Chapter 7

Therapeutic Modalities

OUTCOMES

1. Explain the principles associated with the electromagnetic spectrum and identify the different types of energy found in the nonionizing range of the spectrum.
2. Explain the transfer of energy from one object to another and identify the factors that may affect that transfer.
3. Describe the physiologic effects of cryotherapy and thermotherapy.
4. Describe the indications and contraindications for the various methods of cold and heat treatments, including ultrasound and diathermy.
5. Describe the principles behind ultrasound and explain the physiologic effects and mode of application.
6. Explain the principles of electricity and describe the different types of current.
7. Describe the various parameters that can be manipulated in electrotherapy to produce the desired effects.
8. Explain the various types of electrical stimulating units and the use of each.
9. Describe the benefits attained in each of the five basic massage strokes and explain their application.
10. Identify the principles behind traction and continuous passive motion.
11. Explain and describe the various categories of therapeutic medications used to promote healing, and give examples of common drugs in each category.

The ultimate goal of rehabilitation is to return the injured participant to activity, pain free and fully functional. The rehabilitation process must focus on controlling pain and inflammation, and regaining normal joint range of motion (ROM), flexibility, muscular strength, muscular endurance, coordination, and power. Therapeutic modalities and medications are used to create an optimal environment for injury repair by limiting the inflammatory process and breaking the pain-spasm cycle. Use of any modality depends on the supervising physician's exercise prescription, as well as the injury site, and type and severity of injury. An **indication** is a condition that could benefit from a specific modality, whereas a **contraindication** is a condition that could be adversely affected if a particular modality is used. In some cases, a modality may be indicated and contraindicated for the same condition. For example, thermotherapy (heat therapy) may be contraindicated for tendinitis during the initial phase of the exercise program. However, once acute inflammation is controlled, heat therapy may be indicated. Frequent evaluation of the individual's progress is necessary to ensure that the appropriate modality is being used.

In this chapter, the basic principles associated with the electromagnetic spectrum, and the factors affecting the transfer of energy are addressed initially. The more common therapeutic modalities used in sports injury management are then discussed. The material presented in this chapter is a general overview of the various modalities. Because of the extensive information and clinical skills needed to adequately comprehend and apply therapeutic modalities in a clinical setting, this chapter should not be used in lieu of a specialized course on therapeutic techniques. It is essential that a separate course in therapeutic modalities be a part of any student's professional preparation to become an entry-level athletic trainer.

ELECTROMAGNETIC SPECTRUM

Q After practice, a sprinter complains of a sore right lateral hamstring muscle. Following an assessment, you determine that the individual has a biceps femoris strain; and following acute care protocol, you decide to apply ice, compression, and elevation. How is the energy transmitted between the ice and underlying soft tissues?

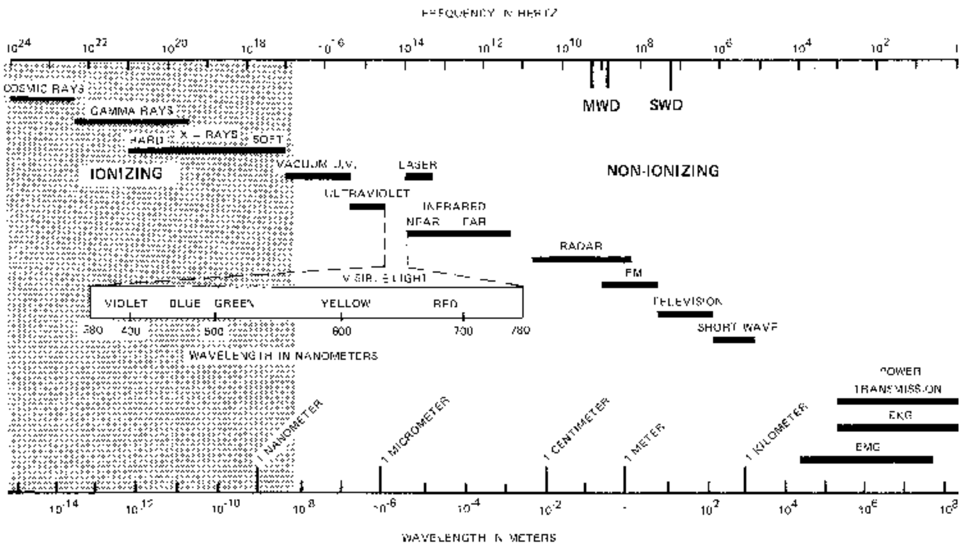
Various forms of energy in the environment impact us each day: the light from the sun, radio waves, heat from an oven, or cold from ice cubes. Each form of energy falls under the category of **electromagnetic radiation**, and can be located on an **electromagnetic spectrum** based on its wavelength or frequency **(Figure 7.1)**. Electrical therapeutic modalities are part of the electromagnetic spectrum. The spectrum is divided into two major zones: the ionizing range and the nonionizing range. Regardless of the range, electromagnetic energy has several common characteristics **(Box 7.1)**.

Ionizing Range

Energy in the ionizing range can readily alter the components of atoms (electrons, protons, and neutrons). This radiation can easily penetrate tissue to deposit energy within the cells. If the energy level is high enough, the cell loses its ability to regenerate, leading to cell death. Used diagnostically in x-rays (in dosages below that required for cell death) and therapeutically to treat certain cancers (above the threshold), the level is strictly controlled and monitored to prevent injury to the patient. It is not used by athletic trainers or physical therapists.

Nonionizing Range

Energy in the nonionizing range is commonly used in the management of musculoskeletal injuries. This portion of the spectrum incorporates ultraviolet, visible, and



➤ **Figure 7.1. Electromagnetic spectrum.**

➤➤ BOX 7.1

Characteristics of Electromagnetic Energy

- Electromagnetic energy is composed of pure energy and does not have a mass.
- Energy travels at the speed of light (300 million meters per second).
- Energy waveforms travel in a straight line and can travel in a vacuum.

infrared light. Electromagnetic waves are produced when temperature rises and electron activity increases. Ultraviolet light has a shorter wavelength than visible light; therefore, it is undetectable by the human eye. This energy source causes superficial chemical changes in the skin and is used to treat certain skin conditions. Sunburns are an example of excessive exposure to ultraviolet rays. Wavelengths greater than visible light are called infrared light, or infrared energy. Infrared wavelengths closest to visible light are called near infrared and can produce thermal effects 5- to 10-mm deep in tissue. Far infrared energy results in more superficial heating of the skin (<2 mm deep). Energy forms with much longer wavelengths are collectively known as diathermy, and can increase tissue temperature through a process called conversion. Microwave and shortwave diathermy are examples of this energy source.

Transfer of Energy

Electromagnetic energy can travel through a vacuum with no transfer medium. Energy moves from an area of high concentration to an area of lower concentration by energy carriers, such as mechanical waves, electrons, photons, and molecules. This energy flow in the form of heat involves the exchange of kinetic energy, or energy possessed by an object by virtue of its motion, and is transferred via radiation, conduction, convection, conversion, or evaporation.

➤ *Radiation*

Radiation is the transfer of energy in the form of infrared waves (radiant energy) without physical contact. All matter radiates energy in the form of heat. Usually, body heat is warmer than the environment, and radiant heat energy is dissipated through the air to surrounding solid, cooler objects. When the temperature of surrounding objects in the environment exceeds skin temperature, radiant heat is absorbed. Shortwave and microwave diathermy are examples of both radiant energy transfer, but also can heat by conversion.

➤ *Conduction*

Conduction is the direct transfer of energy between two objects in physical contact with each other. A difference in temperature is necessary to initiate the movement of kinetic energy from one molecule to another, and the energy moves from an area of high temperature to an area of lower temperature. Examples of conductive thermal agents are ice bags, ice packs, moist hot packs, and paraffin.

➤ *Convection*

Convection, a more rapid process than conduction, occurs when a medium, such as air or water, moves across the body, creating temperature variations. The effectiveness of heat loss or heat gain by conduction depends on how fast the air (or water) next to the body is moved away once it becomes warmed. For example, if air movement is slow, air molecules next to the skin are warmed and act as insulation. In contrast, if warmer air molecules are continually replaced by cooler molecules (e.g., on a breezy day or in a room with a fan), heat loss increases as the air currents carry heat away. Fluidotherapy and whirlpools are examples of therapeutic modalities that exchange energy by convection.

➤ *Conversion*

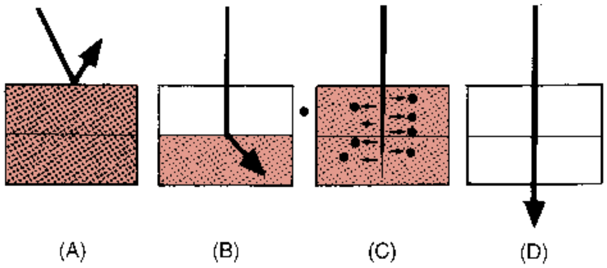
Conversion involves the changing of another energy form (e.g., sound, electricity, or a chemical agent) into heat. In ultrasound therapy, mechanical energy produced by high-frequency sound waves is converted to heat energy at tissue interfaces. In microwave diathermy, high electromagnetic energy is converted into heat, which can heat deep tissues. Chemical agents, such as liniments or balms, create heat by acting as counterirritants to superficial sensory nerve endings, thus reducing the transmission of pain from underlying nerves.

➤ *Evaporation*

Heat loss also can occur during evaporation. Vapocoolant sprays, for example, spread a liquid over the skin surface. The heat absorbed by the liquid cools the skin surface as the liquid changes into a gaseous state. Evaporation is also the means by which the body cools itself on a hot day through the evaporation of sweat.

Factors Affecting Energy Transfer

When electromagnetic energy is transmitted in a vacuum, it travels in a straight line. However, when traveling through a physical medium the path is influenced by the density of the medium and the energy may be reflected, refracted, or absorbed by the material, or it may continue to pass through the material, unaffected by its density **(Figure 7.2)**. **Reflection** occurs when the wave strikes an object and is bent back away from the material. An echo is an example of a reflected



➤ **Figure 7.2. Factors affecting the transmission of energy.** **A,** Reflection. The energy wave may be partially or fully reflected by the tissue layer. **B,** Refraction. The energy wave is bent as it strikes an interface between two different tissue layer densities. **C,** Absorption. Energy can be absorbed by one layer reducing the energy available to deeper tissues. **D,** Transmission. Any energy that is not reflected or absorbed by a tissue layer will continue to pass through the medium to the next layer where it can again be reflected, refracted, absorbed, or transmitted through the tissue.

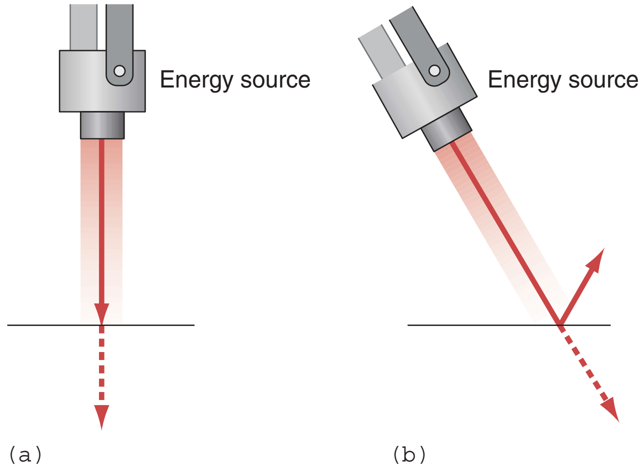
sound. The reflection itself may be complete or partial. **Refraction** is the deflection of waves because of a change in the speed of absorption as the wave passes between media of different densities. If energy passes through a high-density layer and enters a low-density layer, its speed increases. In contrast, if energy passes through a low-density layer to a high-density layer, its speed decreases. **Absorption** occurs when the wave passes through a medium and its kinetic energy is partially or totally assimilated by the tissue. Any energy that is not reflected or absorbed by a tissue layer passes through the layer until it strikes another density layer. It may again be reflected, refracted, absorbed, or transmitted through the medium. Each time the wave is partially reflected, refracted, or absorbed, the remaining energy available to the deeper tissues is reduced. This inverse relationship is called the **law of Grotthus-Draper**: The more energy absorbed by superficial tissues, the less is available to be transmitted to the underlying tissues.

Energy's Effect on Tissue

To be effective, therapeutic modalities must be capable of producing the desired effects at the intended tissue depth. When energy is applied to the body, the maximal effect occurs when energy rays strike the body at a right angle (90°). As the angle deviates from 90°, some of the energy is reflected away from the target site, thereby reducing the level of absorption. The **cosine law (Figure 7.3)** states that, as the angle deviates from 90°, the energy varies with the cosine of the angle:

$$\text{Effective energy} = \text{Energy} \times \text{cosine of the angle of incidence}$$

With radiant energy, a difference of ±10° from the right angle is considered to be within acceptable limits (1). Another law that affects energy absorption is the **inverse square**



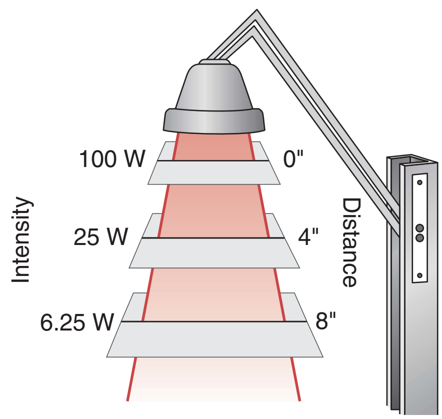
➤ **Figure 7.3. The cosine law.** When energy is applied to a body part, the maximal effect occurs when energy rays strike the body at a right angle (90°). As the angle deviates from 90°, some of the energy is reflected away from the targeted site, thereby reducing the level of absorption.

law (Figure 7.4). This law states that the intensity of radiant energy striking the tissues is directly proportional to the square of the distance between the source of the energy and the tissues: $E = E_S/D^2$.

E_S = amount of energy produced by the source
D^2 = square of the distance between the target and the source
E = resulting energy absorbed by the tissue

This means that each time the distance between the energy and the tissue is doubled, the intensity of the energy received by the tissue is reduced by a factor of four.

A The sprinter had an acute biceps femoris strain. If a crushed-ice bag is used, thermal energy would be transferred from the skin surface to the ice pack via conduction.



➤ **Figure 7.4. The inverse square law.** Heating effect equals *x* **(A).** When the distance between the energy source and the skin is reduced by half, the heating effect is increased by 4*x* (the inverse of ½ equals 2, and 2^2 equals 4).

CRYOTHERAPY

Q If you decided to use an ice pack on the sprinter, how long should you apply the ice? What contraindications may prohibit you from using this modality on the individual?

Cryotherapy describes multiple types of cold application that use the type of electromagnetic energy classified as infrared radiation. When cold is applied to skin (warmer object), heat is removed or lost. This is referred to as heat abstraction. The most common modes of heat transfer with cold application are conduction and evaporation. Cold application for less than 15 minutes causes immediate skin cooling, cooling of subcutaneous tissue after a slight delay, and a longer delay in cooling muscle tissue (2). Depth of cold penetration can reach 5 cm (1). The magnitude of temperature change depends on:

1. Type of cooling agent (e.g., ice versus water)
2. Temperature difference between the cold object and tissue
3. Amount of subcutaneous insulation (fat)
4. Thermal conductivity of the area being cooled
5. Limb circumference
6. Duration of the application (2)

The greater the temperature gradient between the skin and cooling source, the greater the resulting tissue temperature change. Likewise, the deeper the tissue, the longer the time required to lower the temperature. Adipose (fat) tissue acts as an insulator and resists heat transfer; both heat gain and heat loss. The amount of adipose tissue influences the degree and rate at which muscle is cooled, and conversely, return to its precooled temperature.

Cold application leads to vasoconstriction at the cellular level and decreases tissue metabolism (i.e., decreases the need for oxygen), which reduces secondary hypoxia. Capillary permeability and pain are decreased, and the release of inflammatory mediators and prostaglandin synthesis is inhibited. As the temperature of peripheral nerves decreases, a corresponding decrease is seen in nerve conduction velocity across the nerve synapse, thus increasing the threshold required to fire the nerves. The gate theory of pain hypothesizes that cold inhibits pain transmission by stimulating large-diameter neurons in the spinal cord, acting as a counterirritant, which blocks pain perception. Because of the inhibition of nerves and muscle spindle activity, muscles in spasm are relaxed, breaking the pain-spasm cycle, leading to an **analgesic**, or pain-free, effect. Research also has shown that during ice application, a decline in fast-twitch muscle fiber tension occurs, resulting in a more significant recruitment of slow-twitch muscle fibers, thereby increasing muscle endurance (3).

Because vasoconstriction leads to a decrease in metabolic rate, inflammation, and pain, cryotherapy is the modality of choice during the acute phase of an injury. According to Starkey, the therapeutic application of cold ranges in temperature from 0° to 18.3°C (32 to 65°F) (1). However, researchers have identified that maximal decreases in localized blood flow can occur at temperatures ranging from 12.83° to 15°C (55° to 59°F) (4,5). The desired therapeutic range of cooling can be obtained through the use of ice bags (crushed or cubed), commercial ice packs, ice cups (ice massage), cold water baths (immersion or whirlpool), and vapo-coolant sprays. Recent technology also has provided new forms of cold application such as the Cryocuff, or controlled cold therapy (CCT) units.

Cryotherapy is usually applied for 20 to 30 minutes for maximum cooling of both superficial and deep tissues. Barriers used between the ice application and skin can affect heat abstraction. Research has shown that a dry towel or dry elastic wrap should not be used in treatment times of 30 minutes or less. Rather, the cold agent should be applied directly to the skin for optimal therapeutic effects (6,7). Ice application is continued during the first 24 to 72 hours after injury, or until acute bleeding and capillary leakage have stopped, whichever is longer. Another consideration is the length of time it takes to rewarm the injured area. Knight has shown that except for the fingers, the rewarming time to approach normal body temperature is at least 90 minutes (7). This results in a treatment protocol of applying an ice pack for 20 to 30 minutes, followed by 90 minutes of rewarming. Fingers can rewarm more quickly, even following a 20- to 30-minute ice treatment, presumably because of their increased circulation. Fingers need only 20 to 30 minutes to rewarm.

Cold therapy has long been used after arthroscopic knee surgery. Although some researchers have found that the addition of cryotherapy to a regimen of exercises following arthroscopic knee surgery did produce some benefits of increased compliance, improved weight-bearing status, and lower prescription medication consumption (8), other researchers have shown that this use of cold therapy is questionable (9,10).

Certain methods of cryotherapy also may be used prior to ROM exercises and at the conclusion of an exercise bout **(Box 7.2)**. Use of cold treatments before exercise is called **cryokinetics**. Cryokinetics alternates several bouts of cold using ice massage, ice packs, ice immersion, or iced towels with active exercise. The injured body part is numbed (generally 10 to 20 minutes of immersion), and the individual is instructed to perform various progressive exercises. These exercises may begin with simple, non–weight-bearing ROM activities and progress to more complex, weight-bearing activities. All exercise bouts must be pain free. As the mild anesthesia from the cold wears off, the body part is renumbed with a 3- to 5-minute cold treatment. The exercise bout is repeated three to four times each session. The session then ends with exercise if the individual is able to participate, or with cold if the individual is not able to participate in practice.

Methods of cryotherapy include ice massage, ice and cryo packs, ice immersion and cold whirlpools, commercial gel and chemical packs, controlled cold compression units,

➤➤ BOX 7.2

Cryotherapy Application

Indications

- Acute or chronic pain
- Acute or chronic muscle spasm/guarding
- Acute inflammation or injury
- Postsurgical pain and edema
- Superficial first-degree burns
- Used with exercises to:
  - Facilitate mobilization
  - Relieve pain
  - Decrease muscle spasticity

Contraindications

- Decreased cold sensitivity and/or hypersensitivity
- Cold allergy
- Circulatory or sensory impairment
- Raynaud's disease or cold urticaria
- Hypertension
- Uncovered open wounds
- Cardiac or respiratory disorders
- Nerve palsy
- Arthritis

and vapo-coolant sprays. With each method, the individual experiences four progressive sensations: cold, burning, aching, and finally **analgesia**.

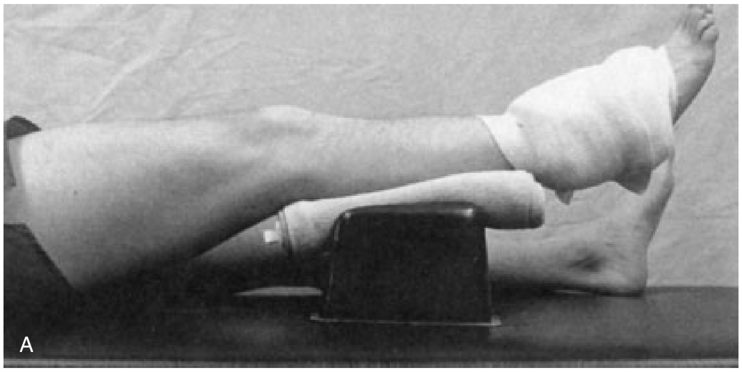
Ice Massage

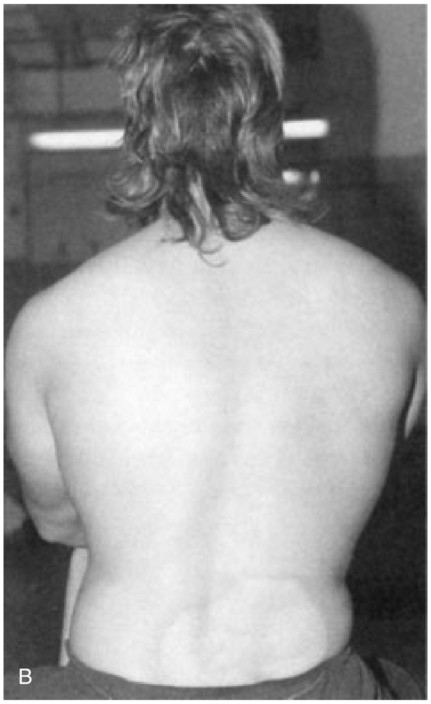
Ice massage is an inexpensive and effective method of cold application. Performed over a relatively small area, such as a muscle belly, tendon, bursa, or trigger point (localized area of spasm within a muscle), it produces significant cooling of the skin and a large reactive **hyperemia**, or increase of blood flow into the region, once the treatment has ended. As such, it is not the treatment of choice in acute injuries. Ice massage is particularly useful for its analgesic effect in relieving pain that may inhibit stretching of a muscle, and has been shown to decrease muscle soreness when combined with stretching (2). It is commonly used prior to ROM exercises and deep friction massage when treating chronic tendinitis and muscle strains.

Treatment consists of water frozen in a cup, then rubbed over an area 10 × 15 cm in small, overlapping circular motions for 5 to 10 minutes. A continuous motion is used to prevent tissue damage. If done properly, skin temperature should not decrease below 15°C (59°F) (2). A wooden tongue depressor frozen in the cup provides a handle for easy application. With ice massage, the stages of cold, burning, and aching pass rapidly within about 1 to 2 minutes. A prolonged aching or burning sensation may result if the area covered is too large, or if a hypersensitive response occurs.

Ice Packs and Contoured Cryocuffs

Ice packs are inexpensive and maintain a constant temperature, making them very effective in cooling tissue. When filled with flaked ice or small cubes, the ice packs can be safely applied to the skin for 30 to 40 minutes without danger of frostbite. Furthermore, ice packs can be molded to the body's contours, held in place by a cold compression wrap, and elevated above the heart to minimize swelling and pooling of fluids in the interstitial tissue spaces **(Figure 7.5A)**. During the initial treatments,





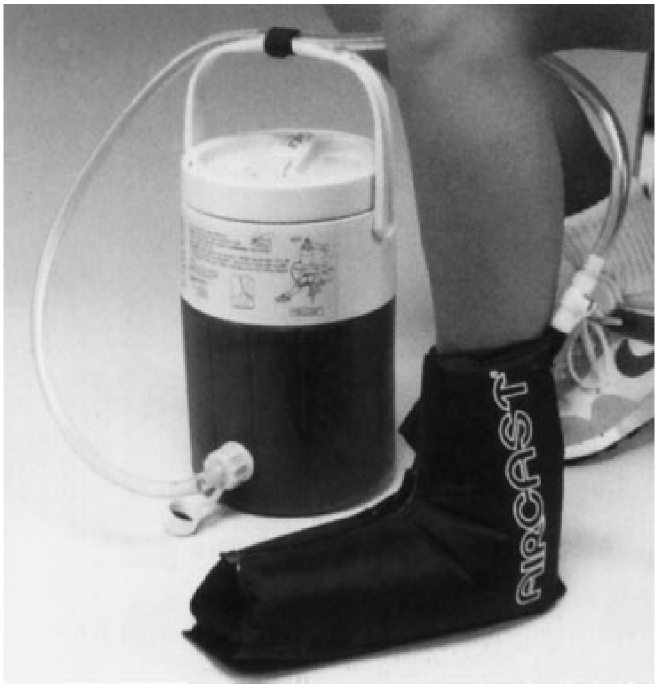
➤ **Figure 7.5. Ice treatments. A,** Ice, compression, and elevation can reduce acute inflammation. **B,** A slightly raised wheal formation may appear shortly after cold application in individuals who are sensitive to cold or have cold allergies.

the skin should be checked frequently for **wheal** or blister formation **(Figure 7.5B)**.

Contoured Cryocuffs use ice water placed in an insulated thermos. When the thermos is raised above the body part, water flows into the Cryo Pack, maintaining cold compression for 5 to 7 hours **(Figure 7.6)**. Although more expensive than ice packs, these devices combine ice and compression over a longer period without threat of frostbite.

Ice Immersion

Ice immersion is used to reduce temperature quickly over the entire surface of a distal extremity (forearm, hand, ankle, or foot). A variety of containers or basins may be used. Because of the analgesic effect and buoyancy of water, ice immersion and cold whirlpools often are used during the inflammatory phase to reduce edema formation after blunt injury **(Field Strategy 7.1)**. Cold whirlpool baths also provide a hydromassaging effect. This is controlled by the amount of air emitted through the electrical turbine. The turbine can be moved up and down, or directed at a specific angle and locked in place. The whirlpool turbine should not be operated unless water totally covers the impeller. In addition to controlling acute inflammation, cold whirlpools can be used to



➤ **Figure 7.6. Contoured Cryocuffs.** When the thermos is raised above the body part, water flows into the Cryo pack, maintaining cold compression for 5 to 7 hours.

FIELD STRATEGY 7.1 Techniques for Using a Whirlpool Bath

1. Inspect the electrical system. To avoid electrical surges, make sure that ground-fault circuit breakers are used in the electrical outlet or in the circuit-breaker box.
2. Apply a povidone-iodine (Betadine) additive, or chloramine-T (Chlorazene) in concentrations of 100 to 200 parts per million (ppm) to the water as an antibacterial agent, especially if the athlete has an open wound.
3. Recommended temperature and treatment time include:

Cold whirlpools	55–65°F	5–15 min
Hot whirlpools		
Extremity	98–110°F	20–30 min
Full body	98–102°F	10–12 min

4. Assist the patient into the water and provide towels for padding and drying off.
5. Turn the turbine on and adjust the height to direct the water flow 6 to 8 inches away from the injury site.
6. Instruct the patient to move the body part through the available range of motion. This increases blood flow to the area, aids in removal of debris, and improves balance and proprioception.
7. Turn the turbine off and remove the patient from the water. Dry the treated area and assist the individual from the whirlpool area.
8. Drain and cleanse the whirlpool tub after each use. Disinfect the hard-to-reach places with glutaraldehyde, formalin alcohol, ethylene oxide, or beta propiolactone to kill sport-forming bacteria. A solution of sodium hypochlorite (chlorine bleach), in concentrations ranging from 500 ppm (1:100 dilution) to 5000 ppm (1:10 dilution) is effective in cleaning surface organic material (blood, mucus).
9. Cultures for bacterial and fungal agents should be conducted monthly from water samples in the whirlpool turbine and drain.

➤ **Figure 7.7.** **Ice immersion.** This technique quickly reduces temperature over the entire surface area of a distal extremity. Toe caps may be used to prevent frostbite of the toes during the treatment.

decrease soft-tissue trauma and increase active ROM after prolonged immobilization.

If the goal is to reduce edema, placing the body part in a stationary position below the level of the heart keeps fluid in the body segment and is contraindicated. This can be avoided by placing a compression wrap over the body part prior to submersion and doing active muscle contractions. Neoprene toe caps may be used to reduce discomfort on the toes.

A bucket or cold whirlpool is filled with water and ice **(Figure 7.7)**. Bucket immersion in 40° to 50°F (4° to 10°C) water or a 50° to 60°F (10° to 15°C) whirlpool cools tissues as effectively as an ice pack. The lower the temperature, the shorter the duration of immersion. Treatment lasts from 5 to 15 minutes. When pain is relieved, the part is removed from the water and functional movement patterns are performed. As pain returns, the area is reimmersed. The cycle continues three to four times.

Contrast Bath

A contrast bath alternates cold and hot tubs or whirlpools. This elicits a local vasoconstriction-vasodilation fluctuation to reduce edema and restore ROM in subacute or chronic injuries. Two whirlpools or containers are placed next to each other. One is filled with cold water and ice at 10° to 18°C (50° to 65°F), and the other is filled with hot water at 38° to 44°C (100° to 111°F) (11). The injured extremity is alternated between the two tubs. One treatment method involves a 3:1 or 4:1 ratio (hot water to cold water) for approximately 20 minutes. In subacute conditions, the treatment begins and ends in cold water prior to starting therapeutic exercise. In chronic conditions, treatment is more often concluded in warm immersion. A second method is to base treatment on a variable time frame. During the first cycle, 75% of the time is in cold water and 25% of the time is in hot water. The second cycle moves to 50% in cold water and 50% in hot water, with the third cycle moving to 25% in cold and 75% in hot water. However, research has failed to demonstrate any significant physiologic effect on intramuscular tissue temperature 1 cm below the skin and subcutaneous fat (12,13). Therefore, contrast therapy may need to be reconsidered as a viable therapeutic modality.

Commercial Gel and Chemical Packs

Commercial gel packs are composed of a flexible gelatinous substance enclosed in a strong vinyl or plastic case, and come in a variety of sizes to conform to the body's natural contours **(Figure 7.8A)**. Used with compression and elevation, they are an effective cold application. The packs are stored at a temperature of about –5°C (–23°F)

➤ **Figure 7.8.** **Commercial and chemical ice packs. A,** Commercial gel packs come in a variety of sizes to conform to the body's natural contours. Chemical ice packs are convenient to carry in a training kit, disposable after a single use, and also can conform to the body part. **B,** However, chemical ice packs can leak and burn the skin.

for at least 2 hours prior to application (2). Because the packs are stored at subzero temperatures, they may cause frostbite if used improperly. A wet towel or cloth should be placed between the pack and skin to prevent frostbite and maintain a hygienic surface for the reusable packs. Treatment time is 15 to 20 minutes.

Chemical packs can be advantageous because they are convenient to carry in a training kit, disposable after a single use, and conform to the body part. A disadvantage of the packs is their expense. The packs are activated by squeezing or hitting the pack against a hard area. The chemical substance has an alkaline pH and can cause skin burns if the package breaks and the contents spill **(Figure 7.8B)**. As such, the packs should never be squeezed or used in front of the face, and if possible, should be placed inside another plastic bag. Treatment ranges from 15 to 20 minutes. In longer treatments, the pack warms and becomes ineffective. Some commercial packs can be refrozen and reused.

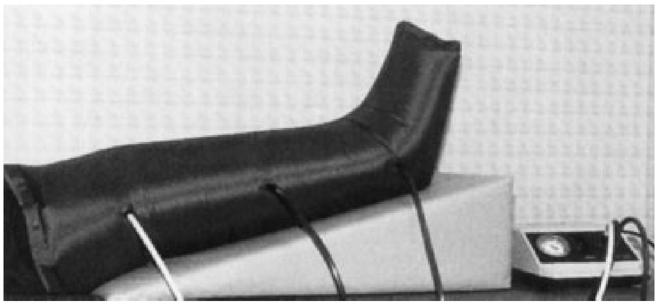
Intermittent Compression Units

Intermittent cold-compression units like the Cryotemp use compression and elevation to decrease blood flow to an extremity and assist venous return, thus decreasing edema. A boot or sleeve is applied around the injured extremity. Cooled water is circulated through the sleeve. Compression is formed when the sleeve is inflated intermittently. This is done for 20 to 30 minutes, several times a day, to pump edema fluid from the extremity **(Figure 7.9)**. During deflation, the patient can do active ROM exercises to enhance blood flow to the injured area. The unit can be used several times a day, but should never be used with a suspected compartment syndrome or fracture, or in an individual with a peripheral vascular disease or impaired circulation.

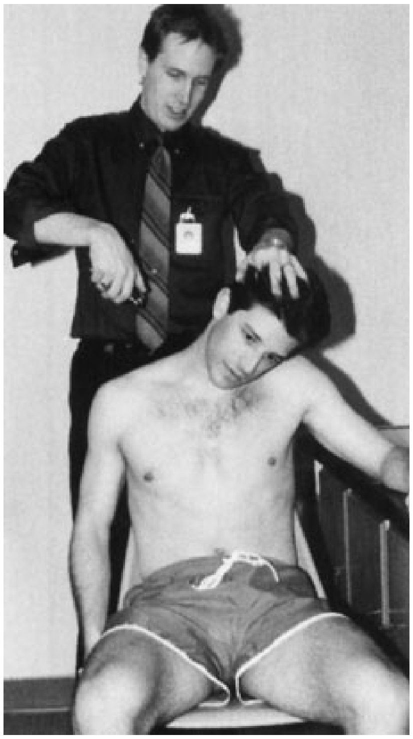
Vapo-coolant Sprays

Fluoromethane is a nonflammable, nontoxic spray that uses rapid evaporation of chemicals on the skin area to cool the skin prior to stretching a muscle **(Figure 7.10)**. The effects are temporary and superficial. When using a vapo-coolant spray to increase ROM in an area where no trigger point is present, the patient is comfortably positioned with the muscle passively stretched. The bottle of vapo-coolant spray is then inverted and held at a 30° to 45° angle and sprayed approximately 12 to 18 inches away from the skin. The entire length of the muscle is sprayed two to three times in a unidirectional, parallel sweeping pattern as a gradual stretch is applied by the clinician.

When using this spray to treat trigger points and myofascial pain, the clinician must first determine the presence of an active trigger point. This is accomplished by putting the muscle under moderate tension, followed by application of firm pressure over the painful site for 5 to 10 seconds. Another technique involves eliciting a jump response. This method also involves placing the muscle under moderate tension. Firm pressure is applied over the tense muscle, and a finger is pulled across the tight band of muscle. If the individual winces or cries out, an active trigger point is present. The individual is then placed in a relaxed, but well-supported position with the involved muscle placed on stretch. The vapo-coolant spray is sprayed from about 12 inches above the skin at an acute angle to the painful site. The entire length of the muscle is sprayed, including the painful site, while the clinician begins a mild passive stretch of the involved muscle, within the patient's tolerance. After several parallel sweeps of the muscle and continued passive stretching, the muscle should be warmed with a hot pack or vigorous massage. The patient should be encouraged to



➤ **Figure 7.9. Controlled cold compression unit.** An air- or water-filled boot or sleeve can provide pressure or intermittent compression to an injured area to decrease edema.



➤ **Figure 7.10. Vapo-coolant sprays.** These sprays temporarily freeze superficial tissues and can reduce the pain-spasm cycle prior to stretching exercises.

actively but gently move the body part throughout the full ROM. The process may need to be repeated; however, it is critical not to overload the muscle with strenuous exercise immediately after the session.

A In applying an ice pack to the posterior thigh of the sprinter, treatment time should range from 20 to 30 minutes. A maximum of 90 minutes should be allowed to rewarm the tissues, followed by another cold treatment. If the individual experiences any skin blanching, numbness, burning, or tingling sensations, the cold treatment should be stopped.

THERMOTHERAPY

Q The sprinter demonstrates a marked improvement in swelling, tenderness, and ROM over the next 5 days, although strength has not totally returned to normal. Is it safe at this time to move to a heat modality, or is there a risk that swelling and edema may return to the region?

Thermotherapy, or heat application, is typically used in the second phase of rehabilitation to increase blood flow and promote healing in the injured area **(Box 7.3)**. If used during the acute inflammatory stage, heat application may overwhelm the injured blood and lymphatic vessels, leading to increased hemorrhage and edema. However, when applied at the appropriate time heat can increase circulation and cellular metabolism; produce an analgesic, or sedative effect; and assist in the resolution of pain and muscle-guarding spasms. Vasodilation and increased circulation result in an influx of oxygen and nutrients into the area to promote healing of damaged tissues. Debris and waste products are removed from the injury site. Used prior to stretching exercises, joint mobilization, or active exercise, thermotherapy can increase extensibility of connective tissue, leading to increased ROM. In the same manner as cold application, heat flow through tissue also varies with the type of tissue, and is called thermal conductivity. Changes in surface tissue temperature caused by superficial heating agents depend on the following:

- Intensity of heat applied
- Time of heat exposure
- Thermal medium for surface heat

The greatest degree of elevated temperature occurs in the skin and subcutaneous tissues within 0.5 cm of the skin surface. In areas with adequate circulation, temperature increases to its maximum within 6 to 8 minutes of exposure. Muscle temperature at depths of 1 to 2 cm increase to a lesser degree and require a longer duration of exposure (15 to 30 minutes) to reach peak values (14). After peak temperatures are reached, a plateau effect or slight decrease in skin temperature is seen over the rest of the heat application. As mentioned, fat is an insulator and has a low thermal conductivity value. Therefore, tissues under a large amount of fat are minimally affected by superficial heating agents. To elevate deep tissues to the desired thermal levels without burning the skin and subcutaneous tissue, a deep-heating agent such as continuous ultrasound or shortwave diathermy should be selected.

With superficial heating agents, heat is transferred by conduction, convection, and radiation. Common examples of superficial thermotherapy are whirlpools, hot tubs and Jacuzzis, moist hot packs, and paraffin baths. Penetrating thermotherapy, including ultrasound, phonophoresis, and diathermy heat, are discussed in more detail later in the chapter.

➤➤ BOX 7.3

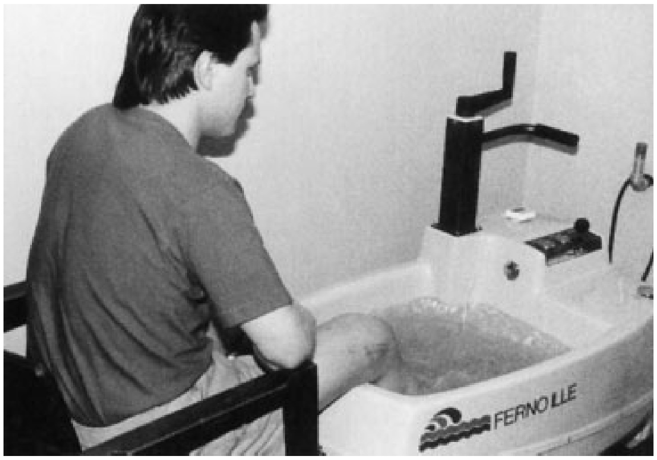
Thermotherapy Application

Indications	Contraindications
Subacute or chronic injuries, to:	Acute inflammation or injuries
Reduce swelling, edema, and ecchymosis	Impaired or poor circulation
Reduce muscle spasm/guarding	Subacute or chronic pain
Increase blood flow, to:	Impaired or poor sensation
Increase range of motion prior to activity	Impaired thermal regulation
Resolve hematoma	Malignancy
Facilitate tissue healing	
Relieve joint contractures	
Fight infection	

Whirlpool and Immersion Baths

Whirlpool and immersion baths combine warm or hot water with a hydromassaging effect to increase superficial skin temperature **(Figure 7.11)**. Tanks may be portable or fixed, and include the more common extremity tanks and full-body therapeutic tubs, such as the Hubbard tank or walk tank.

Physiologically, warm or hot whirlpools are analgesic agents that relax muscle spasms, relieve joint pain and stiffness, provide mechanical débridement, and facilitate ROM exercises after prolonged immobilization. As with cold whirlpools and immersion baths, buoyancy facilitates increased ROM, and the hydromassaging effect is controlled by the amount of air emitted through the electrical turbine. The more agitation, the greater the water movement. The turbine can be moved up and down, or directed at a specific angle and locked in place. Treatment time ranges from 20 to 30 minutes. Total body immersion



➤ **Figure 7.11. Whirlpools.** Hot whirlpools increase superficial skin temperatures, leading to an analgesic effect that can reduce muscle spasm and pain, facilitate range of motion exercises, and promote healing.

exceeding 20 to 30 minutes can dehydrate the individual, leading to dizziness and high body core temperature. Only the body parts being treated should be immersed. Field Strategy 7.1 explains the use of this modality.

For safety reasons, ground-fault circuit interrupters (GFCIs) should be installed in all receptacles or in the circuit breaker box in the hydrotherapy area, and should be no more than 1.5 m away from the tanks. A sensor located within the GFCI monitors current in the hot and neutral lines that feed the receptacle. Because the maximum safe transthoracic current (through intact skin) is deemed to be 5 mA, the GFCI activates at this level and immediately trips the circuit to disconnect all current to the receptacle. These receptacles should be inspected annually to ensure that they are operating properly.

Hot Tubs and Jacuzzis

Although not a common modality in the athletic training room, many individuals have access to hot tubs and Jacuzzis. Because organic contaminants, high water temperature, and turbulence reduce the effectiveness of chlorine as a bacterial agent, infection with *Pseudomonas aeruginosa* causing folliculitis is an alarming and increasing problem. To prevent infection, these tubs must have a good filtration and chlorination system. Chlorine and pH levels should be monitored hourly during periods of heavy use, and calcium hardness should be evaluated weekly (11). The water should be drained, superchlorinated, and refilled once every 3 months. The water temperature should not exceed 38.9°C (102°F).

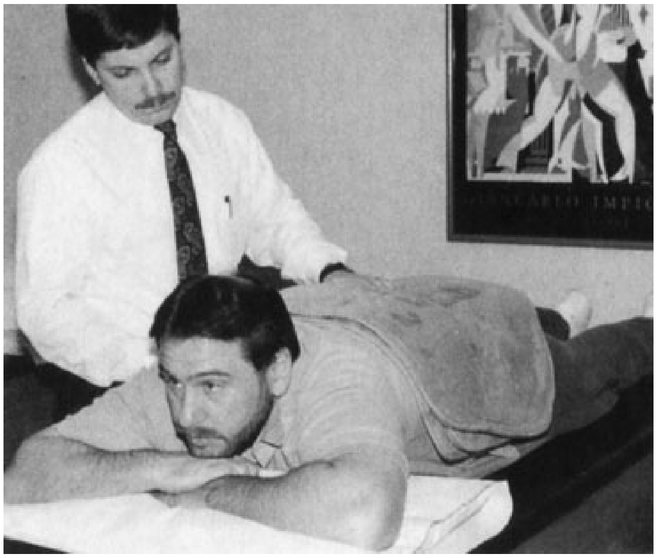
Moist Hot Packs

Moist hot packs provide superficial heat, transferring energy to the individual's skin by way of conduction. Each subsequent underlying tissue layer is heated through conduction from the overlying tissue, reaching a slightly deeper tissue level than a whirlpool. Like other forms of superficial heating, deeper tissues, including the musculature, are usually not significantly heated. The heat transfer is inhibited by subcutaneous fat, which acts as a thermal insulator, and by the increased blood flow through the area that carries away externally applied heat. Moist hot packs are used most often to reduce pain and superficial muscle spasm, and to improve tissue extensibility.

The pack consists of a canvas or nylon case filled with a hydrophilic silicate or other hydrophilic substance, or with sand. The packs are stored in a hot water unit at a temperature ranging from 70° to 75°C (158° to 170°F) **(Figure 7.12)** (14). When removed from the water, the pack is wrapped in a commercial padded cover, or in six to eight layers of toweling, and placed directly over the injury site for 20 minutes. Commercial hot pack covers may need another layer or two of toweling to ensure adequate insulation for the hot pack.

The pack should be secured and completely cover the area being treated. As with other forms of heat application, the patient should only feel a mild to moderate sensation of heat. The patient should never lie on top of the pack, as this may accelerate the rate of heat transfer leading to burns on sensitive skin. After 5 minutes of treatment, the area should be checked for any redness or signs of burning.

The hot packs also should be checked regularly for leaks, and should be discarded if any leaking occurs. This may become evident when cleaning the unit on a monthly basis. Hydrophilic silicate may accumulate on the bottom of the unit, and should be removed so as not to interfere with the heating element.



➤ **Figure 7.12. Moist hot packs.** Moist heat treatments can burn sensitive skin. To avoid this, place the pack in a commercial padded towel, or six to eight layers of towel, and periodically check the skin surface for redness or signs of burning.

Paraffin Baths

Paraffin baths provide heat to contoured bony areas of the body (e.g., feet, hands, or wrists). They are used to treat subacute or chronic rheumatoid arthritis associated with joint stiffness and decreased ROM, as well as other common chronic injuries. A paraffin and mineral oil mixture (6:1 or 7:1 ratio) is heated in a unit at 48° to 52°C (118° to 126°F).

There are two principal methods of application: (1) dip and wrap, and (2) dip and reimmerse. For both methods, the body part is thoroughly cleansed and dried, and all jewelry is removed. The body part is placed in a relaxed position, and then dipped into the bath several times, each time allowing the previous coat to dry **(Figure 7.13)**. The patient should not move the fingers or toes, so as not to break the seal of the glove being formed. In addition, outer layers of paraffin should not extend over new skin, because burning may occur. When completed, the body part is wrapped in a plastic bag and towel to maintain heat, then elevated for 15 to 20 minutes or until heat is no longer generated.

When using the dip and reimmerse method, following the formation of a wax glove, the body part covered by the glove is put back into the wax container for 15 to 20 minutes without moving it. This method results in a more vigorous response relative to temperature elevation and blood flow changes. However, this technique should not be used in individuals predisposed to edema, or those who cannot sit in the position required for treatment.

When the treatment is completed, the wax is peeled off and returned to the bath where it can be reused. The mineral oil in the wax helps keep skin soft and pliable during massage when treating a variety of hand and foot conditions. In comparison with other heat modalities, paraffin wax is not significantly better at decreasing pain or increasing joint ROM. It should not be used in patients with decreased sensation, open wounds, thin scars, skin rashes, or peripheral vascular disease.

➤ **Figure 7.13. Paraffin bath.** The limb is thoroughly cleansed and dipped several times into the paraffin solution. The body part is then wrapped in plastic and a towel to maintain heat, or it can be reimmersed into the solution and held motionless for the duration of the treatment.

Fluidotherapy

Fluidotherapy is a dry heat modality used to treat acute injuries and wounds, decrease pain and swelling, and increase ROM and inadequate blood flow. The unit contains fine cellulose particles that become suspended when a stream of dry hot air is forced between them, making the fluidized bed behave with properties similar to that of liquids. Both temperature and the amount of particle agitation can be varied. Treatment temperature ranges from 38.8° to 47.8°C (102° to 118°F). An advantage of this superficial heating modality is that exercise can be performed during the treatment, and higher treatment temperatures can be tolerated. If a body part has an open wound, a plastic barrier or bag can be placed over the wound to prevent any fine cellulose particles from becoming embedded in the wound and to minimize the risk of cross-contamination. Treatment duration ranges from 15 to 20 minutes.

A The sprinter showed marked improvement after 5 days of ice treatments. As long as the individual does not complain of tenderness to touch, it is probably safe to move to a heat treatment. Heat can increase the local circulation, promote healing, and can be used in conjunction with stretching and mild exercise to strengthen the injured muscle.

ULTRASOUND

Q After 2 weeks, the sprinter is no longer point tender on palpation, but there is still a small, palpable swollen area in the region of the short head of the biceps femoris. What type of heat treatment is most effective at this point of the injury process?

Superficial heating agents were discussed in the previous section. These agents produce temperature elevations in skin and underlying subcutaneous tissues to a depth of 1 to 2 cm. Ultrasound uses high-frequency acoustic (sound) waves, rather than electromagnetic energy, to elicit thermal and nonthermal effects in deep tissue to depths of 3 cm or more. This transfer of energy takes place in the deep structures without causing excessive heating of the overlying superficial structures. The actual mechanism of ultrasound, produced via the **reverse piezoelectric effect**, converts electrical current to mechanical energy as it passes through a piezoelectric crystal (e.g., quartz, barium titanate, and lead zirconate titanate) housed in the transducer head. The vibration of the crystal results in organic molecules moving in longitudinal waves that move the energy into the deep tissues to produce temperature increases (thermal effects), and mechanical and chemical alterations (nonthermal effects). Thermal effects increase collagen tissue extensibility, blood flow, sensory and motor neuron velocity, and enzymatic activity, and decrease muscle spasm, joint stiffness, inflammation, and pain. Nonthermal effects decrease edema by increasing cell membrane and vascular wall permeability, blood flow, protein synthesis, and tissue regeneration, thus promoting the healing process.

The Ultrasound Wave

Unlike electromagnetic energy, sound cannot travel in a vacuum. Sound waves, such as those produced by a human voice, diverge in all directions. This principle allows you to hear someone talking behind you. As the frequency increases, the level of divergence decreases. Like sound waves, the frequencies used in therapeutic ultrasound produce collimated cylindrical beams, similar to a light beam leaving a flashlight, that have a width slightly smaller than the diameter of the transducer head. The **effective radiating area** (ERA) is the portion of the transducer's surface area that actually produces the ultrasound wave.

Frequency and Attenuation

The frequency of ultrasound is measured in megahertz (MHz) and represents the number of waves (in millions) occurring in 1 second. Frequencies range between 0.75 and 3.3 MHz. For a given sound source, the higher the frequency, the less the emerging sound beam diverges. For example, low-frequency ultrasound produces a more widely diverging beam than high-frequency ultrasound, which produces a collimated beam. The more commonly used 1.0-MHz generator is transmitted through superficial tissues and absorbed primarily in deeper tissues at depths of 3 to 5 cm or greater.

Energy contained within a sound beam decreases as it travels through tissue. The level of absorption depends on the type of tissues to which it is applied. Tissues with high protein content (e.g., nerve and muscle tissue) absorb ultrasound readily. Deflection (reflection or refraction) is greater at heterogeneous (different or unrelated) tissue interfaces, especially at the bone-muscle interface. This deflection creates standing waves that increase heat. Ultrasound that is not absorbed or deflected is transmitted through the tissue.

Absorption of sound, and therefore attenuation, increases as the frequency increases. The higher the frequency, the more rapidly the molecules are forced to move against this friction. As the absorption increases, there is less sound energy available to move through the tissue. The 1-MHz machine is most often used on individuals with a high subcutaneous body fat percentage, and whenever the desired effects are in the deeper structures. This ultrasound unit also has been used to stimulate collagen synthesis in tendon fibroblasts after an injury, and stimulate cell division during periods of rapid cell proliferation (15). It has also been used on tendons on the second and fourth days after surgery to increase tensile strength. However, after the fifth day, application decreases tensile strength (16).

The high-frequency 3-MHz machine provides treatment to superficial tissues and tendons with a depth of penetration between 1 and 2 cm (⅓ to ¼ inch). The low penetration depth is associated with limited transmission of energy, a rapid absorption of energy, and a higher heating rate in a relatively limited tissue depth.

Types of Waves

Sound waves can be produced as a continuous or pulsed wave. A continuous wave is one in which the sound intensity remains constant, whereas a pulsed wave is intermittently interrupted. Pulsed waves are further delineated by the fraction of time the sound is present over one pulse period, or duty cycle. This is calculated with the following equation:

Duty cycle = duration of pulse (time on) × 100 pulse period (time on + time off)

Typical duty cycles in the pulse mode range from 0.05 (5%) to 0.5 (50%), with the most commonly used duty cycle being that of 0.02 (20%) (17). Continuous ultrasound waves provide both thermal and nonthermal effects, and are used when a deep, elevated tissue temperature is advisable. Pulsed ultrasound and low-intensity, continuous ultrasound produce primarily nonthermal effects and are used to facilitate repair and soft-tissue healing when a high increase in tissue temperature is not desired.

Intensity

Therapeutic intensities are expressed in watts per square centimeter (W/cm^2), and range from 0.25 to 2.0 W/cm^2. The greater the intensity, the greater the resulting temperature elevation. Thermal temperature can increase 7° to 8°F up to a depth of 5 cm (1). As mentioned, ultrasound waves are absorbed in tissues highest in collagen content, and they are reflected at tissue interfaces, particularly between bone and muscle.

Clinical Uses of Ultrasound

Ultrasound is used to manage several soft-tissue conditions, such as tendinitis, bursitis, and muscle spasm; reabsorb calcium deposits in soft tissue; and reduce joint contractures, pain, and scar tissue **(Box 7.4)**. Wound healing is enhanced with low-intensity, pulsed ultrasound. It is recommended that ultrasound treatment begin 2 weeks after injury during the proliferative phase of healing. Earlier treatment may increase inflammation and delay healing time. Tissue healing is thought to occur predominantly through nonthermal effects. An intensity of 0.5 to 1.0 W/cm^2 pulsed at 20% is recommended for superficial wounds. For skin lesions and ulcers, a frequency of 3 MHz or higher is recommended (17).

Ultrasound is frequently used with other modalities. Used in conjunction with hot packs, muscle spasm and muscle guarding may be reduced. The hot pack produces superficial heating, while the ultrasound, using a 1-MHz

➤➤ BOX 7.4

Ultrasound Application

Indications	Contraindications
Increase deep tissue heating	Acute and postacute hemorrhage
Decrease inflammation and resolve hematomas	Infection
Decrease muscle spasm/spasticity	Thrombophlebitis
Decrease pain	Over suspected malignancy/cancer
Increase extensibility of collagen tissue	Areas of impaired circulation or sensation
Decrease pain of neuromas	Over stress fracture sites
Decrease joint adhesions and/or joint contractures	Over epiphyseal growth plates
Treat postacute myositis ossificans	Over the eyes, heart, spine, or genitals

ultrasound frequency, produces heating in the deeper tissues. Because ultrasound can increase the blood flow to deep tissues, this modality is often used with electrical stimulation units. The electrical current produces a muscle contraction or modulates pain while the ultrasound increases circulation and provides deep heating. This combination of treatment protocols can be effective in treating trigger points and acupuncture points.

Application

Because ultrasound waves cannot travel through air, a coupling agent is used between the transducer head and skin to facilitate passage of the waves. Coupling gels are applied liberally over the area to be treated. The transducer head is then stroked slowly over the area **(Figure 7.14)**. Strokes are applied in small continuous circles or longitudinal patterns to distribute the energy as evenly as possible at a rate of 4 cm/s to prevent **cavitation** (gas bubble formation) in deep tissues (17). The total area covered is usually two to three times the size of the transducer head for every 5 minutes of exposure. If a larger area is covered, the effective dosage and elevated temperature changes delivered to any one region decrease. A firm, uniform amount of pressure exerted on the transducer head maximizes the transmission of acoustic energy between the sound head and tissue interface.

A common alternate method for irregularly shaped areas (e.g., wrist, hand, ankle, or foot) is application under water. If the treatment is given in a metal basin or whirlpool, some of the ultrasound energy is reflected off the metal, thus increasing intensity in certain areas near the metal. In addition, water in a whirlpool often has a large number of air bubbles, which tend to reduce the transmission of ultrasound. This problem is even more pronounced if the turbine was used prior to the ultrasound treatment. For these reasons, metal containers and whirlpools should not be used for underwater treatments. Water treatments are indirect and generally have a 0.5- to 3-cm space between the patient and the sound head. Intensity is increased 0.5 W/cm^2 to compensate for air and minerals in the water (1). Small air bubbles tend to accumulate on the face of the transducer head and the skin surface when this method is used. The clinician should quickly wipe off the accumulated bubbles during the treatment. No jewelry should be worn under the water surface. In addition, the athletic trainer should hold the transducer head so his or her hand is out of the water.

If for some reason, the injured area cannot be immersed in water, a bladder technique may be used. A small balloon in filled with water, and the ultrasound energy is transmitted from the transducer to the injured site through this bladder. Both sides of the balloon should be coated with gel to ensure good contact.

➤ **Figure 7.14. Ultrasound.** A coupling agent is used between the transducer head and area being treated. The head is then moved in small circles or longitudinal strokes to distribute the energy as evenly as possible to prevent damage to the underlying tissues.

Research has shown that ultrasound treatments using gel in direct contact with the patient produce more heat than does ultrasound administered indirectly underwater (18,19). Use of a reusable gel pad is a more recent method of application over bony protuberances or irregular surfaces. These pads, when used with ultrasound gel, have been found to be more effective than using the traditional water bath immersion method (20). Intensity for both gel and underwater treatment is determined by the stage of injury, mode used (pulsed or continuous), desired depth of penetration, and patient tolerance. The patient may feel a mild, warm sensation.

When the treatment goal is to elevate tissue temperature over a large quantity of soft tissue (hip or back), a continuous-wave mode with intensities as high as 1.5 to 2.0 W/cm^2 is typically used. A lower intensity (0.5 to 1.0 W/cm^2) and a higher frequency are used over areas where there is less soft-tissue coverage and where bone is closer to the skin surface. At tissue-bone interfaces, about 35% of the ultrasound beam is reflected, resulting in increased intensity in the soft tissue overlying the bone, particularly the periosteum (18). Elevated temperatures should be maintained at least 5 minutes after the patient reports the sensation of gentle heat, to allow for an increase in extensibility. If heat production in tissues greater than 3 cm deep is the desired effect, 8 minutes of treatment after the patient reports the sensation of heat is the minimum (21).

Phonophoresis

Phonophoresis is a technique whereby the mechanical effects of ultrasound are used to enhance percutaneous absorption of anti-inflammatory drugs (e.g., cortisol, dexamethasone, and **salicylates**) and local analgesics (lidocaine), through the skin to the underlying tissues. One advantage of this modality is that the drug is delivered directly to the site where the effect is sought. High intensities of ultrasound have been used to deliver these medications to depths of 5 to 6 cm subcutaneously into skeletal muscle and peripheral nerves (18).

This technique is used in the postacute stage in conditions to treat painful trigger points, bursitis, contusions, or other chronic soft-tissue conditions. The standard coupling gel is replaced by a gel or cream containing the medication. Commercial chem-pads impregnated with the medication also are readily available, and may be used in lieu of the traditional medicated ointment applicators. Continuous ultrasound is used because tissue permeability is increased by the thermal effects, so the medication is more easily absorbed. Treatment occurs at a lower intensity (1 to 1.5 W/cm^2) for 5 to 15 minutes.

A Ultrasound is an excellent choice in treating a biceps femoris strain. This modality can provide both thermal and nonthermal effects to increase circulation, blood flow, and tissue extensibility, and to reduce hematoma formation and enhance the healing process.

DIATHERMY

Q Diathermy is another form of heat treatment that could be used to treat the sprinter's biceps femoris strain. What type of tissues more readily absorb the heat produced by this modality? Are there any tissues that can limit the absorption rate?

Diathermy, which literally means to heat through, uses electromagnetic energy from the nonionizing radio frequency (RF) part of the spectrum. Because the duration of the impulses is so short, no ion movement occurs. The result is no stimulation of motor or sensory nerves. Rapid vibration of the continuous shortwave diathermy (CSWD) waves is absorbed by the body and converted into heat by the resisting tissues. This elicits deep, penetrating thermal effects. When these waves are interrupted at regular intervals, pulses or bursts of RF energy are delivered to the tissues, and are referred to as pulsed radiofrequency radiation (PRFR). Pulsed radiofrequency radiation may produce either thermal or nonthermal effects on tissues; low power produces nonthermal effects, and high power produces thermal effects.

Therapeutic devices that deliver CSWD and PRFR use high-frequency alternating currents to oscillate at specified radio frequencies between 10 and 50 MHz. The most commonly used RF is 27.12 MHz. Microwave diathermy, another form of electromagnetic radiation, can be directed toward the body and reflected from the skin, and uses ultra-high frequencies (UHF) at 2450 MHz. Microwave diathermy is seldom used today, and is not discussed in this section.

Continuous Shortwave Diathermy

The goal of CSWD is to raise tissue temperature to within the physiologically effective range of 37.5° to 44°C (99.5° to 111.2°F) in deeper tissues (2.5 to 5 cm). This is done by introducing a high-frequency electrical current with a power output of 80 to 120 W. The depth of penetration and extent of heat production depends on wave frequency, the electrical properties of the tissue(s) receiving the electromagnetic energy, and the type of applicator used.

The physiologic effects known to occur with other therapeutic heat treatments are also produced with CSWD. Mild heating is usually desired in acute musculoskeletal conditions, whereas vigorous heating may be needed in chronic conditions. Because the effects occur in deeper tissue, CSWD is used to increase extensibility of deep collagen tissue, decrease joint stiffness, relieve deep pain and muscle spasm, increase blood flow, assist in the resolution of inflammation, and facilitate healing of soft-tissue injuries in the postacute stage **(Box 7.5)**.

There are two methods for heating. One places two condenser plates on either side of the injured area, thus placing the patient in the electrical circuit. The other

➤➤ BOX 7.5

Diathermy Applications

Indications	Contraindications
Bursitis	Over internally and externally worn metallic objects
Joint capsule contractures	Over metal surgical implants
Degenerative joint disease	Over the lumbar, pelvic, or abdominal areas in women with metallic intrauterine devices
Sacroiliac strains	Metal objects within the immediate treatment area
Deep muscles spasms	Unshielded cardiac pacemaker
Ankylosing spondylitis	Over the eyes, testes, and fluid-filled joints
Osteoarthritis	Over ischemic, hemorrhagic, malignant, and acutely inflamed tissues
Chronic pelvic inflammatory disease	Over moist wound dressings, clothing, or perspiration
Epicondylitis	Pregnant abdomen
Subacute inflammation	Patients with hemophilia
	Over epiphyses

method uses an induction coil wrapped around the body part that places the patient in an electromagnetic field. Heating is uneven because different tissues resist energy at different levels, an application of **Joule's law**, which states that the greater the resistance or impedance, the more heat is developed. Tissues with a high fluid content, such as skeletal muscle and areas surrounding joints, absorb more of the energy and are heated to a greater extent, whereas fat is not heated as much. Because the applicators are not in contact with the skin, CSWD can be used for heating skeletal muscle when the skin is abraded, as long as edema is not present.

Pulsed Shortwave Diathermy

Pulsed shortwave diathermy (PSWD), a relatively new type of diathermy, uses a timing circuit to electrically interrupt the 27.12-MHz waves and produce bursts or pulse trains containing a series of high-frequency, sine wave oscillations. Each pulse train has a preset "time on" and is separated from successive pulse trains by a "time off" that is determined by the pulse repetition rate, or frequency. The pulse frequency can be varied from 1 to 700 pulses per second by turning the pulse-frequency control on the equipment operation panel.

The production of heat in tissues depends on the manipulation of peak pulse power, pulse frequency, and pulse duration. The measure of heat production is the mean power, which is lower than the power delivered (80 to 120 W) during most CSWD treatments. Nonthermal effects may be produced at mean power values less than 38 W; thermal effects are produced when mean power values exceed 38 W. Mean powers between 38 and 80 W are appropriate to treat acute and subacute inflammatory conditions, and have been shown to assist in the absorption of hematomas, reduce ankle swelling, and stimulate collagen formation. Pulsed shortwave diathermy is applied to the patient in the same manner as CSWD. Most PSWD devices have the drum type of inductive applicator. Therefore, one could expect less heating of superficial fat and more heating of tissues like superficial muscle, which has a high electrolyte level. Indications and contradictions are the same for PSWD as for CSWD.

A Although shortwave diathermy can provide deep heating to tissues with a higher water content, such as muscle, the extent of muscle heating can be inhibited by the thickness of the subcutaneous fat layer. Therefore, when dealing with a biceps femoris muscle strain, other modalities may be more effective in providing a deep heat treatment.

ELECTROTHERAPY

Q What type of electrotherapy might be used to elicit a muscle contraction in the strained biceps femoris muscle to decrease muscle guarding and atrophy in conjunction with a heat treatment?

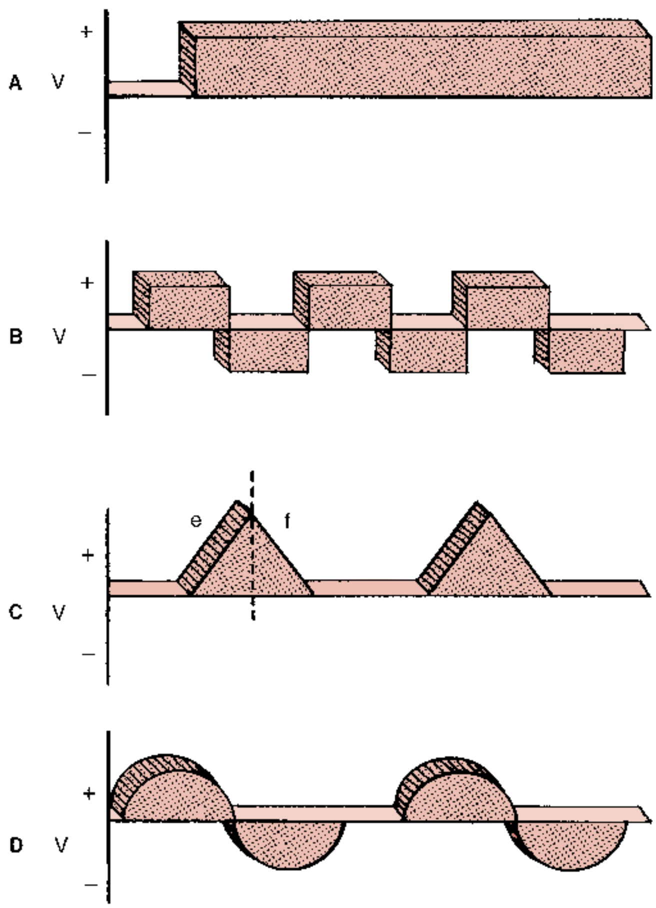
Electrical therapy is a popular therapeutic modality that can be applied to injured or immobilized muscles in the early stages of exercise when the muscle is at its weakest. The various forms of electrotherapy are used to decrease pain; increase blood flow, ROM, and muscle strength; reeducate muscle; facilitate absorption of anti-inflammatory, analgesic, or anesthetic drugs to the injured area; and promote wound healing. An understanding of the clinical use of electrical stimulation requires an understanding of the basic principles of electricity.

Principles of Electricity

Electrical energy flows between two points. In an atom, protons are positively charged, electrons are negatively charged, and neutrons have no charge. Equal numbers of protons and electrons produce balanced neutrality in the atom. Transfer of energy from one atom to the next involves the movement of electrons only from the nucleus, creating an electrical imbalance. This subtraction and addition of electrons causes atoms to become electrically charged, and such atoms are then called ions. An ion that has more electrons is said to be negatively charged; an ion with more protons is positively charged. Ions of similar charge repel each other, whereas ions of dissimilar charge attract one another. The strength of the force and the distance between ions determine how quickly the transfer of energy occurs.

Types of Currents

Four types of electrical current can be applied to tissues **(Figure 7.15)**. Two types fall under the category of continuous current: direct and alternating. Direct current (DC) is a continuous one-directional flow of ions, and is used for pain modulation, to elicit a muscle contraction, or to produce ion movement. Alternating current (AC) is a continuous two-directional flow of ions used for pain modulation or muscle contraction. Pulsed current is a flow of ions in direct or alternating current that is briefly interrupted. It may be one-directional (monophasic), two-directional (biphasic), or polyphasic, which pertains to pulsed currents that usually contain three or more pulses grouped together. These groups of pulses are interrupted for short periods of time and repeat themselves at regular intervals. Pulsed currents are used in interferential and so-called Russian currents. In therapeutic use, each current can be manipulated by altering the frequency, intensity, and duration of the wave or pulse.



➤ **Figure 7.15. Four basic currents.** The shape of the waveforms can be altered by changing the rate of rise and rate of decay. **A,** Direct current (DC) with square wave; **B,** alternating current (AC) with square wave; **C,** monophasic with triangular wave e = rate of rise; f = rate of decay; **D,** biphasic with sine wave.

Current Modifications

Once the basic current type is known, there are several parameters that can be manipulated for the desired effects. The more common parameters include the amplitude, frequency, pulse duration, pulse charge, electrode setup, polarity, mode, duty cycle, and duration of treatment. **Table 7.1** provides some guidelines for parameter modifications to achieve certain therapeutic effects. An electrical unit with the prescribed current type should be selected, and then the modifications indicated for the desired effect should be applied.

➤ *Amplitude*

Amplitude is a measure of the force, or intensity that drives the current. The maximum amplitude is the top or highest point of each phase. The term is synonymous with **voltage** and is measured in millivolts (mV), although some units use milliamperage (mA) as a measure of amplitude. Voltage causes the ions to move, but the actual movement is called **current**. If the current is graphically presented, the voltage is represented by the magnitude of the wave. If resistance remains the same, an increase in voltage will increase the amperage (rate of current flow). Average current can be increased by either increasing pulse duration or increasing pulse frequency or by some combination of the two.

Mediums that facilitate movement of the ions are called **conductors** and include water, blood, and electrolyte solutions such as sweat. Mediums that inhibit movement of the ions are called **resistors**, such as skin, fat, and lotion. The combination of voltage, current, and resistance is measured in ohms (Ω). **Ohm's law** ($I = V/R$) states that current (I) in a conductor increases as the driving force (V) becomes larger, or resistance (R) is decreased. For example, 1 V is the amount of electrical force required to send a current of 1 amp through a resistance of 1 ohm.

➤ *Frequency*

Frequency refers to the number of waveform cycles per second (cps) or hertz (Hz) with alternating current, the number of pulses per second (pps) with monophasic or biphasic current, or the number of bursts per second (bps) with Russian stimulation. One purpose in altering frequency is to control the force of muscle contractions during neuromuscular stimulation. Low-frequency stimulation causes the muscle to twitch with each pulse, cycle, or burst. As frequency increases, stimulation minimizes the relaxation phase of the muscle contraction. In higher frequencies, the stimulation is so fast that no relaxation occurs and a sustained, maximal contraction (tetany) is

TABLE 7.1 PARAMETER MODIFICATION FOR ELECTROTHERAPY

Desired Effect	Current Type	Intensity	Frequency	Pulse Duration	Electrodes	Mode
Muscle contraction	Biphasic	Motor	<15 pps twitch 15–25 pps sum >40 pps tetany	300–500 μs	Ends of muscle motor points	Duty Cycle
	Monophasic	Motor	<15 pps twitch 15–25 pps sum >40 pps tetany	300–500 μs	Negative/ends of muscle or motor points	Alternate or reciprocate duty cycle
Pain control Gate	Biphasic	Sensory	110 pps	30–200 μs	Direct contiguous nerve root dermatomes	Modulated
	Monophasic	Sensory	100–150 pps	Short	Positive/over pain site	Continuous
Opiate release	Biphasic	Motor	1–5 pps	300-500 μs	Trigger points	Burst
	Monophasic	Motor	1–5 pps	300–500 μs	+ (acute) – (chronic)/over pain site	Continuous
Central biasing	Biphasic	Noxious	100–150 pps	250–500 μs	Trigger points	Modulated
Edema reduction	Monophasic	Sensory	80–150 pps	20–200 μs	Negative/over edema	Continuous

Note: Interferential stimulation can be used for muscle contraction, gate, and opiate pain control by using similar parameters. Russian current can be used for muscle contraction by substituting bps for pps. Printed with permission from Holcomb WR. J Sport Rehab 1997;6(3):280.

generated. Therefore, if the intent is to bring about fatigue in a muscle, the clinician can choose the appropriate frequency to bring about this effect.

➤ *Pulse Duration*

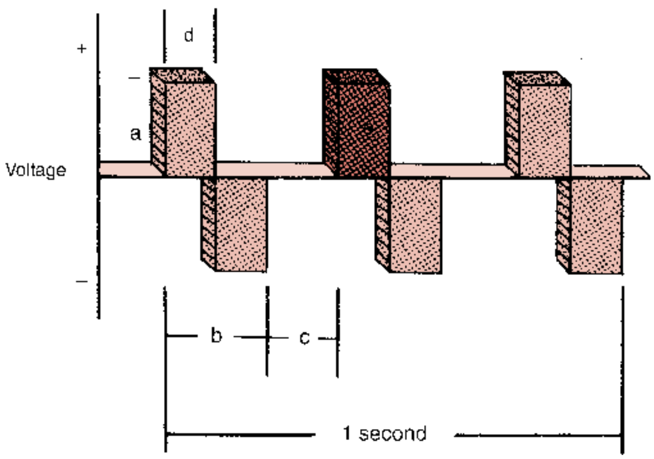
Phase duration, or current duration as it is sometimes called, refers to the length of time that current is flowing. Pulse duration is the length of a single pulse of monophasic or biphasic current. In biphasic current, the sum of the two phases represents the pulse duration, whereas in monophasic current, the phase and pulse duration are synonymous. The time between each subsequent pulse is called the interpulse interval. The combined time of the pulse duration and interpulse interval is referred to as the pulse period. More powerful muscle contractions are generated with pulse duration of 300 to 400 μs.

➤ *Pulse Charge*

In a single phase, the pulse charge, or quantity of an electrical current, is the product of the phase duration and amplitude, and represents the total amount of electricity being delivered to the individual during each pulse. Amplitude, pulse duration, interpulse interval, phase duration, and phase charge are illustrated in **Figure 7.16**.

➤ *Electrode Setup*

Electrical currents are introduced into the body through electrodes and a conducting medium. The smaller active pad has the greatest current density and brings the current into the body. The active electrode ranges from a very small pad to 4 inches square. Water or an electrolyte gel is used to obtain high conductivity. The arrangement of the pads depends on the polarity of the active pad, and not on the number or size. If only one active electrode is used, or if the active electrodes are of the same charge, the arrangement is monopolar. With this pattern, a large dispersal pad is needed to take on the opposite charge of the active pad to complete the circuit. The dispersal pad, from which the electrons leave the body, should be as large as possible to reduce current density. With the low



➤ **Figure 7.16. Graphic illustration of a biphasic current.** a = amplitude (intensity); b = pulse duration; c = interpulse interval; d = phase duration; e = phase charge. Frequency = 3 pps.

current density, no sensation should be felt beneath the dispersal pad. When the active pads are of opposite charges, the arrangement is bipolar. Because this arrangement provides a complete circuit, no dispersal pad is necessary. Interferential stimulation requires a quadripolar electrode arrangement. This is nothing more than a bipolar arrangement from two channels where the currents cross at the treatment site. This electrode arrangement can be seen in **Figure 7.17**.

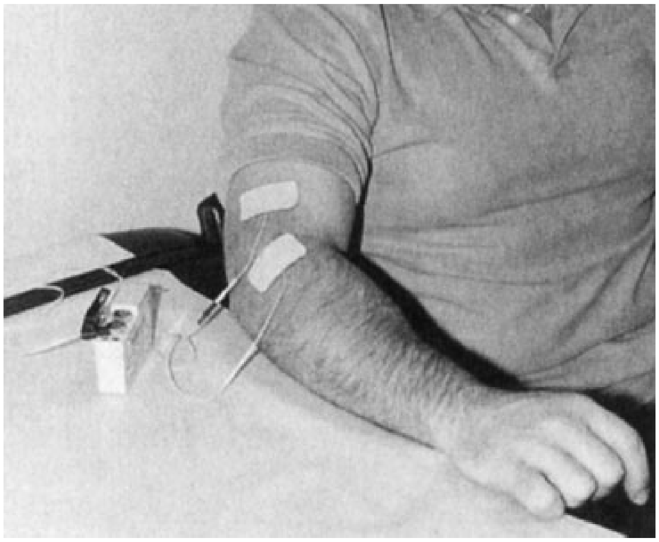
The pads should be placed at least one pad width apart. The closer the pads are, the shallower and more isolated the contraction; the farther apart they are, the deeper and more generalized the contraction. The physiologic effects can occur anywhere between the pads, but usually occur at the active electrode because current density is greatest at this point.

➤ *Polarity*

Polarity refers to the direction of current flow, and can be toward either a positive or negative pole. During direct current and monophasic stimulation, the active electrode(s) can be either positive or negative, and current will flow in a predetermined direction (away from the negative electrode). During AC or biphasic stimulation, the polarity of the active pads alternates between positive and negative with each phase of the current.

➤ *Mode*

In a monopolar arrangement, mode refers to the alternating (reciprocating) or continuous flow of current through the active electrodes. Alternating means that the active electrodes receive current on an alternating basis, whereas with continuous flow, each electrode receives current throughout the treatment period. In neuromuscular stimulation, another popular mode is ramped or surge amplitude. The amplitude gradually builds to the desired level, which improves patient comfort and safety by preventing sudden, powerful muscle contractions.



➤ **Figure 7.17. Transcutaneous electrical nerve stimulation.** Transcutaneous electrical nerve stimulation is used to decrease acute and chronic pain to an injured area.

➤ *Duty Cycle*

Duty cycle refers to the ratio of the amount of time current is flowing (on time) to the amount of time it is not flowing (off time). Used in neuromuscular stimulation, the duty cycle simulates repetitions and rest so as to delay the onset of fatigue. In edema formation, it creates a muscle pump. With neuromuscular stimulation, the recommended duty cycle should be 1:4 or 20% initially (i.e., 10 s on and 40 s off) and should gradually increase as fatigability decreases. Manual control of the duty cycle is necessary to prevent discomfort for the patient.

➤ *Duration of Treatment*

Duration of treatment is the total time the patient is subjected to electrical stimulation. Many units have internal timers. Treatment duration is typically 15 to 30 minutes.

Electrical Stimulating Units

There are several different types of electrical units **(Box 7.6)**. Although it would be much easier to name the units based on the types of current that characterize the stimulation devices, this is not the case. Names are often used to show distinction between the characteristics, indications, and parameters of the various units. Unfortunately, many units could fall under the same general title. To complicate matters further, many common names, such as Galvanic, Faradic, and Russian stimulation are still used, and are discussed later in this section. The more common electrical stimulation units are discussed.

➤ *Transcutaneous Electrical Nerve Stimulation*

Transcutaneous electrical nerve stimulation (TENS) units are typically portable biphasic generators with parameters that allow pain control via high-frequency, low-frequency, and brief-intense stimulation **(Table 7.2)**. The units can produce analgesia and decrease acute and chronic pain, and pain associated with delayed-onset muscle soreness. Transcutaneous electrical nerve stimulation is often used continuously after surgery in a 30- to 60-minute session, several times a day. It is thought that TENS works to override the body's internal signals of pain (gate theory of pain), or stimulates the release of endomorphins, a strong, opiate-like substance produced by the body. The unit uses small carbonized silicone electrodes to transmit electrical pulses through the skin (see

➤➤ BOX 7.6

Application of Neuromuscular Electrical Stimulation

	Indications	Contraindications
TENS	↓ Posttraumatic pain, acute and chronic ↓ Postsurgical pain ↑ Analgesia	Patients with pacemakers Pregnancy (abdominal and/or pelvic area) Pain of unknown origin
High–Voltage Pulsed	↑ Circulation and joint mobility ↑ Muscle re-education and strength ↑ Wound and fracture healing ↑ Nonunion fracture healing ↓ Muscle spasm/spasticity ↓ Pain and edema ↓ Disuse atrophy Denervation of peripheral nerve injuries	Pacemakers Pain of unknown origin Pregnancy (abdominal and/or pelvic area) Thrombophlebitis Superficial skin lesions or infections Cancerous lesions Over suspected fracture sites
Interferential	↑ Circulation and wound healing ↓ Pain, acute and chronic ↓ Reduction of muscle spasm/guarding ↓ Posttraumatic and chronic edema ↓ Abdominal organ dysfunction	Pacemakers Pregnancy (abdominal and/or pelvic area) Thrombophlebitis Pain of unknown origin Prolonged use (may increase muscle soreness)
Low-Intensity Stimulation	↑ Nonunion wound healing ↑ Fracture healing Iontophoresis	Malignancy Hypersensitive skin Allergies to certain drugs

Figure 7.17). Most units are small enough to be worn on a belt and are battery powered. The electrodes are taped on the skin over or around the painful site, but may be secured along the peripheral or spinal nerve pathways. For individuals who have allergic reactions to the tape adhesive, or who develop skin abrasions from repeated applications, electrodes with a self-adhering adhesive are available.

➤ *High-Voltage Pulsed Stimulation*

High-voltage pulsed stimulation (HVPS) units provide a monophasic current with a twin-peak wave form, a relatively short pulse duration and long interpulse interval, and an amplitude range above 150 mV (22). High-voltage pulsed stimulation is often used to re-educate muscle; increase joint mobility; promote wound healing; and

TABLE 7.2 Protocol For Transcutaneous Electrical Nerve Stimulation (TENS) Application

Parameter	High TENS	Low TENS	Brief-Intense
Intensity	Sensory	Motor	Noxious
Pulse frequency	60–100 pps	2–4 pps	Variable
Pulse duration	60–100 μsec	150–250 μsec	300–1000 μsec
Mode	Modulated rate	Modulated burst	Modulated amplitude
Duration	As needed	30 min	15–30 min
Onset of relief	<10 min	20–40 min	<15 min
Duration of relief	Minutes to hours	Hours	<30 min

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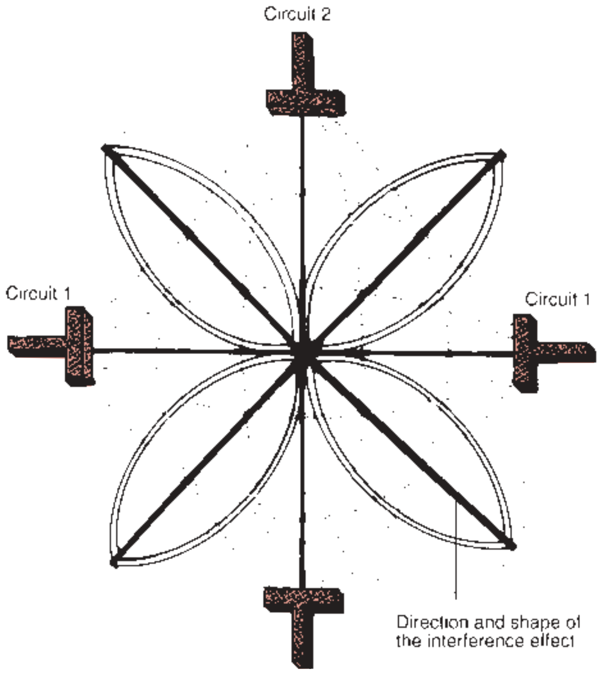
decrease pain, edema, and muscle atrophy, but is ineffective in reducing the soreness, loss of ROM, and loss of strength associated with delayed-onset muscle soreness (DOMS) (23).

➤ Neuromuscular Electrical Stimulation

Neuromuscular electrical stimulation (NMES) units are designed to elicit a muscle contraction, and are typically biphasic currents with a duty cycle. High-voltage electrical stimulation uses an output of 100 to 500 V to reduce edema, pain, and muscle spasm during the acute phase. It is used also to exercise muscle and delay atrophy, maintain muscle size and strength during periods of immobilization, re-educate muscles, and increase blood flow to tissues **(Figure 7.18)**. Direct current is used primarily to stimulate denervated muscle and enhance wound healing, and is used during iontophoresis.

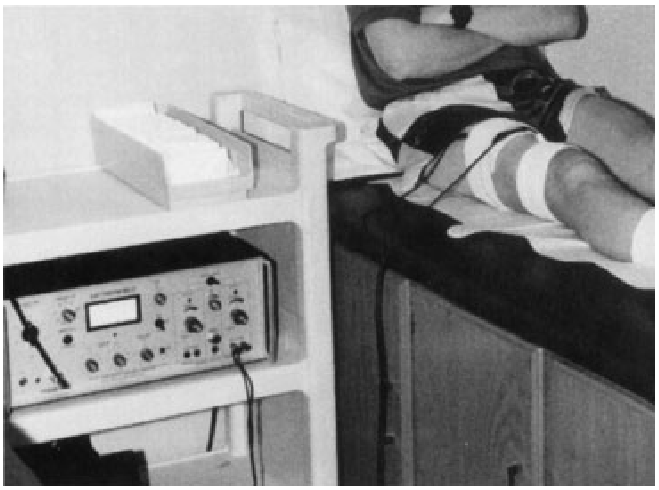
➤ Interferential Stimulation

Interferential current utilizes two separate generators and a quadripolar electrode arrangement to produce two simultaneous AC electrical currents acting on the tissues. The two paired pads are placed perpendicular to each other and the current crosses at the midpoint **(Figure 7.19)**. A predictable pattern of interference occurs as the interference effects branch off at 45 angles from the center of the treatment, in the shape of a four-leaf clover. Tissues within this area receive the maximal treatment effect. When the electrodes are properly placed, the stimulation should be felt only between the electrodes, not under the electrodes. Currents range from 1 to 10 Hz (1 to 100 μA) with the paired pads differing from each other by +1 Hz (1). The higher frequencies lower skin resistance, thus



➤ **Figure 7.19. Interferential current.** When arranged in a square alignment, the quadripolar electrode setup is actually a bipolar arrangement from two channels. An electric field is created where the currents cross between the lines of electric current flow. The maximum interference effect takes place near the center over the treatment site.

eliciting a stronger response with less current intensity. Furthermore, sensory perception is decreased between the pads, allowing for the use of a higher current, which increases stimulation. The amplitude and/or beat frequency can be modulated throughout the treatment by selecting the scan or sweep mode, respectively. Interferential stimulation (IFS) is used to decrease pain, acute and chronic edema, and muscle spasm; strengthen weakened muscles; improve blood flow to an area; heal chronic wounds; and relieve abdominal organ dysfunction.



➤ **Figure 7.18. Electrical muscle stimulation.** These units are used to stimulate muscle to maintain muscle size and strength during immobilization, re-educate muscles, prevent muscle atrophy, and increase blood flow to tissues to decrease pain and spasm.

➤ Low-intensity Stimulation

Low-intensity stimulation (LIS) is the current term to replace the units originally called microcurrent electrical nerve stimulators (MENS) units. Low-intensity stimulation units are available in a variety of waveforms from modified monophasic to biphasic square waves. The units tend to be applied at a subsensory or very low sensory level with a current operating at less than 1000 μA. The devices deliver an electrical current to the body approximately 1/1000 the amperage of TENS, but a pulse duration that may be up to 2500 times longer. The stimulation pathway is not designed to stimulate peripheral nerves to elicit a muscle contraction, but rather is used to reduce acute and chronic pain and inflammation; reduce edema; and facilitate healing in superficial wounds, sprains, strains, fractures, and neuropathies. The efficacy of microcurrent therapy, and subsequently LIS units, is based primarily on anecdotal evidence rather than valid research. It is posited that the current mimics the normal electrical current within the body, which is disrupted with injury, and in doing so, reduces pain and spasm and improves healing (22). Several studies have shown that microcurrent is ineffective in reducing pain and increasing muscle function associated with DOMS (24,25).

➤ *Galvanic Stimulation*

Galvanic stimulation is the common name for any stimulator using direct current.

➤ *Russian Current*

Russian current is a type of neuromuscular stimulation that uses an alternating current with frequencies ranging from 2000 to 10,000 Hz. The current is generated in bursts, with interburst intervals. The number of bps can be manipulated within the therapeutic range. For example, a high-frequency AC current easily penetrates the skin and provides a high-amplitude, low-frequency (bps) current to the muscle. Russian electrical stimulation is designed to produce an isometric contraction and is useful in muscle re-education. Because it induces an isometric contraction, rather than an isotonic one, strength gains do not transfer across the entire joint, but instead are restricted to a narrow arc on either side of the joint angle at which the muscle is stimulated. However, Russian current does permit the individual to contract actively along with the stimulation, provides an adequate work-to-rest interval, and is usually comfortable for the individual.

➤ *Faradic Current*

Faradic current is a specialized, asymmetrical biphasic wave. Although popular in the past, it is now thought to be of little benefit over symmetrical waves (22).

➤ *Iontophoresis*

Iontophoresis uses direct current to drive charged molecules from certain medications, such as anti-inflammatories (hydrocortisone), anesthetics (lidocaine), or analgesics (aspirin or acetaminophen), into damaged tissue. It is used as a local anesthetic to treat inflammatory conditions and skin conditions by reducing edema. Contraindications include allergy to the ion being used, decreased sensation, and placing electrodes directly over unhealed or partially healed skin wounds or new scar tissue. No contact should exist between metal or carbon-rubber electrode components and the skin, and electrodes should never be removed or rearranged until the unit has been turned off. The corticosteroid dexamethasone has been very successful in treating overuse conditions, myofascial syndromes, and plantar fasciitis (26).

Iontophoresis is noninvasive and painless, uses a sterile application, and is excellent for those patients who fear injections. It yields tissue concentrations that are lower than those achieved with injections but greater than those with oral administration, because it avoids enzymatic breakdown in the gastrointestinal tract. A major disadvantage of this treatment is the electrolysis of NaCl in the body by direct current. Electrolysis produces an increased pH (acidic) condition at the cathode (positive electrode), and decreased pH (alkaline) condition at the anode (negative electrode). These pH changes can lead to tissue burns, especially with high intensities or prolonged application. Therefore, the negative electrode should be large, perhaps twice the size of the positive electrode, to reduce current density. With the newer controlled generators and buffered electrodes, clinicians can selectively decrease the current density under the anode to decrease the incidence of burns.

Prior to treatment, the skin must be thoroughly cleansed. Next, well-saturated electrodes are applied over the most focal point of tissue inflammation or pain, unless skin irritation is visible. The polarity of the medication determines which electrode is used to drive the molecules into the skin. The medication is placed under the electrode with the same polarity. When the current is applied, the molecules are pushed away from the electrode and driven into the skin toward the injured site. This localized treatment often is preferred over more disruptive systemic treatments.

A The athletic trainer can combine ultrasound and a high-voltage pulsed stimulator or interferential stimulation to increase blood flow in the biceps femoris muscle. The electrical current can stimulate a muscle contraction to produce muscle pumping, retard atrophy, and strengthen the muscle.

OTHER TREATMENT MODALITIES

Q In some clinical settings, an athletic trainer may not have access to expensive electrical modalities. What other treatment modalities might be used to promote healing of the sprinter's biceps femoris strain?

Many of the electrotherapy modalities are costly and may not be readily available in all clinical settings. In addition, state licensure laws may prohibit an athletic trainer from using certain modalities in a nontraditional setting. As such, it becomes necessary to use other treatment modalities to achieve the same results.

Massage

Massage involves the manipulation of the soft tissues to increase cutaneous circulation, cell metabolism, and venous and lymphatic flow to assist in the removal of edema; stretch superficial scar tissue; alleviate soft-tissue adhesions; and decrease neuromuscular excitability **(Box 7.7)**. As a result, relaxation, pain relief, edema reduction,

➤➤ BOX 7.7

Application of Therapeutic Massage

Indications	Contraindications
Increase local circulation	Acute contusions, sprains, and strains
Increase venous and lymphatic flow	Over fracture sites
Reduce pain (analgesia)	Over open lesions or skin conditions
Reduce muscle spasm	Conditions such as: acute phlebitis, thrombosis, severe varicose veins, cellulitis, synovitis, arteriosclerosis, and cancerous regions
Stretch superficial scar tissue	
Improve systemic relaxation	
Chronic myositis, bursitis, tendinitis tenosynovitis, fibrositis	

and increased ROM can be achieved. To reduce friction between the patient's skin and hand, particularly over hairy areas, lubricants (i.e., massage lotion, peanut oil, coconut oil, or powder) often are used. These lubricants should have a lanolin base or be alcohol free. Massage involves five basic strokes: effleurage (stroking), pétrissage (kneading), tapotement (percussion), vibration, and friction. **Table 7.3** describes the various techniques used in therapeutic massage.

Effleurage is a superficial, longitudinal stroke to relax the patient. When applied toward the heart, it reduces swelling and aids venous return. It is the most commonly used stroke, and begins and ends each massage. Effleurage permits the clinician to evaluate the condition, distribute the lubricant, warm the skin and superficial tissue, and promote relaxation.

Pétrissage consists of pressing and rolling the muscles under the fingers and hands. This "milking" action over deep tissues and muscle increases venous and lymphatic return, and removes metabolic waste products from the injured area. Furthermore, it breaks up adhesions within the underlying tissues, loosens fibrous tissue, and increases elasticity of the skin.

Tapotement uses sharp, alternating, brisk hand movements such as hacking, slapping, beating, cupping, and clapping to increase blood flow and stimulate peripheral nerve endings. Because this technique is used for stimulation, not relaxation, it is not used in most massage treatments.

Vibration consists of finite, gentle, and rhythmical movement of the fingers to vibrate the underlying tissues. It is used for relaxation or stimulation.

Friction is the deepest form of massage, and consists of deep circular motions performed by the thumb, knuckles, or ends of the fingers at right angles to the involved tissue. These deep circular movements can loosen adherent fibrous tissue (scar), aid in absorption of edema, and reduce localized muscular spasm. Transverse friction massage is a deep friction massage performed across the grain of the muscle, tendon sheath, or ligament. Cross-friction massage is the most effective technique, and is used to break up adhesions and promote healing of muscle and ligament tears.

One recent study found that blood flow did not significantly increase with effleurage, pétrissage, and tapotement on either a small or large muscle mass (27). Another study found that manual massage did not have a significant impact on the recovery of muscle function following exercise, or on any of the physiologic factors associated with the recovery process (28). In both studies, the researchers concluded that light exercise of the affected muscles is probably more effective than massage in improving muscle blood flow (thereby enhancing healing) and temporarily reducing muscle soreness. Because the types and duration of massage are typically based on the preference of the individual and clinician, its use in athletic settings for these purposes should be questioned.

Traction

Traction is the process of drawing or pulling tension on a body segment. The most common forms involve lumbar and cervical traction. Spinal traction is more commonly used to treat small herniated disc protrusions that may result in spinal nerve impingement, although it also may be used to treat a variety of other conditions **(Box 7.8)**. The effects of spinal traction include distraction of the vertebral bodies, widening of the vertebral foramen, a combination of distraction and gliding of vertebral facets, and stretching and relaxation of the paraspinal muscles and ligamentous structures of the spinal segment.

A distractive force is commonly applied either with a mechanical device or manually by a clinician. Traction may be applied continuously through a low, distracting force for up to several hours; statically with a sustained distracting force applied for the entire treatment time, usually 30 minutes; or intermittently with a distracting force applied and released for several seconds repeatedly over the course of the treatment time. For example, in lumbar traction a split table is used to eliminate friction. A special nonslip harness lined with vinyl is used to transfer the distractive force comfortably to the patient and stabilize the trunk and thoracic area while the lumbar spine is placed under traction. A distractive force, usually up to one-half of the patient's body weight, is applied for 30 minutes daily for 2 to 4 weeks. Although intermittent traction tends to be more comfortable for the patient, sustained traction is more effective in treating lumbar disc problems. In cervical traction, the patient may be either supine or seated. Again, a nonslip cervical harness is secured under the chin and

TABLE 7.3 TECHNIQUES OF MASSAGE

Technique	Use	Method of Application
Effleurage (stroking)	Relaxes patient Evenly distributes any lubricant Increases surface circulation	Gliding motion over the skin without any attempt to move deep muscles Apply pressure with the flat of the hand; fingers and thumbs spread; stroke toward the heart Massage begins and ends with stroking
Pétrissage (kneading)	Increases circulation Promotes venous & lymphatic return Breaks up adhesions in superficial connective tissue Increases elasticity of skin	Kneading manipulation that grasps and rolls the muscles under the fingers or hands
Tapotement (percussion)	Increases circulation Stimulates subcutaneous structures	Brisk hand blows in rapid succession: hacking with ulnar border slapping with flat hand beating with half-closed fist tapping with fingertips cupping with arched hand
Vibration	Relaxes limb	Fine vibrations made with fingers pressed into a specific body part
Friction (rubbing)	Loosens fibrous scar tissue Aids in absorption of edema Reduces inflammation Reduces muscular spasm	Small circular motions with the fingers, thumb, or heel of hand Transverse friction is done perpendicular to the fibers being massaged

back of the head to transfer the distractive force comfortably to the patient. Recommended force ranges from 10 to 30 pounds.

With manual traction, the clinician applies the distractive force for a few seconds or sometimes with a quick, sudden thrust. This method has been effective in reducing joint pain when the traction in applied within the normal range of joint movement. Because the clinician can feel the relaxation or resistance, it is possible to instantaneously change the patient's position, direction of the force, magnitude of the force, or duration of the treatment, making manual traction more flexible and adaptable than mechanical traction.

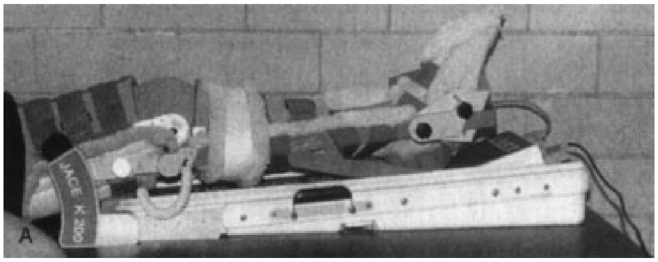
➤➤ **BOX 7.8**

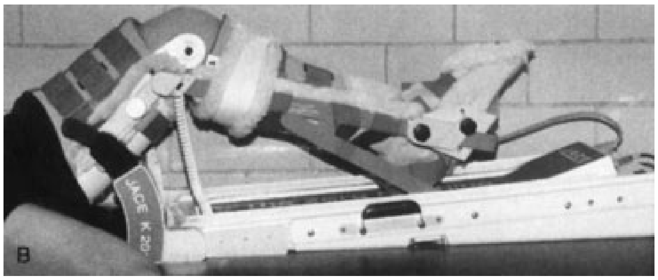
Application of Traction

Indications	Contraindications
Herniated disc protrusions	Unstable vertebrae
Spinal nerve impingement	Acute lumbago
Spinal nerve inflammation	Gross emphysema
Joint hypomobility	S4 nerve root signs
Narrowing of intervertebral foramen	Temporomandibular dysfunction
Degenerative joint disease	Patient discomfort
Spondylolisthesis	
Muscle spasm and guarding	
Joint pain	

Continuous Passive Motion

Continuous passive motion (CPM) is a modality that applies an external force to move the joint through a preset arc of motion **(Figure 7.20)**. It is used primarily postsurgically at the knee, after knee manipulation, or after stable fixation of intra-articular and extra-articular fractures of most joints. It also may be used to improve





➤ Figure 7.20. **Continuous passive motion.** These machines are often used postsurgically to apply an external force to move the joint through a limited range of motion. **A,** Starting position. **B,** Ending position.

wound healing, accelerate clearance of a **hemarthrosis** (blood in a joint), and prevent cartilage degeneration in septic arthritis **(Box 7.9)**. The application is relatively pain-free and has been shown to stimulate the intrinsic healing process; maintain articular cartilage nutrition; reduce disuse effects; retard joint stiffness and the pain-spasm cycle; and benefit collagen remodeling, joint dynamics, and pain reduction (1,29).

A Massage may be used after the acute phase has ended. Stroking and kneading toward the heart may provide some beneficial effects; however, mild exercise may be just as beneficial.

MEDICATIONS

Q What medications might be helpful in promoting healing of this injury? Which medications can be recommended and dispensed by an athletic trainer?

Therapeutic drugs are either prescription or over-the-counter medications used to treat an injury or illness. Common drugs used to control pain, inflammation, and muscle spasm include anesthetics, analgesics, nonsteroidal anti-inflammatory drugs (NSAIDs), adrenocorticosteroids, and muscle relaxants. A more detailed presentation of therapeutic drugs can be found in Chapter 26.

Local anesthetics eliminate short-term pain sensation in a specific body part or region by blocking afferent (sensory) neural transmissions along peripheral nerves. Many of these drugs can be identified by their "-caine" suffixes (e.g., lidocaine, procaine, and benzocaine). The drugs may be topically applied to skin for minor irritations (e.g., burns, abrasions, mild inflammation), introduced into subcutaneous tissues (e.g., bursitis, tendinitis, contusions) via phonophoresis or iontophoresis injected by a physician into soft tissue around a laceration for surgical repair (suturing), or injected by a physician near a peripheral nerve to interrupt nerve transmission (nerve block).

Aspirin is the most commonly used drug to relieve pain and inflammation. Because of its anticlotting properties, it is not used during the acute phase of healing. Aspirin is associated with a number of adverse side effects, including gastrointestinal irritation. Stomach distress can be limited by using coated aspirin to delay release of the drug until it reaches the small intestine, or by taking a buffered aspirin to blunt the acidic effects of aspirin in the stomach. With chronic use or high doses (10 to 30 g), renal problems, liver toxicity, congestive heart failure, hypertension, aspirin intoxication, or poisoning may occur. Normal dosage is 325 to 650 mg every 4 hours.

Acetaminophen (Tylenol) is an analgesic and an **antipyretic** (reduces fever), but does not have any appreciable anti-inflammatory or anticlotting effects. Unlike aspirin, acetaminophen is not associated with gastrointestinal irritation. However, high doses can be toxic to the liver and may be fatal.

Nonsteroidal anti-inflammatory drugs are commonly used to dilate blood vessels and inhibit production of prostaglandins. Certain prostaglandins increase local blood flow, capillary permeability, erythema, and edema associated with inflammation, and are believed to decrease the sensitivity of pain receptors to the effects of other pain producing substances, such as bradykinin (1,16). Therefore, these drugs decrease inflammation, relieve mild to moderate pain (analgesia), decrease body temperature associated with fever, increase collagen strength, and inhibit coagulation and blood clotting. The most important time to administer NSAIDs is in the early stages of healing when prostaglandins produce the most detrimental effects of pain and edema. Prolonged use (2 or more weeks) may actually retard the healing process. Examples of NSAIDs include ibuprofen (e.g., Advil, Nuprin, Motrin, Rufen), naproxen sodium (e.g., Aleve), indomethacin (e.g., Indocin), and piroxicam (e.g., Feldene). **Table 7.4** lists the more common NSAIDS and suggested dosages.

Ibuprofen and the other NSAIDs are administered primarily for pain relief and anti-inflammatory effects. However, they are more expensive than aspirin. Although many are still associated with some stomach discomfort, they provide better effects in many patients. Taking the medication after a meal or with a glass of milk or water greatly reduces stomach discomfort.

Adrenocorticosteroids are steroid hormones produced by the adrenal cortex. Higher doses, referred to as a pharmacologic dose, are typically used to treat endocrine disorders, but can be used to decrease edema, inflammation, **erythema** (inflammatory redness of the

➤➤ BOX 7.9

Application of Continuous Passive Motion

Indications	Contraindications
Postoperative rehabilitation to:	Noncompliant patient
Reduce pain	If use would disrupt surgical repair, fracture fixation, or lead to hemorrhage in postoperative period
Improve general circulation	Malfunction of device
Enhance joint nutrition	
Prevent joint contractures	
Benefit collagen re-modeling	
Following knee manipulation	
Following joint debridement	
Following meniscal or osteochondral repair	
Tendon lacerations	

TABLE 7.4 NONSTEROIDAL ANTI-INFLAMMATORY DRUGS (NSAIDS)

Generic Name	Brand Name	Single Dose	Maximum Daily Dose	Duration
		Over the Counter		
Ibuprofen	Advil, Nuprin, Motrin IB	2 × 200 mg every 4–6 hr	1200 mg	Short
Ketoprofen	Actron, Orudis KT	1 × 12.5 mg every 4–6 hr	75 mg	Short
Naproxen Sodium	Aleve	1 × 220 mg every 8–12 hr	660 mg	Intermediate
		Prescription		
Bromfenac	Duract	25 mg	150 mg	Short
Diclofenac Potassium	Cataflam	50 mg	200 mg	Short
Diclofenac Sodium	Voltaren	25, 50, 75 mg XR 100 mg	200 mg	Short
Etodolac	Lodine	200, 300, 400, 500 mg XL 400, 600 mg	1200 mg	Intermediate
Fenoprofen Calcium	Nalfon	200, 300, 600 mg	3200 mg	Short
Flurbiprofen	Ansaid	50, 100 mg	300 mg	Short
Ibuprofen	Motrin, Rufen	300, 400, 600, 800 mg	3200 mg	Short
Indomethacin	Indocin	25, 50 mg SR 75 mg	200 mg	Short/Intermediate
Ketoprofen	Orudis, Oruvail	50, 75 mg SR 100, 150, 200 mg	300 mg	Short
Ketorolac	Toradol	10 mg	40 mg	Short
Meclofenamate	Meclomen	50, 100 mg	400 mg	Short
Mefenamic Acid	Ponstel	250 mg	1000 mg	Short
Nabumetone	Relafen	500, 750 mg	2000 mg	Long
Naproxen Sodium	Anaprox	275, 550 mg	1375 mg	Intermediate
Naproxen	Naprosyn	250, 375, 500 mg	1500 mg	Intermediate
Naproxen	EC-Naprosyn, Naprelan	375, 500 mg	1500 mg	Intermediate
Oxaprozin	Daypro	600 mg	1800 mg	Very long
Piroxicam	Feldene	10, 20 mg	20 mg	Very long
Sulindac	Clinoril	150, 200 mg	400 mg	Intermediate
Tolmetin Sodium	Tolectin	200, 400, 600 mg	2000 mg	Short

skin), and tenderness in a region. These drugs may be topically applied, given orally, or injected by a physician into a specific area, such as a tendon or joint. Examples of these drugs include cortisone, prednisone, and hydrocortisone. Because many of these drugs can lead to breakdown and rupture of structures, long-term use can depress the adrenal glands, and increase the risk of osteoporosis.

Skeletal muscle relaxants are used to relieve muscle spasms. Muscle spasms can result from certain musculoskeletal injuries or inflammation. When involuntary tension in the muscle cannot be relaxed, it leads to intense pain and a buildup of pain-mediating metabolites (e.g., lactate). A vicious cycle is created with the increased pain leading to more spasm, more pain, and more spasm. Skeletal muscle relaxants break the pain-spasm cycle by depressing neural activity causing the continuous muscle contractions, thus reducing muscle excitability. Muscle relaxants do not prevent muscle contraction, but rather attempt to normalize muscle excitability to decrease pain and improve motor function. Examples of muscle relaxants include Flexeril, Soma, and Dantrium.

A Because of legal liability, athletic trainers cannot recommend, prescribe, or dispense medications. The individual can be seen by the team physician, who may prescribe certain NSAIDs to promote healing, or the individual may voluntarily take over-the-counter medications as needed. However, the athletic trainer should monitor the individual to ensure compliance with manufacturer's suggested guidelines.

Summary

1. Rehabilitation begins immediately after injury assessment with the use of therapeutic modalities to limit pain, inflammation, and loss of ROM.
2. Therapeutic modalities, with the exception of ultrasound, fall under the electromagnetic spectrum

based on their wavelength or frequency. All electromagnetic energy is pure energy that travels in a straight line at the speed of light (300 million meters per second) in a vacuum.
3. Depending on the medium, energy can be reflected, refracted, absorbed, or transmitted.
4. Common therapeutic modalities include cryotherapy, thermotherapy, ultrasound, diathermy, electrical stimulation, massage, traction, continuous passive motion, and medications to promote healing. Although many are used every day in treating musculoskeletal injuries, many must be used under the direction of a physician or an individual properly licensed to do so within the individual state. Being a technician and merely applying a modality is not an acceptable athletic training practice.
5. Cryotherapy is used to decrease pain, inflammation, muscle guarding and spasm, and to facilitate mobilization.
6. Thermotherapy is used to treat subacute or chronic injuries to reduce swelling, edema, ecchymosis, and muscle spasm; increase blood flow and ROM; facilitate tissue healing; relieve joint contractures; and fight infection.
7. Ultrasound produces thermal and nonthermal effects.
   Thermal effects include increased blood flow, extensibility of collagen tissue, sensory and motor nerve conduction velocity, and enzymatic activity; and decreased muscle spasm, joint stiffness, inflammation, and pain.
   Nonthermal effects include decreased edema, and increased blood flow, cell membrane and vascular wall permeability, protein synthesis, tissue regeneration, and the promotion of healing.
8. Diathermy is used to treat joint inflammation (e.g., bursitis, tendinitis, and synovitis), joint capsule contractures, subacute and chronic inflammatory conditions in deep-tissue layers, osteoarthritis, ankylosing spondylitis, and chronic pelvic inflammatory disease.
9. Electrotherapy is used to decrease pain, re-educate peripheral nerves, delay denervation and disuse atrophy by stimulating muscle contractions, reduce post-traumatic edema, and maintain ROM by reducing muscle spasm, inhibiting spasticity, re-educating partially denervated muscle, and facilitating voluntary motor function.
10. Iontophoresis is used to introduce ions into the body tissues by means of a direct electrical current. This treatment is beneficial in reducing inflammation, muscle spasm, ischemia, and edema.
11. Massage involves the manipulation of the soft tissues to increase cutaneous circulation, cell metabolism, and venous and lymphatic flow to assist in the removal of edema; stretch superficial scar tissue; alleviate soft-tissue adhesions; and decrease neuromuscular excitability. Strokes include effleurage, pétrissage, tapotement, vibration, and friction massage.
12. Traction is the process of drawing or pulling tension on a body segment, and is commonly used on the spine to treat herniated disc protrusion, spinal nerve inflammation or impingement, narrowing of intervertebral foramen, and muscle spasm and pain.
13. Continuous passive motion applies an external force to move the joint through a preset arc of motion, and is primarily used postsurgically at the knee, after knee manipulation, or after stable fixation of intra-articular and extra-articular fractures of most joints.
14. Nonsteroidal anti-inflammatory drugs are commonly used to dilate blood vessels and inhibit production of prostaglandins to decrease inflammation, relieve mild-to-moderate pain, decrease body temperature associated with fever, increase collagen strength, and inhibit coagulation and blood clotting.
15. Because of the complexity of each of the therapeutic modalities, students should enroll in a separate therapeutic modalities class permitting practice and demonstration of proper clinical skills associated with the application of therapeutic modalities.
16. While using any modality, if the individual begins to show signs of pain, swelling, discomfort, tingling, or loss of sensation, the treatment should be stopped and the individual should be re-evaluated to determine if the selected modality is appropriate for the current phase of healing.

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