

Chapter 8 -Muscular System

8.1 Introduction

- A. All movements require muscle which are organs using chemical energy to contract.
- B. The three types of muscle in the body are skeletal, smooth, and cardiac muscle.
- C. This chapter focuses on skeletal muscle.

8.2 Structure of a Skeletal Muscle

- A. Each muscle is an organ, comprised of skeletal muscle tissue, connective tissues, nervous tissue, and blood.
- B. Connective Tissue Coverings (Figs. 8.1, 8.17,8.19)
 - 1. Layers of dense connective tissue, called fascia, surround and separate each muscle.
 - 2. This connective tissue extends beyond the ends of the muscle and gives rise to tendons that are fused to the periosteum of bones.
 - 3. Sometimes muscles are connected to each other by broad sheets of connective tissue called aponeuroses.
 - 4. The layer of connective tissue around each whole muscle is the epimysium; the perimysium surrounds individual bundles (fascicles) within each muscle; and each muscle cell (fiber) is covered by a connective tissue layer called endomysium.
- C. Skeletal Muscle Fibers (Figs. 8.1-8.4)
 - 1. Each muscle fiber is a single, long, cylindrical muscle cell.
 - 2. Beneath the sarcolemma (cell membrane) lies sarcoplasm (cytoplasm) with many mitochondria and nuclei; the sarcoplasm contains myofibrils.
 - a. The myofibrils contain two types of filaments – thick and thin filaments
 - b. Thick filaments of myofibrils are made up of the protein myosin.
 - c. Thin filaments of myofibrils are made up of the protein actin.
 - d. The organization of these filaments produces striations.
 - 3. A sarcomere extends from Z line to Z line.
 - a. I bands (light bands) made up of actin filaments are anchored to Z lines.
 - b. A bands (dark bands) are made up of overlapping thick and thin filaments.
 - c. In the center of A bands is an H zone, consisting of myosin filaments only.
 - 4. Beneath the sarcolemma of a muscle fiber lies the sarcoplasmic reticulum (endoplasmic reticulum), which is associated with transverse (T) tubules (invaginations of the sarcolemma).
 - a. Each T tubule lies between two cisternae of the sarcoplasmic reticulum and is open to the outside of the muscle fiber.
 - b. The sarcoplasmic reticulum and transverse tubules activate the muscle contraction mechanism when the fiber is stimulated.
- D. Neuromuscular Junction (Fig. 8.5)
 - 1. The site where the motor neuron and muscle fiber meet is the neuromuscular junction.
 - a. The muscle fiber membrane forms a motor end plate in which the sarcolemma is tightly folded and where nuclei and mitochondria are abundant.
 - b. The cytoplasm of the motor neuron contains numerous mitochondria and synaptic vesicles storing neurotransmitters.

8.3 Skeletal Muscle Contraction (Table 8.1)

- A. Muscle contraction involves several components that result in the shortening of sarcomeres, and the pulling of the muscle against its attachments.
- B. Role of Myosin and Actin (Figs. 8.6-8.8)
 - 1. Myosin consists of two twisted strands with globular cross-bridges projected outward along the strands.
 - 2. Actin is a globular protein with myosin binding sites; tropomyosin and troponin are

- two proteins associated with the surface of the actin filaments.
3. According to the sliding filament theory of muscle contraction, the myosin crossbridge attaches to the binding site on the actin filament and bends, pulling on the actin filament; it then releases and attaches to the next binding site on the actin, pulling again.
 4. Energy from the conversion of ATP to ADP is provided to the cross-bridges from the enzyme ATPase, causing them to be in a “cocked” position.
- C. Stimulus for Contraction (Figs. 8.4-8.5,8.7-8.8)
1. The motor neuron must release the neurotransmitter acetylcholine from its synaptic vesicles into the synaptic cleft in order to initiate a muscle contraction.
 2. Protein receptors in the motor end plate detect the neurotransmitters, and a muscle impulse spreads over the surface of the sarcolemma and into the T tubules, where it reaches the sarcoplasmic reticulum.
 3. Upon receipt of the muscle impulse, the sarcoplasmic reticulum releases its stored calcium to the sarcoplasm of the muscle fiber.
 4. The high concentration of calcium in the sarcoplasm interacts with the troponin and tropomyosin molecules, which move aside, exposing the myosin binding sites on the actin filaments.
 5. Myosin cross-bridges now bind and pull on the actin filaments, causing the sarcomeres to shorten.
 6. After the nervous impulse has been received, acetylcholinesterase rapidly decomposes the acetylcholine.
 7. Then, calcium is returned to the sarcoplasmic reticulum, and the linkages between myosin and actin are broken.
- D. Energy Sources for Contraction (Fig. 8.9)
1. Energy for contraction comes from molecules of ATP. This chemical is in limited supply and so must often be regenerated
 2. Creatine phosphate, which stores excess energy released by the mitochondria, is present to regenerate ATP from ADP and phosphate.
 3. Whenever the supply of ATP is sufficient, creatine phosphokinase promotes the synthesis of creatine phosphate.
 4. As ATP decomposes, the energy from creatine phosphate can be transferred to ADP molecules, converting them back to ATP.
- E. Oxygen Supply and Cellular Respiration (Fig. 8.10)
1. The early phase of cellular respiration yields few molecules of ATP, so muscle has a high requirement for oxygen, which enables the complete breakdown of glucose in the mitochondria.
 2. Hemoglobin in red blood cells carries oxygen to muscle.
 3. The pigment myoglobin stores oxygen in muscle tissue.
- F. Oxygen Debt (Fig. 8.10; Table 8.2)
1. During rest or moderate activity, there is enough oxygen to support aerobic respiration.
 2. Oxygen deficiency may develop during strenuous exercise, and lactic acid accumulates as an end product of anaerobic respiration.
 - a. Lactic acid diffuses out of muscle cells and is carried in the bloodstream to the liver.
 3. Oxygen debt refers to the amount of oxygen that liver cells require to convert the accumulated lactic acid into glucose, plus the amount that muscle cells need to resynthesize ATP and creatine phosphate to their original concentrations.
 4. Repaying oxygen debt may take several hours.
- G. Muscle Fatigue

1. When a muscle loses its ability to contract during strenuous exercise, it is referred to as fatigue.
2. Muscle fatigue usually arises from the accumulation of lactic acid in the muscle.
 - a. A lowered pH as a result of accumulated lactic acid prevents the muscle from contracting.
3. A muscle cramp occurs due to a lack of ATP required to return calcium ions back to the sarcoplasmic reticulum so muscle fibers can relax.

H. Heat Production

1. Contraction of skeletal muscle represents an important source of heat for the body.
2. Much of the energy produced through the reactions of cellular respiration is lost as heat (another source of heat for the body).

8.4 Muscular Responses

- A. One method of studying muscle function is to remove a single fiber and connect it to a device that records its responses to electrical stimulation.
- B. Threshold Stimulus
 1. A muscle fiber remains unresponsive to stimulation unless the stimulus is of a certain strength, called the threshold stimulus.
- C. All-or-None Response
 1. When a muscle fiber contracts, it contracts to its full extent (all-or-none response); it cannot contract partially.
- D. Recording a Muscular Contraction (Fig. 8.11)
 1. A myogram is the recording of an electrically-stimulated muscle contraction.
 2. A single, short contraction involving only a few motor units is referred to as a twitch.
 3. The time delay between when the stimulus is applied and when the muscle contracts is called the latent period, which is less than 0.01 second.
 4. The latent period is followed by a period of contraction and a period of relaxation.
- E. Summation (Fig. 8.12)
 1. A muscle fiber receiving a series of stimuli of increasing frequency reaches a point when it is unable to relax completely and the force of individual twitches combine by the process of summation.
 2. If the sustained contraction lacks any relaxation, it is called a tetanic contraction.
- F. Recruitment of Motor Units (Fig. 8.13)
 1. An increase in the number of activated motor units within a muscle at higher intensities of stimulation is called recruitment.
- G. Sustained Contractions
 1. Summation and recruitment together can produce a sustained contraction of increasing strength.
 2. Muscle tone is achieved by a continuous state of sustained contraction of motor units within a muscle.

8.5 Smooth Muscles

- A. Smooth Muscle Fibers
 1. Smooth muscle cells are elongated with tapered ends, lack striations, and have a relatively undeveloped sarcoplasmic reticulum.
 2. Multi-unit smooth muscle and visceral muscle are two types of smooth muscles.
 - a. In multiunit smooth muscle, such as in the blood vessels and iris of the eye, fibers occur separately rather than as sheets.
 - b. Visceral smooth muscle occurs in sheets and is found in the walls of hollow organs; these fibers can stimulate one another and display rhythmicity, and are thus responsible for peristalsis in hollow organs and tubes. (Fig. 5.22)
- B. Smooth Muscle Contraction

1. The myosin-binding-to-actin mechanism is the mostly same for smooth muscles and skeletal muscles.
2. Both acetylcholine and norepinephrine stimulate and inhibit smooth muscle contraction, depending on the target muscle.
3. Hormones can also stimulate or inhibit contraction.
4. Smooth muscle is slower to contract and relax than is skeletal muscle, but can contract longer using the same amount of ATP.

8.6 Cardiac Muscle (Table 8.8, Fig 5.23)

- A. The mechanism of contraction in cardiac muscle is essentially the same as that for skeletal and smooth muscle, but with some differences.
- B. Cardiac muscle has transverse tubules that supply extra calcium, and can thus contract for longer periods.
- C. Complex membrane junctions, called intercalated disks, join cells and transmit the force of contraction from one cell to the next, as well as aid in the rapid transmission of impulses throughout the heart.
- D. Cardiac muscle is self-exciting and rhythmic, and the whole structure contracts as a unit.

8.7 Skeletal Muscle Actions

- A. Origin and Insertion (Fig. 8.14)
 1. The immovable end of a muscle is the origin, while the movable end is the insertion; contraction pulls the insertion toward the origin.
 2. Some muscles have more than one insertion or origin.
- B. Interaction of Skeletal Muscles
 1. Of a group of muscles, the one doing the majority of the work is the prime mover.
 2. Helper muscles are called synergists; opposing muscles are called antagonists.

8.8 Major Skeletal Muscles (Figs. 8.15-8.16)

- A. Muscles are named according to any of the following criteria: size, shape, location, action, number of attachments, or direction of its fibers.
- B. Muscles of Facial Expression (Fig. 8.17a; Table 8.4)
 1. Muscles of facial expression attach to underlying bones and overlying connective tissue of skin, and are responsible for the variety of facial expressions possible in the human face.
 2. Major muscles include (for action, origin, and insertion, refer to Table 8.4): epicranium, orbicularis oculi, orbicularis oris, buccinator, zygomaticus, and platysma.
- C. Muscles of Mastication (Fig. 8.17a; Table 8.5)
 1. Chewing movements include up and down as well as side-to-side grinding motions of muscles attached to the skull and lower jaw.
 2. Chewing muscles include (refer to Table 8.5 for features of these muscles): masseter and temporalis.
- D. Muscles that Move the Head (Fig. 8.17; Table 8.6)
 1. Paired muscles in the neck and back flex, extend, and turn the head.
 2. Major muscles include (see Table 8.6 for features of this group): sternocleidomastoid, splenius capitis, and semispinalis capitis.
- E. Muscles that Move the Pectoral Girdle (Figs. 8.18-8.19; Table 8.7)
 1. The chest and shoulder muscles move the scapula.
 2. Major muscles include (see Table 8.7 for origin, insertion, and action): trapezius, rhomboideus major, levator scapulae, serratus anterior, and pectoralis minor.
- F. Muscles that Move the Arm (Figs. 8.18-8.21; Table 8.8)
 1. Muscles connect the arm to the pectoral girdle, ribs, and vertebral column, making the arm freely movable.
 2. Flexors (see Table 8.8 for origin, insertion, and action) include the coracobrachialis

- and pectoralis major.
 - 3. Extensors (see Table 8.8 for origin, insertion, and action) include the teres major and latissimus dorsi.
 - 4. Abductors (see Table 8.8 for origin, insertion, and action) include the supraspinatus and the deltoid.
 - 5. Rotators (see Table 8.8 for origin, insertion, and action) are the subscapularis, infraspinatus, and teres minor.
- G. Muscles that Move the Forearm (Figs. 8.20-8.22; Table 8.9)
 - 1. These muscles arise from the humerus or pectoral girdle and connect to the ulna and radius.
 - 2. Flexors (see Table 8.9 for origin, action, and insertion) are the biceps brachii, brachialis, and brachioradialis.
 - 3. An extensor (see Table 8.9 for origin, action, and insertion) is the triceps brachii muscle.
 - 4. Rotators (see Table 8.9 for origin, action, and insertion) include the supinator, pronator teres, and pronator quadratus.
- H. Muscles that Move the Hand (Figs. 8.22-8.23, Table 8.10)
 - 1. Movements of the hand are caused by muscles originating from the distal humerus, and the radius and ulna.
 - 2. Flexors (see Table 8.10 for origin, insertion, and action) include the flexor carpi radialis, flexor carpi ulnaris, palmaris longus, and flexor digitorum profundus.
 - 3. Extensors (see Table 8.10 for origin, insertion, and action) include the extensor carpi radialis longus, extensor carpi radialis brevis, extensor carpi ulnaris, and extensor digitorum.
- I. Muscles of the Abdominal Wall (Fig. 8.19; Table 8.11)
 - 1. This group of muscles connects the rib cage and vertebral column to the pelvic girdle.
 - a. A band of tough connective tissue, the linea alba, extending from the xiphoid process to the symphysis pubis, serves as an attachment for certain abdominal wall muscles.
 - 2. These four muscles include (see Table 8.11 for origin, insertion, and action): external oblique, internal oblique, transverse abdominis, and rectus abdominis.
- J. Muscles of the Pelvic Outlet (Fig. 8.24; Table 8.12)
 - 1. The superficial urogenital diaphragm fills the space within the pubic arch, and the deeper pelvic diaphragm forms the floor of the pelvic cavity.
 - 2. Pelvic diaphragm (see Table 8.12 for origin, insertion, and action) includes the levator ani.
 - 3. Urogenital diaphragm (see Table 8.12 for origin, insertion, and action) includes the superficial transversus perinei, bulbospongiosus, and ischioavernosus.
- K. Muscles that Move the Thigh (Figs. 8.25-8.27; Table 8.13)
 - 1. The muscles that move the thigh are attached to the femur and to the pelvic girdle.
 - 2. Anterior group (see Table 8.13 for origin, insertion, and action) includes the psoas major and iliacus.
 - 3. Posterior group (see Table 8.13 for origin, insertion, and action) is made up of the gluteus maximus, gluteus medius, gluteus minimus, and tensor fasciae latae.
 - 4. Thigh adductors (see Table 8.13 for origin, insertion, and action) include the adductor longus, adductor magnus, and gracilis.
- L. Muscles that Move the Leg (Figs. 8.25-8.27; Table 8.14)
 - 1. This group connects the tibia or fibula to the femur or pelvic girdle.
 - 2. Flexors (see Table 8.14 for origin, insertion, and action) are the biceps femoris, semitendinosus, semimembranosus, and sartorius.

3. An extensor (see Table 8.13 for features) is the quadriceps femoris group made up of four parts: rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius.
- M. Muscles that Move the Foot (Figs. 8.28-8.30; Table 8.15)
1. Muscles that move the foot are attached to the femur, fibula, or tibia, and move the foot upward, downward, or in a turning motion.
 2. Dorsal flexors (for features, see Table 8.15) include the tibialis anterior, peroneus tertius, and extensor digitorum longus.
 3. Plantar flexors (for features see Table 8.15) are the gastrocnemius, soleus, and flexor digitorum longus.
 4. An invertor (for features, see Table 8.15) is the tibialis posterior.
 5. An evertor (for features, see Table 8.15) is the peroneus longus.