

The Muscular System

The muscular system includes over 700 skeletal muscles that are directly or indirectly attached to the skeleton by tendons or aponeuroses. The muscular system produces movement, as the contractions of skeletal muscles pull on the attached bones. Muscular activity does not always result in movement, however; it can also be important in stabilizing skeletal elements and preventing movement. Skeletal muscles are also important in guarding entrances or exits of internal passageways, such as those of the digestive, respiratory, urinary, or reproductive systems, and in generating heat to maintain our stable body temperatures.

Skeletal muscles contract only under the command of the nervous system. For this reason, clinical observation of muscular activity may provide direct information about the muscular system, and indirect information about the nervous system. The assessment of facial expressions, posture, speech, and gait can be an important part of the physical examination. Classical signs of muscle disorders include the following:

- *Gower's sign* is a distinctive method of standing from a sitting or lying position on the floor. This method is used by children with *muscular dystrophy* (p. 65). They move from a sitting position to a standing position by pushing the trunk off the floor with the hands and then moving the hands to the knees. The hands are then used as braces to force the body into the standing position. This extra support is necessary because the pelvic muscles are too weak to swing the weight of the trunk over the legs.
- *Ptosis* is a drooping of the upper eyelid. It may be seen in *myasthenia gravis* (p. 66), *botulism* (p. 65), *myotonic dystrophy* (p. 65), or following damage to the cranial nerve (N III) innervating the *levator palpebrae superioris muscle* of the eyelid.
- A *muscle mass*, an abnormal dense region within a muscle, is sometimes seen or felt in a skeletal muscle. A muscle mass may result from torn muscle or tendon tissue, a hematoma, or the deposition of bone around a skeletal muscle, as in *myositis ossificans*.
- Abnormal contractions may indicate problems with the muscle tissue or its innervation. *Muscle spasticity* exists when a muscle has excessive muscle tone. A *muscle spasm* is a sudden, strong, and painful involuntary contraction.
- *Muscle flaccidity* exists when the relaxed skeletal muscle appears soft and relaxed and its contractions are very weak or absent.
- *Muscle atrophy* is skeletal muscle deterioration, or *wasting*, due to disuse, immobility, or interference with the normal muscle innervation.
- Abnormal patterns of muscle movement, such as *tics*, *choreiform movements*, or *tremors*, and

muscular paralysis are usually caused by nervous system disorders. These movements will be described further in sections dealing with abnormal nervous system function.

SIGNS AND SYMPTOMS OF MUSCULAR SYSTEM DISORDERS

Two common symptoms of muscular disorders are *pain* and *weakness* in the affected skeletal muscles. The potential causes of muscle pain include:

1. *Muscle trauma*: Examples of traumatic injuries to a skeletal muscle would include a laceration, a deep bruise or crushing injury, a muscle tear, or a damaged tendon.
2. *Muscle infection*: Skeletal muscles may be infected by viruses, as in some forms of myositis, or colonized by parasitic worms, such as those responsible for *trichinosis* (p. 64). These infections usually produce pain that is restricted to the involved muscles. Diffuse muscle pain may develop in the course of other infectious diseases, such as influenza or measles.
3. *Related problems with the skeletal system*: Muscle pain may result from skeletal problems, such as arthritis (p. 59) or a sprained ligament near the point of muscle origin or insertion.
4. *Problems with the nervous system*: Muscle pain may be experienced due to inflammation of sensory neurons or stimulation of pain pathways in the CNS.

Muscle strength can be evaluated by applying an opposite force against a specific action. For example, the examiner might exert a gentle extending force while asking the patient to flex the arm. Because the muscular and nervous systems are so closely interrelated, a single symptom, such as muscle weakness, can have a variety of different causes (Figure A-22). Muscle weakness may also develop as a consequence of a condition that affects the entire body, such as anemia or acute starvation.

Figure A-23 (p. 64) provides an overview of muscular system disorders.



Necrotizing Fasciitis

EAP p. 178

Several bacteria produce enzymes such as *hyaluronidase* or *cysteine protease*. Hyaluronidase breaks down hyaluronic acid and the proteoglycans (large polysaccharide molecules linked by polypeptide chains) that make up the intercellular cement between adjacent cells. Cysteine protease breaks down connective tissue proteins. These bacteria are dangerous because they can spread rapidly by liquifying the matrix and dissolving the intercellular cement that holds epithelial cells together. The *streptococci* are one group of bacteria that secrete both of these enzymes. *Streptococcus A* bacteria are

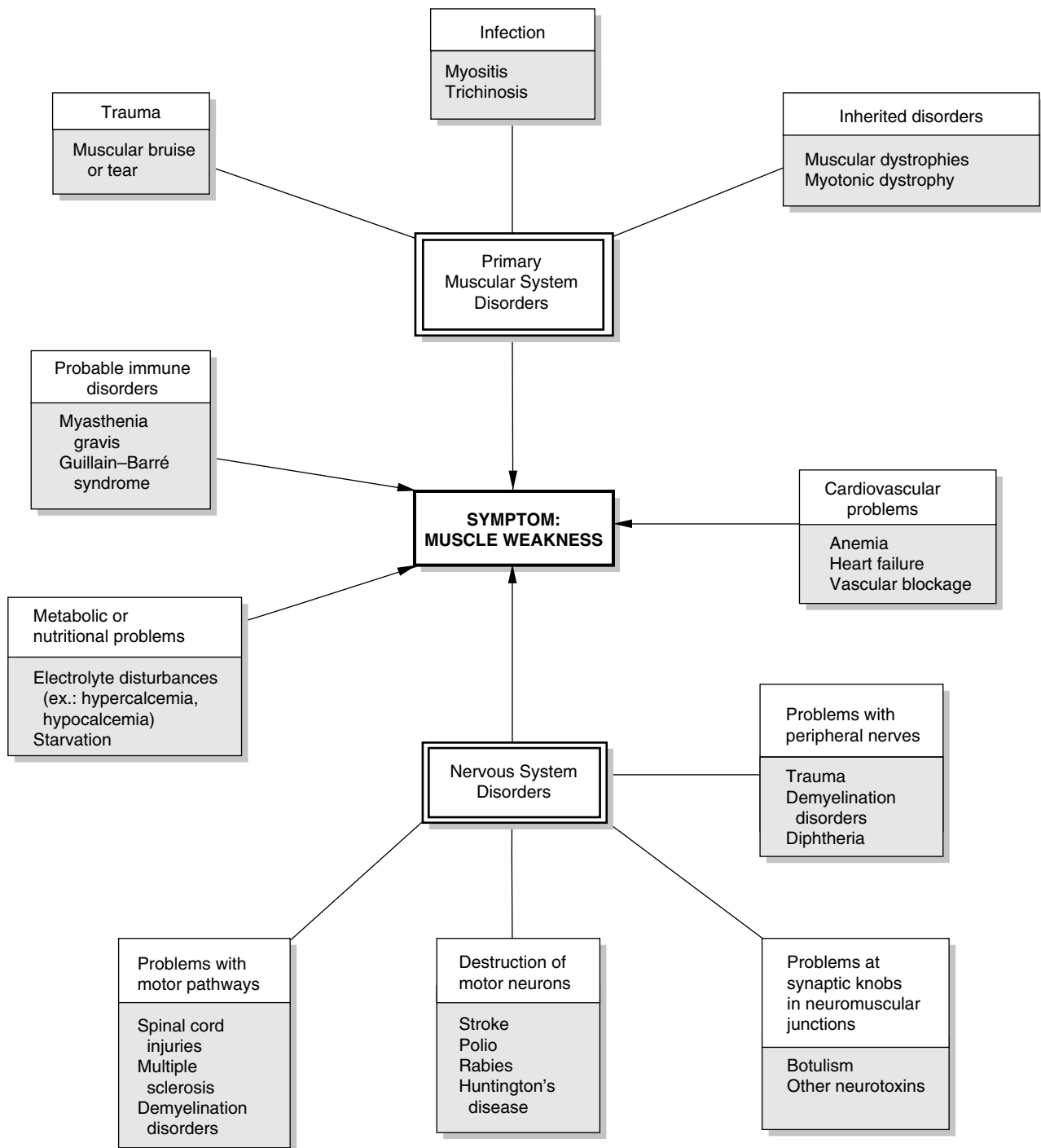


Figure A-22 Potential Causes of Muscle Weakness

involved in many human diseases, most notably “strep throat,” a pharyngeal infection. In most cases the immune response is sufficient to contain and ultimately defeat these bacteria before extensive tissue damage has occurred.

However, in 1994 tabloid newspapers had a field day recounting stories of “killer bugs” and “flesh-eating bacteria” that terrorized residents of the city of Gloucester, England. The details were horrific—

minor cuts become major open wounds, with inter- or connective tissues dissolving. There were only 7 reported cases, but 5 of the victims died. The pathogen responsible was a strain of *Streptococcus A* that overpowered immune defenses and swiftly invaded and destroyed soft tissues. More over, the pathogens eroded their way along the fascial wrapping that covers skeletal muscles and other organs. The term for this condition is **necrotizing fasciitis**.

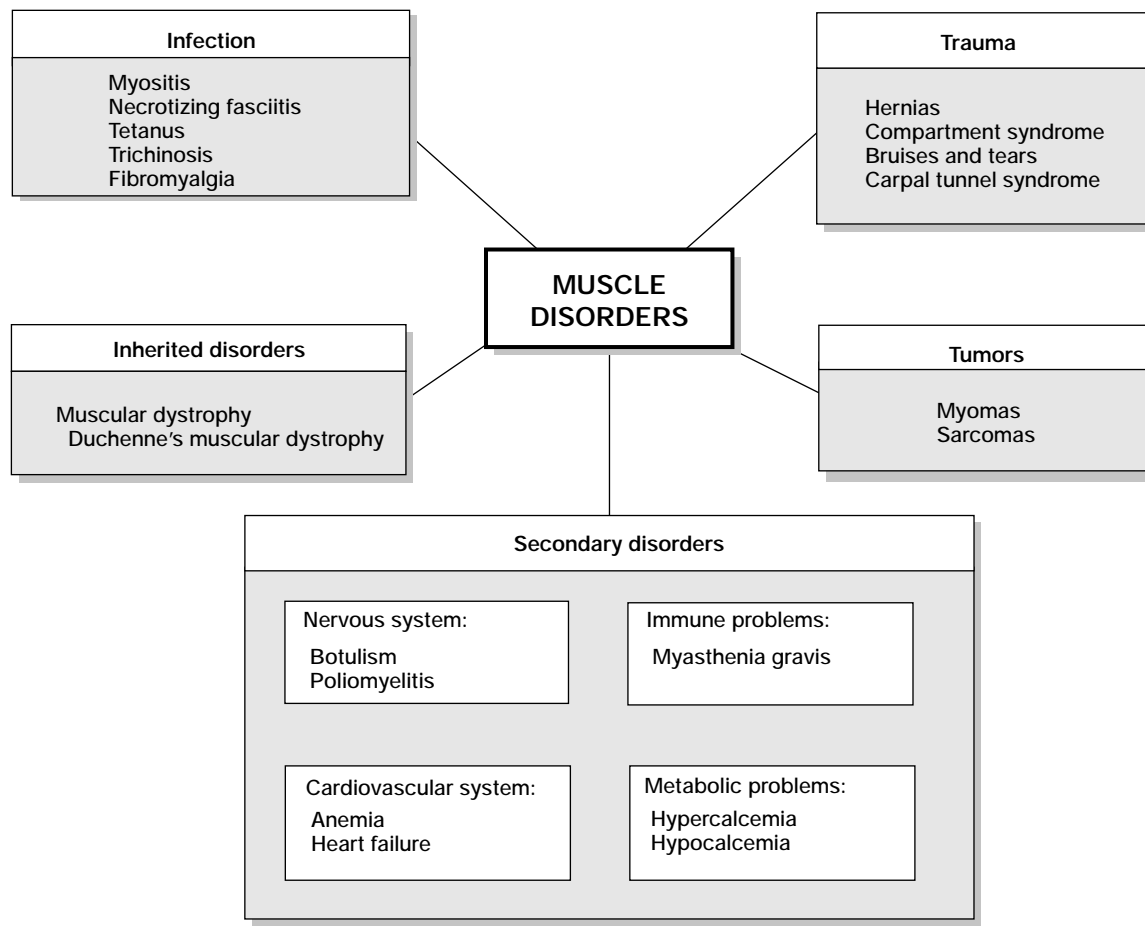


Figure A-23 Disorders of the Muscular System

In some cases the muscle tissue was also destroyed, a condition called *myositis*.

The problem is not restricted to the United Kingdom. Some form of very aggressive infectious soft tissue invasion occurs roughly 75–150 times annually in the U.S. At present it is uncertain whether the recent surge in myositis and necrotizing fasciitis reflects increased awareness of the condition or the appearance of a new strain of strep bacteria.



Trichinosis

EAP p. 178

Trichinosis (trik-i-NŌ-sis; *trichos*, hair + *nosos*, disease) results from infection by a parasitic nematode worm, *Trichinella spiralis*. Symptoms include diarrhea, weakness, and muscle pain. The muscular symptoms are caused by the invasion of skeletal muscle tissue by larval worms, which create small pockets within the perimysium and endomysium. Muscles of the tongue, eyes, diaphragm, chest, and leg are most often affected.

Larvae are common in the flesh of pigs, horses, dogs, and other mammals. The larvae are killed when the meat is cooked; people are most often exposed by eating undercooked pork. Once eaten, the larvae mature within the intestinal tract, where they mate and produce eggs. The new generation of

larvae then migrates through the body tissues to reach the muscles, where they complete their early development. The migration and subsequent settling produce a generalized achiness, muscle and joint pain, and swelling in infected tissues. An estimated 1.5 million Americans carry *Trichinella* around in their muscles, and up to 300,000 new infections occur each year. The mortality rate for people who have symptoms severe enough to require treatment is approximately 1 percent.



Fibromyalgia and Chronic Fatigue Syndrome

EAP p. 178

Fibromyalgia (*-algia*, pain) is a disorder that has formally been recognized only since the mid-1980s. Although first described in the early 1800s, the condition is still somewhat controversial because the reported symptoms cannot be linked to any anatomical or physiological abnormalities. However, physicians now recognize a distinctive pattern of symptoms that warrant consideration as a clinical entity.

Fibromyalgia may be the most common musculoskeletal disorder affecting women under 40 years of age. There may be as many as 6 million cases in the United States today. Symptoms include chronic

aches, pain, and stiffness and multiple tender points at specific, characteristic locations. The four most common tender points are (1) just below the kneecap, (2, 3) distal to the medial and lateral epicondyles of the humerus, and (4) the junction between the second rib and the cartilage attaching it to the sternum. An additional clinical criterion is that the pains and stiffness cannot be explained by other mechanisms. Individuals with this condition frequently report chronic fatigue; they feel tired on awakening and often complain of awakening repeatedly during the night.

Most of these symptoms could be attributed to other problems. For example, chronic depression can lead to fatigue and poor-quality sleep. As a result, the pattern of tender points is really the diagnostic key to fibromyalgia. This symptom distinguishes fibromyalgia from **chronic fatigue syndrome (CFS)**. The current symptoms accepted as a definition of CFS include (1) sudden onset, usually following a viral infection, (2) disabling fatigue, (3) muscle weakness and pain, (4) sleep disturbance, (5) fever, and (6) enlargement of cervical lymph nodes.

Attempts to link either fibromyalgia or CFS to a viral infection or to some physical or psychological trauma have not been successful, and the cause remains unknown. Treatment is limited to relieving symptoms when possible. For example, anti-inflammatory medications may help relieve pain, drugs can be used to promote sleep, and exercise programs may help maintain normal range of motion.



The Muscular Dystrophies

EAP p. 185

The **muscular dystrophies** (DIS-trō-fēz) are inherited diseases that produce progressive muscle weakness and deterioration. One of the most common and best understood conditions is **Duchenne's muscular dystrophy (DMD)**. This form of muscular dystrophy appears in childhood, often between the ages of 3 and 7. The condition generally affects only males. A progressive muscular weakness develops, and the individual usually dies before age 20 because of respiratory paralysis. Skeletal muscles are primarily affected, although for some reason the facial muscles continue to function normally. In later stages of the disease, the facial muscles and cardiac muscle tissue may also become involved.

The skeletal muscle fibers in a person with DMD patient are structurally different from those of other individuals. Abnormal membrane permeability, cholesterol content, rates of protein synthesis, and enzyme composition have been reported. DMD sufferers also lack a protein, called *dystrophin*, found in normal muscle fibers. It is attached to the inner surface of the sarcolemma near the triads. Although the functions of this protein remain uncertain, dystrophin is suspected to play a role in the regulation of calcium ion channels in the sarcolemma. In children with DMD, calcium channels remain open for an extended period,

and calcium levels rise to the point that key proteins denature. The muscle fiber then degenerates. Researchers have recently identified and cloned the gene for dystrophin; that gene is located on the X chromosome. Rats with DMD have been cured by insertion of this gene into their muscle fibers, a technique that may eventually be used to treat human patients.

The inheritance of DMD is sex-linked: Women carrying the defective genes are unaffected, but each of their male children will have a 50 percent chance of developing DMD. Now that the specific location of the gene has been identified, it is possible to determine whether or not a woman is carrying the defective gene. It is also possible to use an innovative prenatal test to determine if a fetus has this condition. In this procedure, a small sample of fluid is collected from the membranous sac that surrounds the fetus. This fluid contains fetal cells, called *amniocytes*, that are collected and cultivated in the laboratory. Researchers then insert a gene, called *MyoD*, that triggers their differentiation into skeletal muscle fibers. These cells can then be tested not only for the signs of muscular dystrophy but for indications of other inherited muscular disorders.

MYOTONIC DYSTROPHY. **Myotonic dystrophy** is a form of muscular dystrophy that occurs in the united states at an incidence of 13.5 per 100,000 population. Symptoms may develop in infancy, but more often develop after puberty. As with other forms of muscular dystrophy, adults developing myotonic dystrophy experience a gradual reduction in muscle strength and control. Problems with other systems, especially cardiovascular and digestive systems, often develop. There is no effective treatment.

The inheritance of myotonic dystrophy is unusual because children of an individual with myotonic dystrophy commonly develop more severe symptoms than those of the parent. The increased severity of the condition appears to be related to the presence of multiple copies of a specific gene on chromosome 19. For some reason, the nucleotide sequence of that gene gets repeated several times, and the number can increase from generation to generation. This has been called a "genetic stutter." The greater the number of copies, the more severe the symptoms. It is not known why the stutter develops, nor how the genetic duplication affects the severity of the condition.



Botulism

EAP p. 184

Botulinus (bot-ū-LĪ-nus) **toxin** prevents the release of ACh at the synaptic terminal. It thus produces a severe and potentially fatal paralysis of skeletal muscles. A case of botulinus poisoning is called **botulism**.¹ The toxin is produced by a bacterium, *Clostridium botulinum*, that does not need oxygen to grow and reproduce. Because the organism can live

¹This disorder was described 200 years ago by German physicians treating patients poisoned by dining on contaminated sausages. *Botulus* is the Latin word for sausage.

quite well in a sealed can or jar, most cases of botulism are linked to improper canning or storing procedures, followed by failure to cook the food adequately before eating. Canned tuna or beets, smoked fish, and cold soups have most often been involved with cases of botulism. Boiling for a half hour destroys both the toxin and the bacteria.

Symptoms usually begin 12–36 hours after eating a contaminated meal. The initial symptoms are often disturbances in vision, such as seeing double or a painful sensitivity to bright lights. These symptoms are followed by other sensory and motor problems, including blurred speech and an inability to stand or walk. Roughly half of botulism patients experience intense nausea and vomiting. These symptoms persist for a variable period (days to weeks), followed by a gradual recovery; some patients are still recovering after a year.

The major risk of botulinus poisoning is respiratory paralysis and death by suffocation. Treatment is supportive: bed rest, observation, and, if necessary, use of a mechanical respirator. In severe cases drugs that promote the release of ACh, such as *guanidine hydrochloride*, may be administered. The overall mortality rate in the United States is about 10 percent.



Myasthenia Gravis

EAP p. 184

Myasthenia gravis (mī-as-THĒ-nē-uh GRA-vis) is characterized by a general muscular weakness that is often most pronounced in the muscles of the arms, head, and chest. The first symptom is usually a weakness of the eye muscles and drooping eyelids. Facial muscles are often weak as well, and the individual develops a peculiar smile known as the “myasthenic snarl.” As the disease progresses, pharyngeal weakness leads to problems with chewing and swallowing, and it becomes difficult to hold the head upright.

The muscles of the upper chest and upper extremities are next to be affected. All the voluntary muscles of the body may ultimately be involved. Severe myasthenia gravis produces respiratory paralysis, with a mortality rate of 5–10 percent. However, the disease does not always progress to such a life-threatening stage. For example, roughly 20 percent of patients experience eye problems with no other symptoms.

The condition results from a decrease in the number of ACh receptors on the motor end plate. Before the remaining receptors can be stimulated enough to trigger a strong contraction, the ACh molecules are destroyed by cholinesterase. As a result, muscular weakness develops.

The primary cause of myasthenia gravis appears to be a malfunction of the immune system. Roughly 70 percent of the individuals with myasthenia gravis have an abnormal thymus, an organ involved with the maintenance of normal immune function. In myasthenia gravis, the immune response attacks the ACh receptors of the motor end plate as if they were foreign proteins. For

unknown reasons, women are affected twice as often as men. Estimates of the incidence of this disease in the United States range from 2 to 10 cases per 100,000 population.

One approach to therapy involves the administration of drugs, such as *neostigmine*, that are termed **cholinesterase inhibitors**. As their name implies, these compounds are enzyme inhibitors; they tie up the active sites at which cholinesterase normally binds ACh. With cholinesterase activity reduced, the concentration of ACh at the synapse can rise enough to stimulate the surviving receptors and produce muscle contraction.



Polio

EAP p. 184

Because skeletal muscles depend on their motor neurons for stimulation, disorders that affect the nervous system can have an indirect effect on the muscular system. The *poliovirus* is a virus that does not produce clinical symptoms in roughly 95 percent of infected individuals. The virus produces variable symptoms in the remaining 5 percent. Some individuals develop a nonspecific illness resembling the flu. A second group of individuals develop a brief *meningitis* (p. 74), an inflammation of the protective membranes surrounding the CNS. In the third group of people, the virus attacks somatic motor neurons in the CNS.

In this third form of the disease, the individual develops a fever 7–14 days after infection. The fever subsides, but recurs roughly a week later, accompanied by muscle pain, cramping, and paralysis of one or more limbs. Respiratory paralysis may also occur, and the mortality rate for this form of polio is 2–5 percent for children and 15–30 percent of adults. If the individual survives, some degree of recovery usually occurs over a period of up to 6 months.

For unknown reasons, the survivors of paralytic polio may develop progressive muscular weakness 20–30 years after the initial infection. This *postpolio syndrome* is characterized by fatigue, muscle pain, and weakness, and, in some cases, muscular atrophy. There is no treatment for this condition, although rest seems to help.

Polio has been almost completely eliminated from the U.S. population due to a successful immunization program. In 1954 there were 18,000 new cases in the United States; there were 8 in 1976, and none since 1994. The World Health Organization now reports that polio has been eradicated from the entire Western Hemisphere. Unfortunately, many parents refuse to immunize their children against the poliovirus, because they assume that the disease has been “conquered.” Failure to immunize is a mistake because (1) there is still *no cure* for polio, (2) the virus remains in the environment in many areas of the world, and (3) up to 38 percent of children ages 1–4 have not been immunized. A major epidemic could therefore develop very quickly if the virus were brought into the United States from another part of the world.

Hernias

EAP p. 204

When the abdominal muscles contract forcefully, pressure in the abdominopelvic cavity can increase dramatically, and those pressures are applied to internal organs. If the individual exhales at the same time, the pressure is relieved, because the diaphragm can move upward as the lungs collapse. But during vigorous isometric exercises or when lifting a weight while holding one's breath, pressure in the abdominopelvic cavity can rise to 106 kg/cm^2 (1500 lb/in.^2), roughly 100 times normal pressures. Pressures this high can cause a variety of problems, among them the development of a *hernia*.

A **hernia** develops when a visceral organ protrudes abnormally through an opening in a muscular wall or partition. There are many types of hernias; we will consider only *inguinal* (groin) *hernias* and *diaphragmatic hernias* here.

Late in the development of the male, the testes descend into the scrotum by passing through the abdominal wall at the **inguinal canals**. In the adult male, the spermatic ducts and associated blood vessels penetrate the abdominal musculature at the **inguinal canals** on their way to the abdominal reproductive organs. In an inguinal hernia, the inguinal canal enlarges, and the abdominal contents such as a portion of the intestine (or more rarely the bladder) are forced into the inguinal canal (Figure A-24). If the herniated structures become trapped or twisted within the inguinal sac, surgery may be required to prevent serious complications. Inguinal hernias are not always caused by unusually high abdominal pressures. Injuries to the abdomen, or inherited weakness or distensibility of the canal, may have the same effect.

The esophagus and major blood vessels pass through an opening in the diaphragm, the muscle that separates the thoracic and abdominopelvic cavities. In a **diaphragmatic hernia**, also called a *hiatal hernia* (hī-Ā-tal; *hiatus*, a gap or opening),

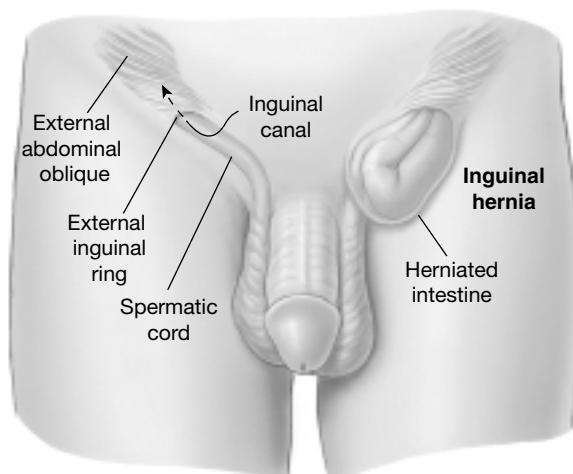


Figure A-24 An Inguinal Hernia

abdominal organs slide into the thoracic cavity, most often through the *esophageal hiatus*, the opening used by the esophagus. The severity of the condition will depend on the location and size of the herniated organ(s). Hiatal hernias are actually very common, and most go unnoticed. Radiologists see them in about 30 percent of individuals whose upper gastrointestinal tracts are examined with barium contrast techniques. When clinical complications develop, they usually occur because abdominal organs that have pushed into the thoracic cavity are exerting pressure on structures or organs there. As is the case with inguinal hernias, a diaphragmatic hernia may result from congenital factors or from an injury that weakens or tears the diaphragmatic muscle.

Sports Injuries

EAP p. 208

Sports injuries affect amateurs and professionals alike. A 5-year study of college football players indicated that 73.5 percent experienced mild injuries, 21.5 percent moderate injuries, and 11.6 percent severe injuries during their playing careers. Contact sports are not the only activities that show a significant injury rate; a study of 1650 joggers running at least 27 miles per week reported 1819 injuries in a single year.

Muscles and bones respond to increased use by enlarging and strengthening. Poorly conditioned individuals are therefore more likely to subject their bones and muscles to intolerable stresses than are people in good condition. Training is also important in minimizing the use of antagonistic muscle groups and keeping joint movements within the intended ranges of motion. Planned warm-up exercises before athletic events stimulate circulation, improve muscular performance and control, and help prevent injuries to muscles, joints, and ligaments. Stretching exercises stimulate muscle circulation and help keep ligaments and joint capsules supple. Such conditioning extends the range of motion and prevents sprains and strains when sudden loads are applied.

Dietary planning can also be important in preventing injuries to muscles during endurance events, such as marathon running. Emphasis has often been placed on the importance of carbohydrates, leading to the practice of “carbohydrate loading” before a marathon. But while operating within aerobic limits, muscles also utilize amino acids extensively, so an adequate diet must include both carbohydrates and proteins.

Improved playing conditions, equipment, and regulations also play a role in reducing the incidence of sports injuries. Jogging shoes, ankle or knee braces, helmets, and body padding are examples of equipment that can be effective. The substantial penalties now earned for personal fouls in contact sports have reduced the numbers of neck and knee injuries.

Several injuries common to those engaged in active sports may also affect nonathletes, although

the primary causes may differ. A partial listing of activity-related conditions includes the following:

- *Bone bruise*: Bleeding within the periosteum of a bone
- *Bursitis*: Inflammation of the bursae around one or more joints
- *Muscle cramps*: Prolonged, involuntary, and painful muscular contractions
- *Sprains*: Tears or breaks in ligaments or tendons
- *Strains*: Tears in muscles
- *Stress fractures*: Cracks or breaks in bones subjected to repeated stresses or trauma
- *Tendinitis*: Inflammation of the connective tissue surrounding a tendon

Many of these conditions have been discussed in previous chapters.

Finally, many sports injuries would be prevented if people who engage in regular exercise used common sense and recognized their personal limitations. It can be argued that some athletic events, such as the ultramarathon, place such excessive stresses on the cardiovascular, muscular, respiratory, and urinary systems that they cannot be recommended, even for athletes in peak condition.

Carpal Tunnel Syndrome EAP p. 211

Tenosynovitis is the inflammation of a tendon sheath. Carpal tunnel syndrome results from tenosynovitis of the tendon sheath surrounding the flexor tendons of the palm. The inflammation leads to compression of the *median nerve*, a mixed (sensory and motor) nerve that innervates the palm. Symptoms include pain, especially on palmar flexion, a tingling sensation or numbness on the palm, and weakness in the abductor pollicis. This condition is fairly common and often strikes those engaged in repetitive hand movements, such as typing, working at a computer keyboard, or playing the piano. Treatment involves administration of anti-inflammatory drugs such as aspirin, injection of anti-inflammatory agents, such as *glucocorticoids* (steroid hormones produced by the adrenal cortex), and use of splints to prevent wrist flexion and stabilize the region.

Carpal tunnel syndrome is an example of a *cumulative trauma disorder*, or *overuse syndrome*. These disorders are caused by repetitive movements of the arms, hands, and fingers. These musculoskeletal problems now account for over 50 percent of all work-related injuries in the United States.

CRITICAL-THINKING QUESTIONS

3-1. A patient experiencing a severe hyperkalemia could have the following related problems:

- a. a below-normal potassium ion concentration of the interstitial fluid
- b. a more-negative membrane potential of nerves and muscles
- c. unresponsive skeletal muscles and cardiac arrest
- d. muscle weakness and increased strength of twitch contractions
- e. all of the above

3-2. Making hospital rounds, Dr. R., an anesthesiologist, meets with a first-semester anatomy and physiology student named CeCe who is scheduled for surgery the next day. Having just finished the unit on skeletal muscles and the nervous system, CeCe is eager to learn about the anesthesia that will be used during the surgery. Dr. R. explains he will be using a drug, *succinyl choline*, that competes with acetylcholine and blocks the action of this neurotransmitter at the neuromuscular junction. What effect will this have on CeCe's skeletal muscles?

- a. produce paralysis of all the skeletal muscles
- b. cause tetany of the skeletal muscles

- c. increase the force and strength of muscle contractions

CeCe answers this question correctly but becomes immediately concerned about this effect on a select group of skeletal muscles. What is CeCe concerned about?

3-3. Tom broke his right leg in a football game. After six weeks in a cast, the cast is finally removed, and when he takes his first few steps, he loses his balance and falls. What is the most likely explanation?

- a. the bone fracture is not completely healed
- b. the right leg muscles have atrophied due to disuse
- c. Tom has an undiagnosed neuromuscular disorder

3-4. Samples of muscle tissue are taken from a champion tennis player and a nonathlete of the same age and gender. Both samples are subjected to enzyme analysis. How would you expect the two samples to differ?

3-5. Calvin steps into a pothole and twists his ankle. He is in a great deal of pain and cannot stand. In the hospital, the examining physician notes that Calvin can plantar flex and dorsiflex the foot, but he cannot perform inversion without extreme pain. Which muscle has probably been injured?

NOTES