorten the muscle, thus protecting it from harm. This response is called the myotatic reflex. As the extrafusal fibers adjust their length to protect the muscle, gamma motor neurons adjust the tension of the muscle spindle to maintain its length-monitoring function.

If you have ever had a physician test your reflexes, you have witnessed the myotatic reflex. A reflex hammer is used to tap and quickly stretch the patellar tendon at the front of the knee. This action usually prompts the quadriceps muscles on the front of the thigh to contract. Your leg kicks out, telling the doctor that your muscle spindle is working correctly.

Golgi Tendon Organs

Golgi tendon organs are another important type of proprioceptor. These structures are woven into the connective tissue present in tendons and monitor changes in muscle tension. Muscle tension is created through either stretching or contraction.

If a muscle generates excessive tension, either through strong muscle contraction or excessive stretch, the Golgi tendon organ will inhibit muscle contraction and prompt the muscle to relax. It also prompts the opposite muscle group to contract. Both actions decrease tension on the affected muscle. This response is called the inverse myotatic reflex. We see this response in “cliffhanger” movies when the bad guy is hanging on for dear life and then his fingers just “let go.” This “letting go” is a function of the Golgi tendon organs trying to protect his hand and arm muscles from damage.

Both muscle spindles and Golgi tendon organs are capable of reciprocal inhibition. Reciprocal inhibition describes the relaxation of one muscle while the opposite contracts. This allows the body to move and not fight against itself. Appropriate give and take must occur between opposing muscle groups in order for smooth, coordinated movement to take place.

Other Proprioceptors

The body relies on other proprioceptors besides the muscle spindles and Golgi tendon organs. Receptors deep within the inner ear, the skin, connective tissue, and joint capsule provide additional feedback regarding body position and movement.

Vestibular Apparatus

The vestibular apparatus of the inner ear provides feedback about head position. When you tilt your head, crystals of calcium carbonate housed in the apparatus move in response to gravity. This movement stimulates specialized cells that send signals to the brain indicating relative head position. Damage or infection in the inner ear can compromise balance and equilibrium and decrease proprioception.

Mechanoreceptors

Mechanoreceptors are specialized nerve endings that deform in response to pressure. This deformation is similar to squishing a rubber ball in your hand. By registering the speed and amount of deformation, they indicate position and movement of their associated structures. Two types of mechanoreceptors contribute to proprioception:

- Pacinian corpuscles reside in skin, connective tissue around muscles, and tendons. They detect the initial application of vibration or deep pressure in these tissues, and thereby help to monitor direction and speed of body movement.
- Ruffini corpuscles are scattered throughout joint capsules. Here they determine the exact position of the joint as the joint capsule distorts.

RANGE OF MOTION

Range of motion is a term used to describe the extent of movement possible at a joint. Each joint has a range of movement that is normally available at that joint. This normal range can be limited by several factors including the shape of the bones that form the joint, the ligaments that hold the bones together, the length of the muscles that cross that joint, the amount of tone or nervous system control in the same muscles, injury or a chronic response to injury such as swelling or scar tissue formation, and other factors like age and gender.

Range of motion can be divided into three categories: active, passive, and resisted range of motion.

Active Range of Motion

Active range of motion occurs when a person moves a given body part through its possible motions independently. It therefore demonstrates a client’s willingness and ability to voluntarily perform available motions at that joint. All structures and systems must work together in order to accomplish active movement. Slightly less motion is possible compared to passively (discussed shortly) because the nervous system limits the range of movement to protect the muscles and tendons around the joints.

Guidelines for assessing active range of motion include:
1. Have the client assume a comfortable, upright position with well-aligned posture.
2. Position yourself where you can observe the motion as well as the client’s facial expressions, which might reveal that the movement is causing the client pain.
3. Demonstrate the motion you want the client to perform. As you demonstrate, instruct the client to move within his or her own comfort range. Use common terminology. For example, ask the client to “Straighten your right arm and lift it above your head leading with your thumb.”
4. Now ask the client to perform the movement. Observe for any limitation of motion or break in normal rhythm or symmetry.

5. When appropriate, have the client repeat the movement on the opposite side and compare the two.

6. Inquire about limiting factors, differentiating between sensations of stretch, approximation (body runs into itself), pain, and apprehension or guarding. These sensations are described shortly.

7. Document your findings for comparison.

**Passive Range of Motion**

Passive range of motion occurs when the client is resting and the therapist moves a joint through its possible motions. The joint is taken through its full possible motion, as the client remains relaxed. The practitioner is then able to determine the **endfeel** (or **limiting factor**) for that joint. Endfeel describes the perceived quality of movement at the end of a joint’s available range of motion. The type of endfeel a joint displays provides insight into the health and function of passive or inert stabilizers such as ligaments and joint capsules, as well as the muscles and tendons being stretched during the movement. These would include the antagonist muscles from the performed movement (i.e., passive elbow flexion would assess the health and function of the elbow extensors).

There are four types of healthy endfeel.

- **In bony endfeel**, the contact of two bones is limiting. This is sometimes described as a **hard endfeel** and can be found at the end of elbow extension (Fig. 3-12A).
- **In capsular endfeel**, the joint capsule provides a firm limitation. For example, if you internally rotate the client’s thigh you will encounter a “leathery” feel at the end of the movement (Fig. 3-12B).
- **In springy (or muscular) endfeel**, the stretching of muscles and tendons limits joint motion. For example, the latissimus dorsi and teres major muscles are stretched with shoulder abduction creating a more elastic feel compared to the leathery capsular endfeel (Fig. 3-12C).
- **Approximation** is a fourth type of healthy endfeel, in which the body runs into itself, as when the forearm meets the upper arm, limiting elbow flexion (Fig. 3-12D).

Abnormal endfeel is possible when a joint is injured or diseased. **Muscle spasm** (also called **guarding**), is characterized by jerky or shaky movements prior to expected end range. This can result from muscle or joint injury prompting the nervous system to limit movement. **Springy block** is a

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3-12. Different types of normal endfeel. The blue arrow indicates direction of movement. 
A. Bony or hard endfeel of elbow extension. 
B. Capsular endfeel of hip internal rotation. 
C. Springy endfeel of shoulder abduction. 
D. Approximation endfeel of elbow flexion.
rubbery or bouncy stoppage that occurs prior to end range. It usually results from torn cartilage such as the meniscus of the knee occluding joint movement. **Loose or empty** endfeel occurs where abnormal motion is allowed where a ligament or joint capsule should prevent it. Finally, **spongy** endfeel is squishy or boggy and indicates swelling in a joint. Each abnormal endfeel indicates injury or pathology in the joint and should be evaluated by a physician. Examples of normal and abnormal endfeel are summarized in Table 3-3.

Guidelines for performing passive range of motion include:

1. Place your client in a comfortable and supported position where you can observe joint movement as well as the client’s facial expression.
2. Support surrounding joints in order to protect them and maximize relaxation.
3. Instruct the client to relax fully as you take the joint through the appropriate range of motion.
4. Inquire about discomfort or pain as you perform the movement.
5. Take the joint to endfeel and identify the type as normal (bony, capsular, springy, or approximation) or abnormal (muscle spasm/guarding, springy block, loose/empty, or spongy).
6. When appropriate, repeat movement on other side and compare the two.
7. Document your findings including amount of motion as well as corresponding endfeel.

**Resisted Range of Motion**

Resisted range of motion occurs when the client meets the resistance of the practitioner in attempting to produce movement at a joint. It is used to assess the health and function of contracting muscles and their corresponding tendons. The nervous system, muscle fibers, and tendons all work together to generate force against gravity and the practitioner’s resistance.

Guidelines for performing resisted range of motion include:

1. Have the client assume a comfortable, upright position with well-aligned posture.
2. Place yourself in a position where you can resist movement and, ideally, observe the client’s facial expression. A mirror can be useful when you are unable to face your client directly.
3. When appropriate, stabilize the joint proximal to the one being tested either positionally or with your other hand. This helps decrease compensation and maximize your ability to target specific muscles.

### Table 3-3. Normal and Abnormal Endfeel

<table>
<thead>
<tr>
<th>Type of Endfeel</th>
<th>Motion Limiter</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Normal endfeel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bony</td>
<td>Contact of bones</td>
<td>Elbow extension</td>
</tr>
<tr>
<td>Capsular</td>
<td>Joint capsule stretch</td>
<td>Hip rotation</td>
</tr>
<tr>
<td>Springy</td>
<td>Muscle/tendon stretch</td>
<td>Shoulder abduction</td>
</tr>
<tr>
<td>Approximation</td>
<td>Body contact</td>
<td>Elbow flexion</td>
</tr>
<tr>
<td><strong>Abnormal endfeel</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscle spasm/guarding</td>
<td>Injured muscle, tendon, or joint</td>
<td>Pain, muscle strain</td>
</tr>
<tr>
<td>Springy block</td>
<td>Torn cartilage, foreign body in joint</td>
<td>Torn meniscus in knee</td>
</tr>
<tr>
<td>Loose/empty</td>
<td>Lack of limitation</td>
<td>Torn ligament or joint capsule (sprain)</td>
</tr>
<tr>
<td>Spongy</td>
<td>Swelling</td>
<td>Acute ligament sprain or inflamed bursa</td>
</tr>
</tbody>
</table>
4. Demonstrate the movement you will be resisting. Instruct the client to meet the resistance you apply.
5. Apply resistance, and ask the client to attempt the joint movement (Fig. 3-13). The muscle contraction your client generates will typically be static (isometric); that is, no movement will usually occur. The client need only meet your resistance, not try to overcome it.
6. Inquire about discomfort or pain as the client performs the movement.
7. When appropriate, repeat the movement on the other side and compare the two.
8. Grade the client’s resistance according to Table 3-4. Note your findings in the client’s record.

The ranges of motion possible at all joints and procedures for evaluating each will be discussed in each regional chapter of this book.

**SUMMARY**

- Muscle tissue is one of the four primary tissue types in the human body. Three types of muscle tissue are cardiac, smooth, and skeletal. Each has a specialized function reflecting its anatomical configuration and location.
- Skeletal muscles serve several purposes in the body including initiation of motion, maintenance of posture, protection of underlying structures, generation of heat, and fluid pumping.
- Skeletal muscle fibers have parallel or pennate fiber arrangements depending on the location and function of the muscle. Parallel arrangements maximize range of motion while pennate arrangements maximize force production.
- Factors that may influence skeletal muscle names include fiber direction, location, action, size, shape, and number of heads.
- Skeletal muscle tissue has several properties essential to its function. These include extensibility, elasticity, excitability, conductivity, and contractility. Contractility is unique to muscle tissue.
- Muscles and muscle fibers are organized into multiple levels by layers of connective tissue including the epimysium, perimysium, and endomysium. This arrangement protects fragile muscle fibers and directs forces toward the bones.
- Muscle cells contain multiple nuclei, a sarcolemma or cell membrane, and a sarcoplasm that houses specialized organelles.
- Myofilaments are specialized proteins responsible for force production. Troponin, tropomyosin, and actin proteins form the thin filament while myosin proteins make up the thick filament.
- Thick and thin filaments interact according to the sliding filament mechanism to generate force within a muscle. This process is initiated and governed by the nervous system using electrical signals called action potentials.
- Factors that influence the amount of force produced by a muscle include the number of motor units recruited, muscle cross-sectional area, fiber arrangement, and muscle length.
- Slow twitch, fast twitch, and intermediate types of muscle fibers make energy differently and serve individual purposes in the body. The distribution and development of these fibers is scattered and dependent upon genetics, muscle function, and patterns of physical activity.
- Muscles generate isometric, concentric, and eccentric contractions. Together, these contraction types stabilize the body and generate and control movement.
- Muscles are organized as agonists responsible for movement, synergists working together, or antagonists balancing each other. Healthy relationships between muscle groups are critical to posture and functional movement.
- First-class, second-class, and third-class levers are present in the human body. Different arrangements of the axis, force, and resistance accomplish different goals including balance, power, speed, and range of motion.

### Table 3-4. Grading Resisted Range of Motion

<table>
<thead>
<tr>
<th>Numerical Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Able to maintain test position against gravity and maximal resistance.</td>
</tr>
<tr>
<td>4</td>
<td>Able to maintain test position against gravity and moderate resistance.</td>
</tr>
<tr>
<td>4+</td>
<td>Able to resist maximal resistance, but unable to maintain this resistance.</td>
</tr>
<tr>
<td>4–</td>
<td>Able to maintain test position against gravity and less-than-moderate resistance.</td>
</tr>
<tr>
<td>3+</td>
<td>Able to maintain test position against gravity and minimal resistance.</td>
</tr>
<tr>
<td>3</td>
<td>Able to maintain test position against gravity.</td>
</tr>
</tbody>
</table>

Resisted range of motion scores below “3” are indicative of pathology and should be evaluated by a physician.
Together, proprioceptors enhance movement and protect the structures involved.

- Active range of motion is voluntary movement without outside assistance. It requires coordinated effort between multiple systems of the body.
- Passive range of motion requires movement by an outside source. It is used to assess endfeel and inert structures such as ligaments and joint capsules.
- Resisted range of motion utilizes controlled opposition to movement to evaluate the health of dynamic structures like muscles and tendons.

**FOR REVIEW**

**Multiple Choice**

1. Characteristics of cardiac muscle cells include:
   A. voluntary control, striated
   B. voluntary control, unstriated
   C. involuntary control, striated
   D. involuntary control, unstriated

2. Characteristics of smooth muscle cells include:
   A. voluntary control, striated
   B. voluntary control, unstriated
   C. involuntary control, striated
   D. involuntary control, unstriated

3. Characteristics of skeletal muscle cells include:
   A. voluntary control, striated
   B. voluntary control, unstriated
   C. involuntary control, striated
   D. involuntary control, unstriated

4. The most powerful muscle fiber arrangement is:
   A. multipennate
   B. triangular
   C. unipennate
   D. fusiform

5. A tissue characteristic that is unique to muscle tissue is:
   A. conductivity
   B. contractility
   C. excitability
   D. elasticity

6. The *quadratus femoris* muscle is named for which properties?
   A. size and location
   B. number of heads and action
   C. location and fiber direction
   D. shape and location

7. The fiber type that can alter how it makes energy depending upon use is:
   A. slow-twitch fibers
   B. fast-twitch fibers
   C. intermediate fibers
   D. all of the above

8. Sprinting, jumping, and throwing primarily utilize which type of muscle fiber?
   A. slow-twitch fibers
   B. fast-twitch fibers
   C. intermediate fibers
   D. all of the above

9. Muscle contractions used to initiate movements in the body are:
   A. isometric contractions
   B. concentric contractions
   C. eccentric contractions
   D. all of the above

10. A muscle that assists another with its movement or function is called a(n):
    A. agonist
    B. antagonist
    C. prime mover
    D. synergist

**Sequencing**

Place the following events of muscle contraction into the correct order.

11. _____ Nerve cell sends action potential down its axon.
12. _____ Action potential reaches the transverse tubules.
13. _____ Synaptic vesicles release acetylcholine (ACh).
14. _____ Calcium ions bind to troponin.
15. _____ Acetylcholine (ACh) binds to receptors on the sarcolemma.
16. _____ Tropomyosin proteins distort and active sites on actin are exposed.
17. _____ Muscle relaxation occurs, returning sarcomere to resting length.
18. _____ Shortening of the sarcomere begins.
19. _____ Sarcoplasmic reticulum releases calcium ions.
20. _____ Cross-bridges form between actin binding sites and myosin heads.
Short Answer

21. List the functions of skeletal muscle.

22. Identify all of the properties of skeletal muscle tissue and explain the significance of each to movement.

23. Identify and describe all of the factors that influence force production by a muscle.

24. Briefly explain the purpose of intermediate fibers and how they will adapt to different types of sport training.

25. In your own words, define proprioception. Identify and describe specific anatomical structures that contribute to proprioception.

26. Identify the structures in the picture below.

Try This!

Create a set of cards using muscle names from Figure 3-10. Each card should have the muscle name written on one side. Shuffle your cards and draw one. Say out loud everything you know about this muscle from its name. Remember, the name may tell you things like its fiber direction, location, action, size, shape, or number of heads.

To further challenge yourself, draw a picture of the muscle on the other side of the card. Include the muscle’s unique fiber arrangement. Shuffle and draw a card without looking at the picture. Can you remember its fiber arrangement? Is it parallel or pennate? What shape is it: fusiform, circular, or triangular? If pennate, is it uni, bi, or multipennate?

As a final challenge, see if you can identify the muscle as primarily slow twitch or fast twitch dominant. Remember, small, deep, postural muscles tend to be slow twitch dominant while large powerful muscles tend to be fast twitch dominant. You can look up the muscle profile in Chapters 4-9 to see if you are correct.

Suggested Readings


