Basic Athletic Training
Course Pack B

CHAPTER

12

Therapeutic Modalities

STUDENT OUTCOMES

1. Explain the principles associated with the electromagnetic spectrum and identify the 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 can affect this transfer.
3. Describe the physiological effects of cryotherapy and thermotherapy.
4. List the indications and contraindications for the various methods of cold and heat treatments, including ultrasound and diathermy.
5. Explain the principles that govern ultrasound, including

the physiological effects and modes 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. Explain the principles that govern traction and continuous passive motion.

INTRODUCTION

The ultimate goal of rehabilitation is to return the injured participant to activity in a pain-free and fully rehabilitated condition. The rehabilitation process must focus on controlling pain and inflammation and on 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 on the injury site and the 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 by a particular modality. In some cases, a modality may be indicated and contraindicated for the same condition. For example, thermotherapy 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 (using patient outcomes) is necessary to ensure that the appropriate modality is being used.

This chapter initially addresses the basic principles associated with the electromagnetic spectrum and the factors affecting the transfer of energy. Then, the more common therapeutic modalities used in injury management are discussed. The material presented is a general overview of the various modalities. Because of the extensive information and clinical skills that are 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 such a course be a part of the professional preparation of an athletic trainer as well as continually utilizing current evidence-based literature and meta-analysis of therapeutic modalities.

ELECTROMAGNETIC SPECTRUM

? During practice, a lacrosse player sustains a contusion to the posterior aspect of the upper arm. A bag of crushed ice is applied to the injured area using a compression wrap. Should the ice bag be applied directly to the skin or over a layer of towel covering the skin? Explain the process of energy transmission between the ice bag and the underlying soft tissues.

On a daily basis, the environment is impacted by a variety of energy forms. 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 (Fig. 12.1). Electrical therapeutic modalities are part of the electromagnetic spectrum, which is divided into two major zones: the ionizing range and the nonionizing range. Regardless of the range, electromagnetic energy has several common characteristics:

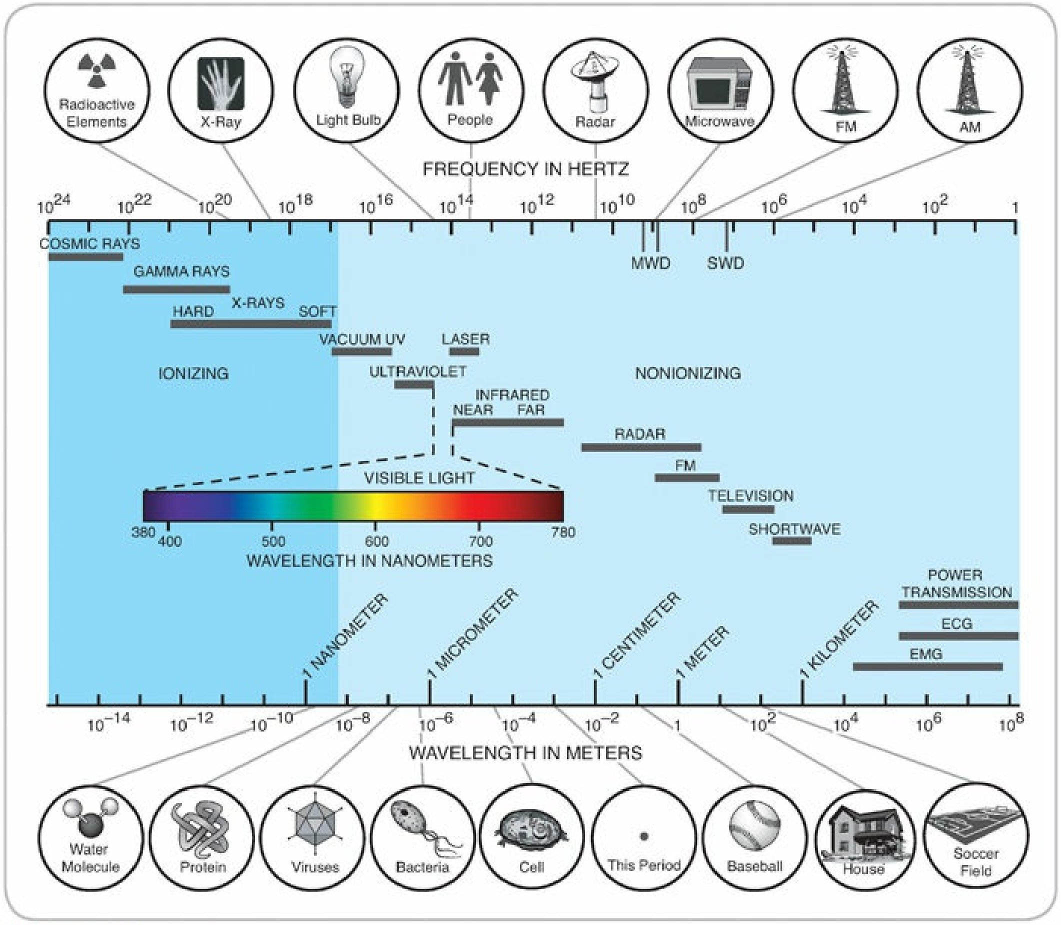

Figure 12.1. Electromagnetic spectrum. The electromagnetic spectrum covers a wide range of wavelengths and frequencies. UV, ultraviolet; ECG, electrocardiogram.

- 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.
- Energy requires no transmission medium.

Ionizing Range

Energy in the ionizing range can readily alter the components of atoms (i.e., 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 radiography (i.e., in X-ray dosages below that required for cell death) and therapeutically to treat certain cancers (i.e., 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 commonly is used in the management of musculoskeletal injuries. This portion of the spectrum incorporates ultraviolet, visible, and infrared light. Electromagnetic waves are produced when the temperature rises and the 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. The infrared wavelengths closest to visible light are called near-infrared energy and can produce thermal effects 5 to 10 mm deep in tissue. The infrared wavelengths farthest from the visible are called far-infrared energy and result 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 both examples of radiant energy transfer, but they can also 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 the speed at which the air or water next to the body is moved away once it becomes warmed. For example, if air movement is slow, the 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 can occur during evaporation as well. The body cools itself on a hot day when sweat forms as a liquid over the skin surface. The heat absorbed by the liquid cools the skin surface as the liquid changes into a gaseous state.

Factors Affecting Energy Transfer

When electromagnetic energy is transmitted in a vacuum, it travels in a straight line. When traveling through a physical medium, however, the path is influenced by the density of the medium, and the energy may be reflected, refracted, or absorbed by the material or may continue to pass through the material unaffected by its density (Fig. 12.2). **Reflection** occurs when the wave strikes an object and is bent back away from the material. An echo is an example of a reflected 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 and enters a high-density layer, its speed decreases. **Absorption** occurs when the wave passes through a medium, and its kinetic energy is either 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 layer with a different density, where 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 the superficial tissues absorb, the less energy is available to be transmitted to the underlying tissues.

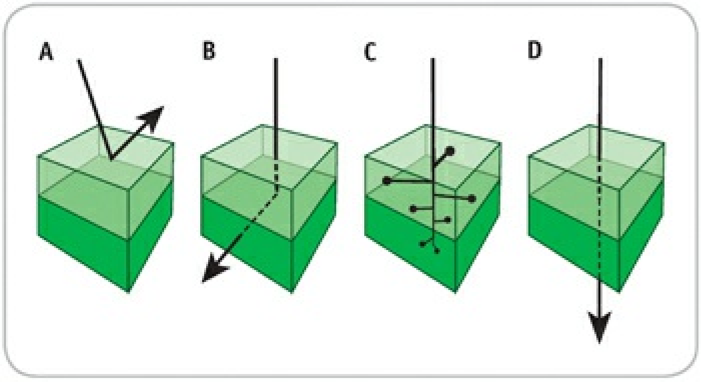

Figure 12.2. **Factors affecting the transmission of energy. A, Reflection.** The energy wave may be partially or fully reflected by the tissue layer. **B, Refraction.** The energy wave is bent as it strikes an interface between two different tissue layer densities. **C, Absorption.** Energy can be absorbed 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.

Effect of Energy 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** (Fig. 12.3) states that as the angle deviates from 90°, the energy varies with the cosine of the angle:

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

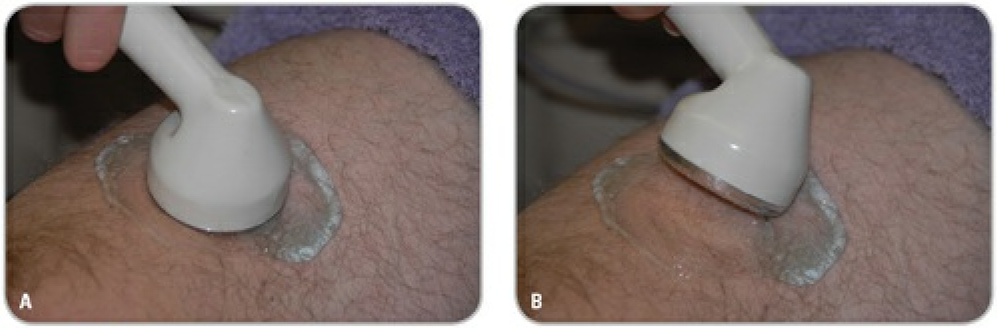

Figure 12.3. The cosine law. A, When energy is applied to a body part, the maximal effect occurs when energy rays strike the body at a right angle (90°). **B,** As the angle deviates from 90°, some of the energy is reflected away from the targeted site, thereby reducing the level of absorption. This concept is critical in the application of ultrasound.

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 law** (Fig. 12.4), which 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:

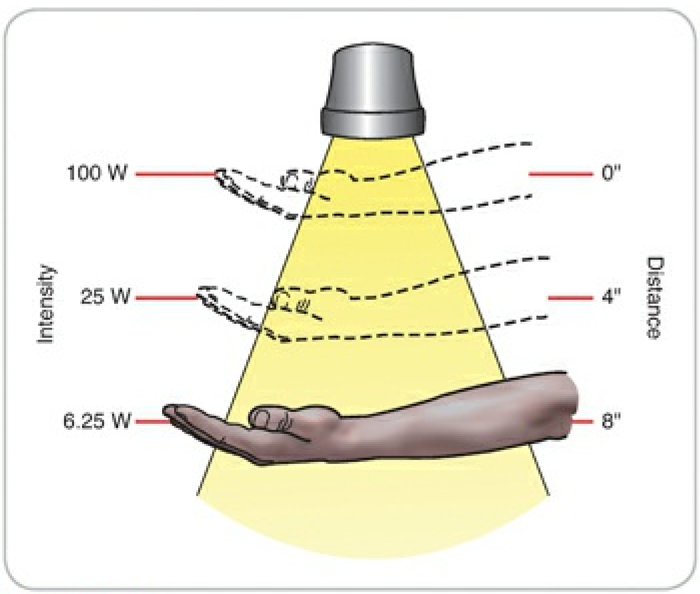

Figure 12.4. The inverse square law. Heating effect equals x(a). When the distance between the energy source and the skin is reduced by half, the heating effect is increased by fourfold (inverse of 1/2 = 2, and $2^2 = 4$).

$$E = \frac{E_S}{D^2}$$

Where

E_S = amount of energy produced by the source,

D^2 = square of the distance between the target and the source, and

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.

The bag of crushed ice can be applied directly to the skin of the lacrosse player. Because the thermal energy is being transferred via conduction, application directly to the skin promotes a more efficient and effective transfer of cold to the injured area.

CRYOTHERAPY

In treating the lacrosse player's contusion, for how long a period should the ice bag be applied? What contraindications may prohibit the use of cold in this case?

Cryotherapy describes multiple types of cold application that use the kind of electromagnetic energy classified as infrared radiation. When cold is applied to skin, which is a warmer object, heat is removed or lost; this is referred to as heat abstraction, or cooling. The most common modes of heat transfer with cold application are conduction and evaporation. Cold application causes vasoconstriction and decreased vascular permeability, which can lead to decreased cell metabolism, inflammation, circulation, pain perception, muscle spasm, muscle force production, and increased tissue stiffness.[2] The intent of cold application immediately following injury is to reduce the area of secondary injury, thus limiting the total amount of damaged tissue that needs repair. Depth of cold penetration can reach 4 to 5 cm and is dependent on the duration of treatment, the depth, and type of tissue. The longer the treatment, the greater the depth of cooling and the greater the decrease in temperature. The magnitude of temperature change depends on the following:

- The type of cooling modality (e.g., ice massage versus ice slush, where treatment temperature differs)
- The temperature difference between the cold object and soft tissue
- The use of a compression wrap to secure the cold agent
- The insulating medium between the skin and cold agent
- The amount of subcutaneous insulation (adipose tissue/fat)
- The depth of the target tissue
- The vascularity and thermal conductivity of the area being cooled
- The limb circumference
- The sympathetic nervous system
- The duration of the application

The greater the temperature gradient between the skin and cooling source, the greater the resulting temperature change in the tissue. Likewise, the deeper the tissue, the more time is required to lower the temperature (e.g., treatment on a wrist versus a thigh). Adipose 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, the return to its precooled temperature.

Cold therapy is used to lower the temperature in soft tissues (e.g., subcutaneous tissue, muscle, or joints), reduce pain, and control edema. 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 occurs in nerve conduction velocity across the nerve synapse, increasing the threshold required for nerves to fire. 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 and leading to an **analgesic**, or pain-free, effect. 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. The therapeutic application of cold cools the surface skin temperature between 1° and 10°C (33° to 50°F)[4]; 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).[5,6] The desired therapeutic range of cooling can be obtained through the use of ice bags (e.g., crushed or cubed), commercial ice packs, ice cups (e.g., ice massage), and cold water baths (e.g., immersion or whirlpool). Recent technology also has provided new forms of cold application, such as the Cryo/Cuff or Game Ready or cold and compression therapy (CCT) units.

Cryotherapy is usually applied for 20 to 30 minutes several times a day for maximum cooling of both superficial and deep tissues. Treatment times may vary depending on the thickness of the adipose layer. When using ice packs, it was found that the time required to lower deep tissue temperature for selected skinfold thicknesses of 0 to 10 mm, 11 to 20 mm, 21 to 30 mm, and 31 to 40 mm were 12, 30, 40, and 60 minutes, respectively.[7] Barriers used between the ice application and skin also 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.[4,8] Using a compression wrap to secure the cold agent (e.g., ice pack) to the body part, however, produces a significant reduction in subcutaneous tissue temperatures as compared with simply placing the cold agent on the skin.[9] 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 required to rewarm the injured area. Knight[4] has shown that except for the fingers, the rewarming time to approach normal body temperature is at least 90 minutes. 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.

One challenge, when working with athletes, is the practice of securing ice to an injury site in the athletic training room and having the individual walk to his or her residence. Intramuscular tissue temperature continually cools (34° to 28°C) at rest during the application of ice, which can be as great as 3.9° to 5.4°C cooler during a 20- to 30-minute treatment period. However, no change in intramuscular tissue temperature was shown during the same time period while walking.[10] The current trend of wrapping "to go" ice bags to the leg is not likely to achieve deep tissue cooling despite surface temperature decreases.

Certain methods of cryotherapy also may be used before ROM exercises and at the conclusion of an exercise bout (**Box 12.1**). 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 by applying cold for 10 to 20 minutes, 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 ends with exercise if the individual is able to participate in activity or with cold if the individual is not able to participate in activity.

BOX 12.1 Cryotherapy Application

Indications

Acute or chronic pain

Acute or chronic muscle spasm/guarding

Acute inflammation or injury

Postsurgical pain and edema

Neuralgia

Superficial first-degree burns

Used with exercises to:

- Facilitate mobilization
- Relieve pain
- Decrease muscle spasticity

Contraindications

Decreased cold sensitivity and/or hypersensitivity

Cold allergy/cold-induced urticaria

Circulatory or sensory impairment

Raynaud phenomenon

Advanced diabetes

Hypertension

Uncovered open wounds

Cardiac or respiratory disorders

Nerve palsy

Arthritis

Lupus

Methods of cryotherapy include cold packs, ice massage, ice immersion, and cold and compression therapy units. Regardless of the methods of application, the individual feels four progressive sensations: cold, burning, aching, and **analgesia**.

Cold Packs

Cold packs are administered in four common methods: plastic bags filled with crushed, flaked, or cubed ice; reusable cold gel packs; CCT units; and instant (chemical) cold packs. Most methods are inexpensive and maintain a constant temperature, making them very effective at cooling tissue.

Ice Bags

When filled with flaked ice or small cubes, ice bags 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 compression wrap, and elevated above the heart to minimize swelling and pooling of fluids in the interstitial tissue spaces (Fig. 12.5A). During the initial treatments, the skin should be checked frequently for wheal or blister formation indicating an allergy to cold (Fig. 12.5B). A disadvantage of this application method is the cost of the ice machine, which can be expensive.

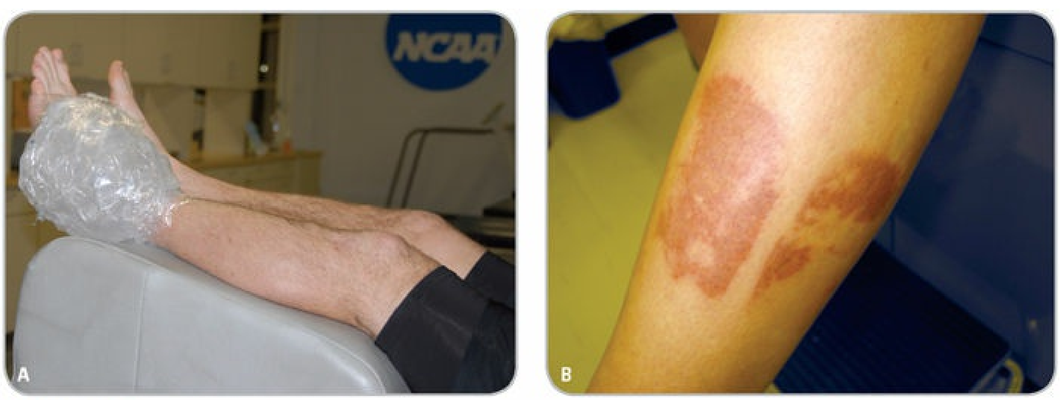

Figure 12.5. Ice treatments. A, Ice, compression, and elevation can reduce acute inflammation. **B,** A slightly raised wheal formation may appear shortly after cold application in individuals who are sensitive to cold or who have cold allergies.

Reusable Cold Packs

Reusable commercial gel packs contain silica gel enclosed in a strong vinyl or plastic case, and they come in a variety of sizes to conform to the body's natural contours (Fig. 12.6). Used with compression and elevation, they are an effective method of cold application. The packs should be stored at a temperature of approximately −5°C (−23°F) for at least 2 hours before 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 the skin to prevent frostbite and to maintain a hygienic surface for the reusable packs. Treatment time ranges from 15 to 20 minutes.

Figure 12.6. Commercial gel packs. Commercial gel packs come in a variety of sizes to conform to the body's natural contours.

Cold and Compression Therapy Units

CCT units use static, external compression and cold application to decrease blood flow to an extremity and to assist venous return, to decrease edema, and to increase the effective depth of cold penetration. In doing so, both pain and recovery time is decreased. Commercial circulating cold-water wraps, such as Cryo/Cuff (Aircast Inc, Summit, NJ), Polar Care (Breg Inc, Vista, CA), and **Game Ready** (CoolSystems Inc, Concord, CA), use ice water placed in an insulated thermos. When the thermos is raised above the body part, water flows into the pad wrapped around the injured extremity, maintaining cold compression for 5 to 7 hours (Fig. 12.7A). These often are applied after surgery over dressings and casts. Some CCT units provide a motorized, intermittent compression treatment when cooled water is circulated through a boot or sleeve around the injured body part, and the sleeve is inflated intermittently. This is done for 20 to 30 minutes several times a day to pump edematous fluid from the extremity (Fig. 12.7B). During deflation, the patient can perform active ROM exercises to enhance blood flow to the injured area. The unit can be used several times a day but never with a suspected compartment syndrome or fracture or in an individual with a peripheral vascular disease or impaired circulation.

Figure 12.7. **Cold compression therapy units. A,** These devices provide circumferential cold compression around a specific body part. When the thermos is raised above the body part, water flows throughout the unit, maintaining cold compression for 5 to 7 hours. **B,** Some units have a motorized unit that can provide pressure or intermittent compression to an injured area to decrease edema.

Instant Cold Packs

Instant (chemical) cold packs are convenient to carry in an athletic training kit, can be disposed of after a single use, and can conform to a body part. Each bag contains two chemicals separated by a plastic barrier. When the barrier is ruptured, the chemicals mix, producing cold. Disadvantages of this type of application are the short duration of the cold application, the expense in using the pack only once, and the potential of the pack to tear or leak. The chemical substance that produces the cold has an alkaline pH, which can cause burns if the liquid substance comes in contact with the skin. 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.

Ice Massage

Ice massage is an inexpensive and effective method of cold application. Performed over a relatively small area, such as a muscle belly, a tendon, a bursa, or a trigger point, 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 cases of acute injury. An ice massage is particularly useful for its analgesic effect in relieving pain that may inhibit stretching of a muscle, and it has been shown to decrease muscle soreness when combined with stretching.[2] It commonly is used before ROM exercises and deep friction massage when treating chronic tendinitis and muscle strains.

Treatment consists of water frozen in a cup, which is rubbed over an area 10 cm × 15 cm using small, overlapping, circular motions for 5 to 10 minutes. A continuous motion is used to prevent tissue damage. If this treatment is applied properly, skin temperature usually will not drop below 15°C (59°F); therefore, the risk of damaging tissue and producing frostbite is minimal.[2] A wooden tongue depressor frozen in the cup can provide a handle for easy application. During ice massage, the stages of cold, burning, and aching pass rapidly, within approximately 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 Immersion

Ice immersion (ice slush bath) is used to reduce temperature quickly over the entire surface of a distal extremity (e.g., forearm, hand, ankle, or foot). A variety of containers or basins may be used. Because of the analgesic effect and the buoyancy of water, ice immersion and cold whirlpools often are used during the inflammatory phase to reduce an edema formation after a blunt injury. If the goal is to reduce an 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 before submersion and performing 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 (**Fig. 12.8**). Bucket immersion in 4° to 10°C (40° to 50°F) water or a 10.0° to 15.6°C (50° to 60°F) whirlpool cools tissues as effectively as an ice pack. The lower the temperature, the shorter the duration of immersion. Treatment lasts from 10 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 or four times.

Figure 12.8. 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.

Cold whirlpool baths also provide a hydromassaging effect. The intensity of the effect is controlled by the amount of air that is 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 decrease soft-tissue trauma and to increase active ROM after prolonged immobilization.

The ice bag can be applied to the lacrosse player's injured upper arm for a period of 20 to 30 minutes. After a maximum of 90 minutes to allow for the rewarming of the area, another cold treatment should be initiated. This process should be followed throughout the remainder of the day. If the patient experiences any skin blanching, numbness, burning, or tingling sensations, the cold treatment should be stopped.

THERMOTHERAPY

? Following 5 days using cold treatments for the upper arm contusion, the lacrosse player shows significant improvement. The only significant finding is a slight decrease in strength as compared bilaterally with the uninvolved arm. Can the application of heat be advantageous during this stage in the healing process? What criteria would indicate that it is safe to use a heat modality at this time?

Thermotherapy, or heat application, typically is used during the second phase of rehabilitation to increase blood flow and to promote healing in the injured area (Box 12.2). If used during the acute inflammatory stage, heat application may overwhelm the injured blood and lymphatic vessels, leading to increased hemorrhage and edema. When applied at the appropriate time, however, 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 the healing of damaged tissues. Debris and waste products are removed from the injury site. Used before stretching exercises, joint mobilization, or active exercise, thermotherapy can increase the 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.

BOX 12.2 Thermotherapy Application

Indications

Subacute or chronic injuries, to:

- Reduce swelling, edema, and ecchymosis
- Reduce muscle spasm/guarding

Subacute or chronic muscle spasm

Increase blood flow to:

- Increase ROM prior to activity

- Resolve hematoma
- Facilitate tissue healing
- Relieve joint contractures
- Fight infection

Contraindications

Acute inflammation or injuries

Impaired or poor circulation

Subacute or chronic pain

Advanced arthritis

Impaired or poor sensation

Impaired thermal regulation

Malignancy/neoplasms

Thrombophlebitis

Superficial heating agents involve the transfer of heat through conduction, convection, and radiation. Common examples of superficial thermotherapy are warm whirlpools or immersion, moist heat packs, paraffin baths, fluidotherapy, and infrared lamps. Penetrating thermotherapy, including ultrasound, phonophoresis, and diathermy, is discussed in more detail later in this chapter.

To attain therapeutic effects from vigorous heating, tissue temperature must be elevated to between 40° and 45°C (104° to 113°F). Within these temperatures, hyperemia, which indicates increased blood flow, occurs. Potential tissue damage can occur with temperatures above this range; temperatures below this range are considered to be only mild heating and insufficient to stimulate cellular metabolism enough to cause therapeutic effects.[11,12] Changes in surface tissue temperature caused by superficial heating agents depend on the intensity of heat applied, the time of heat exposure, the volume of tissue exposed, and the 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 increases to a lesser degree and requires a longer duration of exposure (i.e., 15 to 30 minutes) to reach peak values.[12] After peak temperatures are reached (i.e., approximately 7 to 9 minutes), 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.

Hydrotherapy Tanks

Whirlpool and hydrotherapy tanks combine warm or hot water with a hydromassaging effect to increase superficial skin temperature (**Fig. 12.9**). 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.

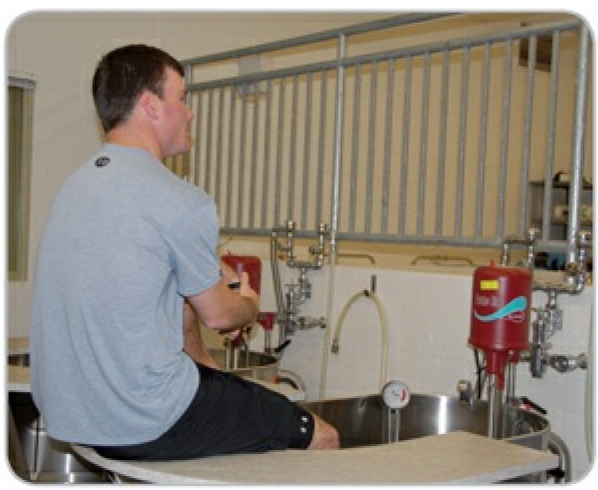

Figure 12.9. Whirlpools. Hot whirlpools increase superficial skin temperatures, leading to an analgesic effect that can reduce muscle spasm and pain, facilitate ROM exercises, and promote healing.

Whirlpools are analgesic agents that relax muscle spasms, relieve joint pain and stiffness, provide mechanical debridement, 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 that is 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 exceeding 20 to 30 minutes can dehydrate the individual, leading to dizziness and a high body core temperature. Only the body parts being treated should be immersed. Application Strategy 12.1 explains the use of this modality.

APPLICATION STRATEGY 12.1

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. Instruct the patient not to turn the turbine on or off or touch any electrical connections while in the whirlpool or while the body is wet.
3. Apply a whirlpool disinfectant according to the manufacturer's directions.
4. If an open wound is present on the body part being treated, add a disinfectant such as povidone, povidone-iodine, or sodium hypochlorite to the water.
5. Recommended temperature and treatment times include the following:

Cold whirlpools	10°–16°C (55°–65°F) 5–15 minutes
Hot whirlpools	32°–49°C (98°–110°F) 20–30 minutes

   Temperature and time is decreased as the body area being treated increases.
6. Assist the patient into the water and provide towels for padding and drying off.
7. Turn the turbine on and adjust the height to direct the water flow 6 to 8 in away from the injury site.

8. Instruct the patient to move the body part through the available ROM. This increases blood flow to the area, aids in the removal of debris, and improves balance and proprioception.
9. Turn the turbine off and remove the patient from the water. Dry the treated area and assist the patient from the whirlpool area.
10. Drain and cleanse the whirlpool tub after each use. Refill the tub with hot water (48.9°C [120.0°F]) to safely operate the turbine. Add a commercial disinfectant, antibacterial solution, or chlorine bleach to the water, following the manufacturer's directions. Run the turbine for at least 1 minute to allow the agent to cycle through the internal components. Drain the whirlpool.
11. Disinfect the interior hard-to-reach places with a brush and cleaner, paying attention to the external turbine, thermometer stem, drain, welds, and other areas that may harbor germs and organic material (blood, mucus). Thoroughly rinse the tub.
12. Clean the exterior of the tub with a stainless steel cleaner or other appropriate cleaner.
13. Cultures for bacterial and fungal agents should be conducted monthly from water samples in the whirlpool turbine and drain.
14. Have the whirlpool turbine inspected and the thermometer calibrated annually by a qualified service technician.

Many athletic training facilities also have large hydrotherapy tubs that can accommodate 4 to 16 athletes at a time. 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 associated with use of both hydrotherapy tanks and whirlpools. If an infection is to be prevented, these tubs must have an effective filtration and chlorination system. Chlorine and pH levels should be monitored hourly during periods of heavy use, and calcium hardness should be evaluated weekly.[13] The water temperature should not exceed 38.9°C (102°F). The water should be drained, superchlorinated, and refilled once a week. In an ideal setting, whirlpools should be drained, cleaned, and sanitized after each patient.

For safety reasons, ground-fault circuit interrupters (GFCIs) should be installed in all receptacles or in the circuit breaker box in the hydrotherapy area. They should be no more than 1.5 m away from the tanks. A sensor located within the GFCI monitors the 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 proper operation.

Moist Heat Packs

Heat 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 occurs with a whirlpool. Like other forms of superficial heating, deeper tissues, including the musculature, are 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, which carries away externally applied heat. Hot packs most often are used to promote soft-tissue healing, to reduce pain and superficial muscle spasm while promoting general relaxation, and to improve tissue extensibility. The most efficient way to warm up the musculoskeletal tissue is with exercise (biking, elliptical trainer).

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) (**Fig. 12.10**). When removed from the water, a pack should be wrapped in a commercial padded cover or in six to eight layers of toweling and then placed directly over the injury site for 20 to 30 minutes. Commercial hot pack covers may need additional layers of toweling to ensure adequate insulation for the hot pack.

Figure 12.10. Moist hot packs. Moist heat treatments can burn sensitive skin. As such, the pack should be placed in a commercial padded towel or in six to eight layers of toweling, and the skin surface should be checked periodically for redness or signs of burning.

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, because this may accelerate the rate of heat transfer, leading to burns on sensitive skin. Following 5 minutes of treatment, the area should be checked for any redness or signs of burning. At the conclusion of the treatment, the hot pack should be replaced in the heating unit for rewarming. It is strongly recommended that the hot pack temperature should be measured before use, because rewarming varies depending on the temperature of the hot pack before its return to the heating unit, on size of the heating unit, and on the number of used packs simultaneously returned for reheating.[14]

The hot packs should be checked regularly for leaks, and a hot pack 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.

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 and diseases, such as systemic sclerosis.[15] A paraffin and mineral oil mixture (6:1 or 7:1 ratio) is heated in a unit at 45° to 54°C (113° to 129°F). The purpose of adding mineral oil is to lower the melting temperature of paraffin from 54°C (129°F) to between 45° and 50°C (113° to 122°F), thus making the mixture more comfortable for patients during the treatment.

Several methods of paraffin application may be employed; however, two principal methods of application are used: dip and wrap, and dip and reimmersed. For both methods, the body part should be thoroughly cleansed and dried, and all jewelry should be removed. The body part should be placed in a relaxed position and then dipped into the bath several times, each time allowing the previous coat to dry (Fig. 12.11). 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 should be wrapped in a plastic bag and towel to maintain heat and then elevated for 15 to 20 minutes (or until heat is no longer generated).

Figure 12.11. Paraffin bath. A thoroughly cleansed limb is 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.

When using the dip and reimmersed method, after the formation of a wax glove, the body part covered by the glove is put back into the wax container for 10 to 20 minutes without moving it. This method results in a more vigorous response relative to temperature elevation and changes in blood flow. This technique should not be used in individuals predisposed to edema, however, or in those who cannot sit in the position required for treatment.

When the treatment is completed, the wax should be peeled off and returned to the bath, where it can be reused. The mineral oil in the wax helps to keep the 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.

Fluidotherapy

Fluidotherapy is a dry thermal modality that transfers its energy (i.e., heat) to soft tissues by forced convection. Heat is transferred through the forced movements or agitation (blower action) in the unit chamber of heated air and Cellex particles, which are then circulated around the treated body part, making the fluidized bed behave with properties similar to those of liquids. Used to treat acute injuries and wounds, to decrease pain and swelling, and to increase ROM and inadequate blood flow, this modality is more effective than paraffin wax baths and warm whirlpool tubs at inducing absolute temperature increases in peripheral joint capsules and muscles.[16] Both the temperature and the amount of particle agitation can be varied. Treatment temperature ranges from 46° to 51°C (115° to 124°F).[11]

For optimal heating, the patient should remove all jewelry and wash the treated body parts before positioning the body area in the fluidotherapy chamber. A skin sensory heat discrimination test of the patient is mandatory before considering an application of this modality. This test consists of setting the amount of heat needed, the speed of particle agitation required, and the total treatment session duration.

Advantages of this superficial heating modality include that exercise can be performed during the treatment, higher treatment temperatures can be tolerated, and heat is distributed over the entire limb surface area with minimal to no pressure applied to the treated site. 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.

The lacrosse player's upper arm contusion showed significant improvement after 5 days of ice treatments. As long as the patient does not report point tenderness at the involved area, it probably is safe to move to a heat treatment. Heat can increase the local circulation and, in doing so, promote healing. It also can be used in conjunction with stretching and mild exercise to strengthen the injured muscle.

ULTRASOUND

?

Two weeks after the injury, the lacrosse player is pain-free. There is a small, palpable, swollen area in the triceps at the spot where the force was sustained. What type of heat treatment would be most effective at this point in the healing process?

Superficial heating agents were discussed in the previous section. These agents produce temperature elevations in the 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, or 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 (i.e., thermal effects) as well as mechanical and chemical alterations (i.e., 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 (i.e., mechanical effects) increase skin permeability, thus decreasing the inflammatory response, reducing pain, and facilitating the soft-tissue healing process. Both pulsed and continuous ultrasound reduces nerve conduction velocity of pain nerve fibers.

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 people to hear others talking while standing or being positioned behind them. 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** 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) that occur in 1 second. Frequencies range between 0.75 and 3.0 MHz. For any given source of sound, the higher the frequency, the less the emerging sound beam diverges. For example, low-frequency ultrasound produces a more, widely diverging beam compared with high-frequency ultrasound, which produces a collimated beam. The more commonly used 1-MHz ultrasound heats tissue from 3 to 5 cm deep, whereas 3-MHz ultrasound heats tissue usually from 2 to 3 cm deep.[17,18]

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 (i.e., 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.

The 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, less sound energy is available to move through the tissue. The 1-MHz machine most often is used on individuals with a high percentage of subcutaneous body fat 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 as well as cell division during periods of rapid cell proliferation.[19] In addition, it has been used on tendons on the second and fourth days after surgery to increase tensile strength. After the fifth day, however, application decreases tensile strength.[20]

The high-frequency, 3-MHz machine provides treatment to superficial tissues and tendons, with a depth of penetration between 1 and 2 cm (1/3 to 1/4 in). The low penetration depth is associated with limited transmission of energy, rapid absorption of energy, and 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:

$$\text{Duty cycle} = \frac{\text{Duration of pulse (time on)} \times 100}{\text{Pulse period (time on + time off)}}$$

Typical duty cycles in the pulse mode range from 0.05 (5%) to 0.5 (50%), with the most commonly used duty cycle being 0.02 (20%).[21] 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 2.5 cm deep in the muscle after the application of ultrasound at 1.5 W/cm^2 for 10 minutes.[22] As mentioned, ultrasound waves are absorbed in those tissues that are highest in collagen content, and they are reflected at tissue interfaces, particularly between bone and muscle.

Clinical Uses

Ultrasound is used to manage several soft-tissue conditions, such as tendinitis, bursitis, and muscle spasm; to reabsorb calcium deposits in soft tissue; and to reduce joint contractures, pain, and scar tissue (**Box 12.3**). In other areas, musculoskeletal ultrasound frequently is used to determine the presence or absence of tendon tears or the extent of dermal injuries.[23,24] Wound healing is enhanced with low-intensity, pulsed ultrasound. It is recommended that ultrasound treatment should begin 2 weeks after an injury, during the proliferative phase of healing. An 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.[21]

BOX 12.3 Ultrasound Application

Indications

Deep tissue heating

Acute inflammatory conditions (pulsed)

Chronic inflammatory conditions (pulsed or continuous)

Spasticity/muscle spasm

Trigger areas

Increase extensibility of collagen tissue

Joint adhesions/contractures

Neuroma

Postacute myositis ossificans

Contraindications

Acute and postacute hemorrhage (continuous)

Infection

Thrombophlebitis

Areas of impaired circulation/sensation

Over stress fracture sites or osteoporosis

Over suspected malignancy/cancer

Over the pelvic or lumbar areas during menstruation or pregnancy

Over epiphyseal growth plates

Over the eyes, heart, skull, spine, or genitals

Over active sites of infection or sepsis

Over an implanted pacemaker

Over exposed metal that penetrates the skin

Ultrasound often is used with other modalities. When used in conjunction with hot packs, muscle spasm and muscle guarding may be reduced. The hot pack produces superficial heating, and the ultrasound, using a 1-MHz ultrasound frequency, produces heating in the deeper tissues. Because ultrasound can increase the blood flow to deep tissues, this modality often is used with electrical stimulation units. The electrical current produces a muscle contraction or modulates pain; the ultrasound increases circulation and provides deep heating. This combination of treatment protocols can be effective in treating both trigger and acupuncture points.

Application

Because ultrasound waves cannot travel through air, a coupling agent is used between the transducer head and the skin to facilitate the 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 (**Fig. 12.12**). Strokes are applied in small, continuous circles or longitudinal patterns to distribute the energy as evenly as possible at a rate of 4 cm per second to prevent **cavitation** (gas bubble formation) in deep tissues.[25] The total area covered usually is two- to threefold 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 that are 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 the tissue interface.

Figure 12.12. 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.

A common alternate method for irregularly shaped areas (e.g., wrist, hand, ankle, or foot) is application under water. A rubber-type basin should be used for these treatments. For several reasons, metal containers and whirlpools should not be used for underwater treatments. If the treatment is given in a metal basin or whirlpool, some of the ultrasound energy is reflected off the metal, thus increasing the 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 before the ultrasound treatment. Water treatments are indirect and generally have a 0.5- to 3-cm space between the patient and the sound head. Intensity is increased by 0.5 W/cm^2 to compensate for air and minerals in the water. 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 clinician should hold the transducer head so that 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 is filled with water or aqueous gel. To prevent blockage of the ultrasound energy, all air pockets must be eliminated. 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.

Research has shown that ultrasound treatments using gel in direct contact with the patient produce more heat than is produced with ultrasound administered indirectly underwater.[26–30] A reusable gel pad is another 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.[30] Intensity for both gel and underwater treatment is determined by the stage of injury, the mode used (i.e., pulsed or continuous), the desired depth of penetration, and patient tolerance. The patient may feel a mild, warm sensation.

When the goal of treatment is to elevate tissue temperature over a large quantity of soft tissue (e.g., hip or back), a continuous-wave mode with intensities as high as 1.5 to 2.0 W/cm^2 typically is used. A lower intensity (0.5 to 1.0 W/cm^2) and a higher frequency are used over areas with less soft-tissue coverage and where bone is closer to the skin surface. At tissue–bone interfaces, approximately 35% of the ultrasound beam is reflected, resulting in an increased intensity in the soft tissue overlying the bone, particularly the periosteum.[26] Elevated temperatures should be maintained for at least 5 minutes after the patient reports the sensation of gentle heat to allow an increase in extensibility. If heat production in tissues greater than 3 cm deep is the desired effect, 10 minutes of treatment after the patient reports the sensation of heat is the minimum.[29]

Phonophoresis

Phonophoresis is a technique in which the mechanical effects of ultrasound are used to enhance percutaneous absorption of anti-inflammatory drugs (e.g., cortisol, dexamethasone, and **salicylates**) and local analgesics (e.g., 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. Phonophoresis is believed to accelerate functional recovery by decreasing pain and promoting healing. High ultrasound intensities have been used to deliver these medications to depths of 5 to 6 cm subcutaneously into skeletal muscle and peripheral nerves.[31] Pulsed-wave ultrasound appears to be more effective than continuous-wave ultrasound in decreasing inflammation.[32]

This technique is used during the postacute stage in conditions to treat painful trigger points, bursitis, contusions, or other chronic soft-tissue conditions, such as epicondylitis.[21,33] Phonophoresis also may be helpful in treating neuropathic pain, including phantom pain and central pain.[34] The standard coupling gel is replaced by a gel or cream containing the medication. Commercial chempads 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 and, therefore, the medication is more easily absorbed. Treatment occurs at a lower intensity (i.e., 1.0 to 1.5 W/cm^2) for 5 to 15 minutes.

Ultrasound would be an accepted treatment for the small, palpable, swollen area in the triceps. Ultrasound can provide both thermal and nonthermal effects to increase circulation, blood flow, and tissue extensibility and to reduce hematoma formation and to optimize the healing process.

SHORTWAVE DIATHERMY

In treating the lacrosse player's triceps contusion, would diathermy be an accepted treatment?

Diathermy, which literally means "to heat through," uses electromagnetic energy from the nonionizing radio frequency 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.

Two types of generators are used for heating. One places two condenser plates (capacitive or condenser field) on either side of the injured area, thus placing the patient in the electrical circuit. The other method uses an induction coil (induction field) 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, this method can be used for heating skeletal muscle when the skin is abraded so long as an edema is not present.

Shortwave diathermy can be delivered as either a continuous or a pulsed form. The 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 and is used primarily in chronic conditions. When these waves are interrupted at regular intervals, pulsed (or bursts of) radio frequency energy are delivered to the tissues and are referred to as pulsed radio frequency radiation (PRFR). PRFR may produce either thermal or nonthermal effects on tissues. Low power produces nonthermal effects, and high power produces thermal effects. Pulsed shortwave diathermy may be used in acute and subacute conditions, preventing tissue temperatures from rising too fast or too high.

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 radio frequency is 27.12 MHz. Microwave diathermy, another form of electromagnetic radiation, can be directed toward the body and reflected from the skin; it uses ultrahigh frequencies (UHF) at 2,450 MHz. Microwave diathermy is seldom used today, however, 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 44.0°C (99.5° to 111.2°F) in deeper tissues (2.5 to

5.0 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 the extent of heat production depends on wave frequency, the electrical properties of the tissues receiving the electromagnetic energy, and the type of applicator used.

The physiological effects known to occur with other therapeutic heat treatments also are produced with CSWD. Mild heating usually is 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 the extensibility of deep collagen tissue, to decrease joint stiffness, to relieve deep pain and muscle spasm, to increase blood flow, to assist in the resolution of inflammation, and to facilitate the healing of soft-tissue injuries in the postacute stage (**Box 12.4**).

BOX 12.4 Diathermy Applications

Indications

Chronic inflammation (bursitis, tendinitis, myositis, osteoarthritis, etc.)

Joint capsule contractures

Degenerative joint disease

Sacroiliac strains

Acute or chronic pain

Subacute inflammation

Deep muscle spasms

Ankylosing spondylitis

Osteoarthritis

Chronic pelvic inflammatory disease

Epicondylitis

Contraindications

Over internally and externally worn metal objects

Over metal surgical implants

Metal objects within immediate area

Unshielded cardiac pacemaker

Peripheral vascular disease

Patients with hemophilia

Sensitive areas, including over:

- Lumbar, pelvic, or abdominal areas in women with metallic intrauterine devices
- Ischemic, hemorrhagic, malignant, and acutely inflamed tissues
- Eyes, face, skull, genitals, and swollen joints
- Moist wound dressings, clothing, or perspiration
- Pregnant abdomen
- Epiphyseal plates in children

Pulsed Shortwave Diathermy

Pulsed shortwave diathermy (PSWD) is known by several names, including pulsed electromagnetic fields, pulsed electromagnetic energy, and PRFR. A relatively new type of diathermy, it 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," which 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 that is delivered

(80 to 120 W) during most CSWD treatments. Nonthermal effects may be produced at mean power levels below 38 W; thermal effects are produced when mean power levels exceed 38 W. Mean power levels between 38 and 120 W are appropriate for the treatment of acute and subacute inflammatory conditions and have been shown to assist in the absorption of hematomas, the reduction of ankle swelling, and the stimulation of collagen formation. PSWD 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 such as the superficial muscle, which has a high electrolyte level. Indications and contradictions are the same for PSWD as for CSWD.

Shortwave diathermy can provide deep heating to tissues with a higher water content, such as muscle. It is important to recognize, however, that the extent of muscle heating can be inhibited by the thickness of the subcutaneous fat layer. As such, other modalities may be more effective in providing a deep heat treatment.

ELECTROTHERAPY

?

In conjunction with a heat treatment for the lacrosse player's upper arm contusion, what type of electrotherapy could be used to elicit a muscle contraction and, in doing so, decrease muscle guarding and atrophy?

Electrical therapy is a popular therapeutic modality that can be applied to injured or immobilized muscles during the early stages of a therapeutic exercise program, 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 the 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. The transfer of energy from one atom to the next involves the movement of electrons only from the nucleus, thereby 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 that has more protons is said to be positively charged. Ions of similar charge repel each another, 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 currents can be applied to tissues (**Fig. 12.13**). 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 to modulate pain, elicit a muscle contraction, or produce ion movement. Alternating current (AC) is a continuous, two-directional flow of ions used to modulate pain or elicit a muscle contraction. A third classification, pulsed current, represents a type of current that has been modulated to produce specific biophysical effects. With this type of current, a flow of ions in a DC or AC is briefly interrupted. The current may be one-directional (monophasic), two-directional (biphasic), or polyphasic (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.

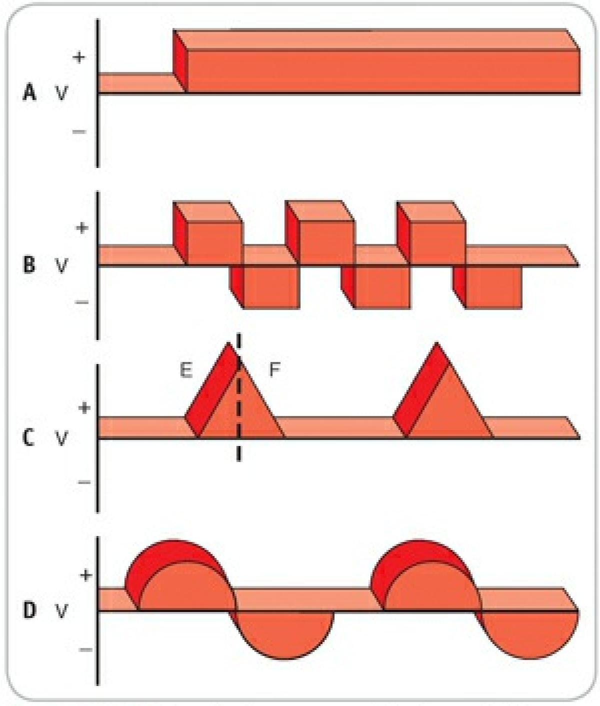

Figure 12.13. Four basic currents. The shape of the waveforms can be altered by changing the rate of rise and the rate of decay. **A,** DC with square wave. **B,** AC with square wave. **C,** Monophasic with triangular wave. *E,* rate of rise; *F,* rate of decay. **D,** Biphasic with sine wave.

Current Modifications

Once the basic current type is known, several parameters 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.[35] 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 milliampere (mA) as a measure of amplitude. Voltage causes the ions to move, but the actual movement is called the **current**. If the current is presented graphically, the voltage is represented by the magnitude of the wave.

If resistance remains the same, an increase in voltage will increase the amperage (i.e., the rate of current flow). An average current can be increased by increasing the pulse duration, increasing the pulse frequency, or some combination of the two.

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

Frequency

Frequency refers to the number of waveform cycles per second (cps) or hertz (Hz) with AC, 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 (<15 pps) causes the muscle to twitch with each pulse, cycle, or burst. As the frequency increases (15 to 40 pps), stimulation minimizes the relaxation phase of the muscle contraction. At higher frequencies (>40 pps), the stimulation is so fast that no relaxation occurs and a sustained, maximal contraction (tetany) is generated. Therefore, if the intent is to fatigue 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 a monophasic or biphasic current. In a biphasic current, the sum of the two phases represents the pulse duration, whereas in a 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 the interpulse interval is referred to as the pulse period. More powerful muscle contractions are generated with a pulse duration of 300 to 500 μs. A duration of less than 1 μs will not stimulate denervated muscle, regardless of the current's amplitude.

Pulse Charge

In a single phase, the pulse charge, or the 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 12.14.

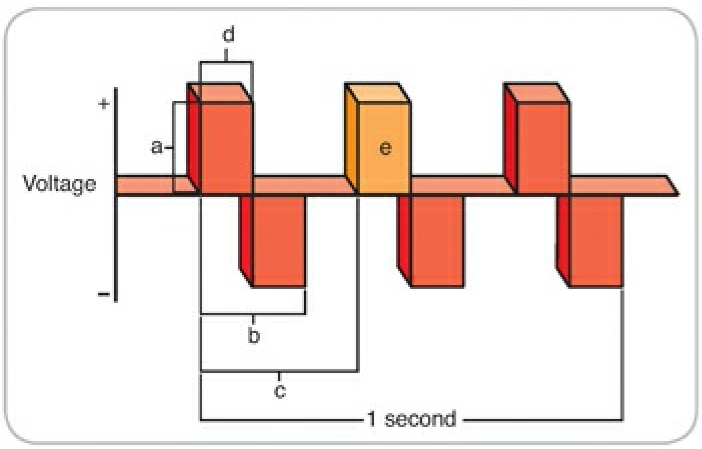

Figure 12.14. Graphic illustration of a biphasic current. *a*, amplitude (intensity); *b*, pulse duration; *c*, interpulse interval; *d*, phase duration; *e*, phase charge. Frequency, three pulses per second.

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 one that is 4-in 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, 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. This pattern requires the use of a large dispersal pad to take on the charge opposite that of the active pad and, in doing so, completes 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 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 12.15**.

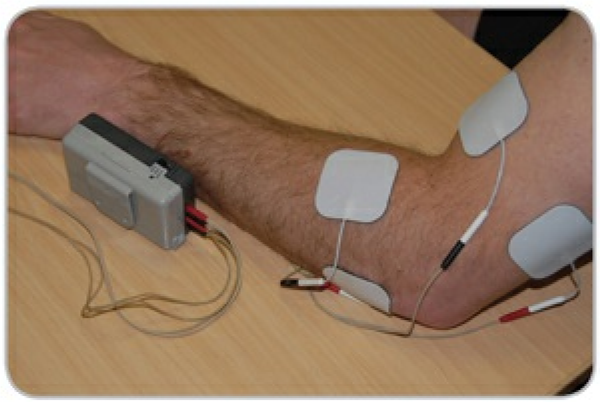

Figure 12.15. Transcutaneous electrical nerve stimulation. A transcutaneous electrical nerve stimulation unit is used to decrease acute and chronic pain to an injured area.

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 the pads are, the deeper and more generalized the contraction. The physiological 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 a negative pole. During DC 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, the term mode refers to the alternating (reciprocating) or continuous flow of current through the active electrodes. The term 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 builds gradually to the desired level, which improves patient comfort and safety by preventing sudden, powerful muscle contractions.

Duty Cycle

Duty cycle refers to the ratio of the amount of time that current is flowing (i.e., on time) to the amount of time it is not flowing (i.e., 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 seconds on and 40 seconds 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

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

Electrical Stimulating Units

Several different types of electrical stimulating units are available (**Box 12.5**). 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 often are 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.

BOX 12.5 Application of Neuromuscular Electrical Stimulation

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

TENS, transcutaneous electrical nerve stimulation.

Transcutaneous Electrical Nerve Stimulation

By varying the selection and setting of pulse duration, pulse/burst frequency, and current amplitude, clinicians can program transcutaneous electrical nerve stimulation (TENS) units to deliver one of the five basic therapeutic modes

(Table 12.1)[11]:

TABLE 12.1 The Five Classic Modes of TENS Therapy and Their Respective Biophysical and Physiological Characteristics

	CONVENTIONAL	ACUPUNCTURE-LIKE	BRIEF-INTENSE	BURST	MODULATION
Pulse duration	Short (<150 μs)	Long (>150 μs)	Long (150 μs)	N/A	Variable
Frequency	High (>120 Hz)	Low (<10 Hz)	High (>120 Hz)	Low (<10 Hz)	Variable
Current amplitude	Comfortable	Comfortable/tolerable	Comfortable/tolerable	Comfortable	Variable
Nerve fibers preferentially depolarized	S	S-M	S-M-N	S-M	Variable
Preferential mechanism of pain modulation	Nonopiate	Opiate	Opiate	Opiate	Variable
Onset of analgesia	Rapid (within minutes)	Slow (within hours)	Rapid (within minutes)	Slow (within hours)	Variable
Duration of analgesia	Short (< few hours)	Long (> hours)	Long (> few hours)	Long (> few hours)	Variable

N/A, not available; *S*, sensory; *S-M*, sensory-motor; *S-M-N*, sensory-motor-nociceptive.

Printed with permission from Bélanger AY. *Therapeutic Electrophysical Agents: Evidence Behind Practice.* Baltimore, MD: Lippincott Williams & Wilkins; 2009:31.

1. Conventional TENS units typically are portable, biphasic generators with parameters that allow pain control via electrical pulses having short duration, high frequency, and low-to-comfortable current amplitude.
2. Acupuncture-like TENS has electrical pulses of long duration, low frequency, and comfortable-to-tolerable current amplitude. It is called acupuncture-like because the pulse frequency is low, resembling that used in acupuncture therapy.
3. Brief-intense TENS has electrical pulses of long duration, high frequency, and comfortable-to-tolerable current amplitude. It gets its name because the duration of application is briefer and the current amplitude is higher than in the other modes, triggering a somewhat brief yet intense stimulation during treatment.
4. Burst TENS delivers bursts of pulses, not individual pulses, of low frequency at comfortable current amplitude.
5. Modulation TENS delivers random electronic modulation of pulse duration, pulse frequency, and current amplitude.

The units can produce analgesia and can decrease acute and chronic pain as well as pain associated with delayed-onset muscle soreness, although the duration of analgesia is unpredictable. TENS has also been shown to be effective in providing short-term pain relief in low back pain but is not as statistically effective as anterior–posterior joint mobilization or transdermal analgesic patches.[36] Often, TENS is 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 to stimulate the release of endorphins, a strong, opiate-like substance produced by the body. The unit uses small, carbonized silicone electrodes to transmit electrical pulses through the skin (**Fig. 12.16**). 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 they also 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 that are self-adhering are available.

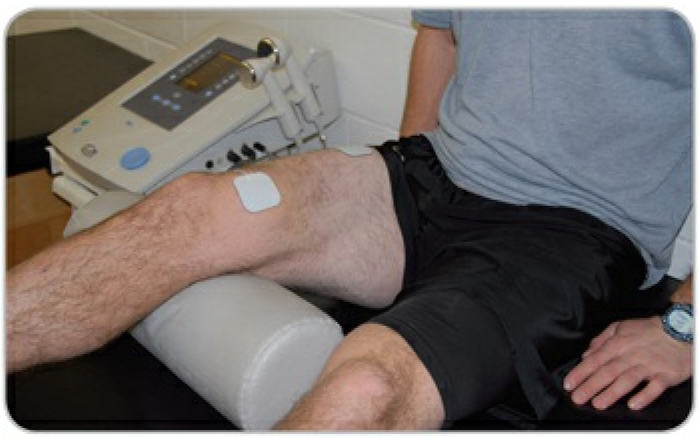

Figure 12.16. Electrical muscle stimulation. These units are used to stimulate muscle to maintain muscle size and strength during immobilization, to reeducate muscles, to prevent muscle atrophy, and to increase blood flow to tissues and to thereby decrease pain and spasm.

High-Voltage Pulsed Stimulation

High-voltage pulsed stimulation uses a monophasic current with a twin-peak waveform, a relatively short pulse duration and a long interpulse interval, and an amplitude range above 150 mV. The short-phase duration activates sensory and type II motor nerves without stimulating pain fibers. High-voltage pulsed stimulation often is used to reeducate muscle; increase joint mobility; promote dermal wound healing; and decrease pain, edema, muscle spasm, and muscle atrophy, but it is ineffective in reducing the soreness, loss of ROM, and loss of strength associated with delayed-onset muscle soreness.[37]

Neuromuscular Electrical Stimulation

Neuromuscular electrical stimulation (NMES) units are designed to elicit a muscle contraction of moderately high intensity with relatively little patient discomfort, and they typically involve 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 also is used to exercise muscle and delay atrophy, maintain muscle size and strength during periods of immobilization, reeducate muscles, and increase blood flow to tissues (**Fig. 12.16**). DC is used primarily to stimulate denervated muscle and to enhance wound healing as well as during iontophoresis.

Interferential Stimulation

An interferential current uses 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 (**Fig. 12.17**). 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 placed properly, the stimulation should be felt only between the electrodes, not under the electrodes. Most medium-frequency, sinusoidal currents used to generate interferential current have a medium-frequency range of 3,000 to 5,000 Hz and are programmable to deliver beats (or envelopes) of interferential current at a low-frequency range of approximately 1 to 200 bps.[11] The higher frequencies lower skin resistance, thus eliciting a stronger response with less current intensity. Furthermore, sensory perception is decreased between the pads, allowing 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 is used to decrease pain, acute and chronic edema, and muscle spasm; to strengthen weakened muscles; to improve blood flow to an area; to heal chronic wounds; and to relieve abdominal organ dysfunction.

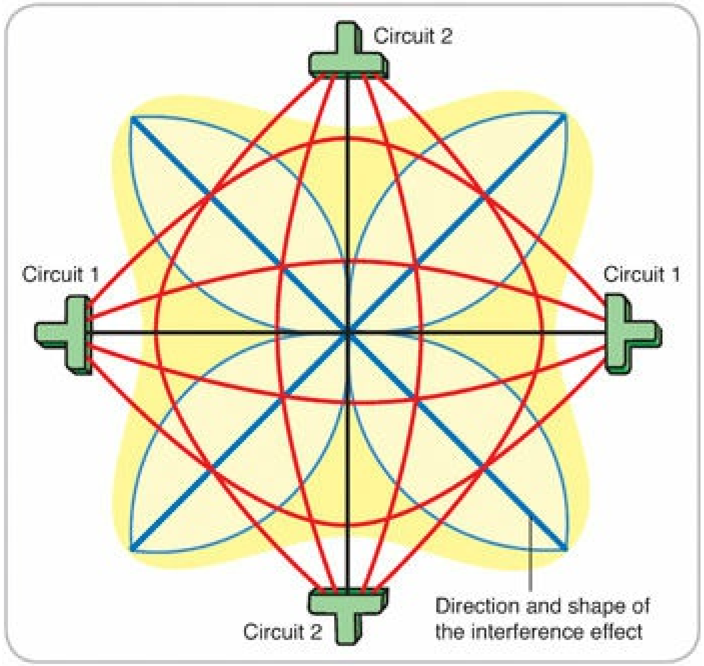

Figure 12.17. Interferential current. When arranged in a square alignment, the quadripolar electrode setup actually is a bipolar arrangement from two channels. An electric field is created where the currents cross between the lines of the electrical current flow. The maximum interference effect takes place near the center over the treatment site.

Low-Intensity Stimulation

Low-intensity stimulation (LIS) is the current term to replace the units originally called microcurrent electrical nerve stimulators (MENS) units. LIS 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 1,000 µA. The devices deliver an electrical current to the body with approximately 1/1,000 the amperage of TENS but with a pulse duration that may be up to 2,500-fold 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, of LIS units is based primarily on anecdotal evidence rather than on 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 spasms and improves healing.[38] Several studies have shown that microcurrent is ineffective at reducing pain and increasing muscle function associated with delayed-onset muscle soreness.[39,40]

Galvanic Stimulation

Galvanic stimulation is the common name for any stimulator using DC.

Russian Current

Russian current is a type of neuromuscular stimulation that uses AC, with frequencies ranging from 2,000 to 10,000 Hz. The current is generated in bursts, with interburst intervals. The number of bursts per second can be manipulated within the therapeutic range. For example, a high-frequency AC easily penetrates the skin and provides a high-amplitude, low-frequency current to the muscle. Russian electrical stimulation is designed to produce an isometric contraction and is useful in muscle reeducation. Because it induces an isometric rather than an isotonic contraction, 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. Russian current, however, does permit the individual to contract actively along with the stimulation, provides an adequate work-to-rest interval, and usually is comfortable for the individual.

Faradic Current

Faradic current is a specialized, asymmetrical biphasic wave. Although popular in the past, it now is thought to have little benefit over symmetrical waves.[37]

Iontophoresis

Iontophoresis uses a DC monophasic waveform with a peak current amplitude of up to 5 mA. The current drives charged molecules from certain medications, such as anti-inflammatories (dexamethasone), anesthetics (lidocaine), or analgesics (aspirin or acetaminophen), into damaged tissue. It is used as a local anesthetic to treat inflammatory conditions, such as arthritis, myositis ossificans, and plantar fasciitis; myofascial pain syndrome; and skin conditions by reducing edema. Contraindications include an allergy to the ion being used, decreased sensation, and placement of 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.

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 DC. Electrolysis produces an increased pH (acidic) condition at the cathode (negative electrode) and a decreased pH (alkaline) condition at the anode (postive 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.

Before 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 active (delivery) electrode with the same polarity. The return electrode is placed 4 to 6 in away. When the current is applied, the molecules are pushed away from the active electrode and into the skin toward the injured site. The medication can penetrate 6 to 20 mm below the skin surfaces and, in many instances, can reach the depth of tendinous structures, although the dose of the medication reaching this depth is not universally accepted. This localized treatment often is preferred over more disruptive systemic treatments.

The use of ultrasound and a high-voltage pulsed stimulator or interferential stimulation will increase blood flow to the involved muscle. The electrical current can stimulate a muscle contraction to produce muscle pumping, can retard atrophy, and can strengthen the muscle.

LASER THERAPY

Laser therapy uses specific wavelengths of laser light that, when absorbed, can lead to specific physiological responses in the body. What medical conditions might benefit from the use of laser therapy?

Low-level laser (LLL) therapy is a broad term for the application of light to provide therapeutic treatments for orthopedic injuries, skin conditions, and psychological problems such as depression and seasonal affective disorder. Devices include light-emitting diodes (LEDs), superluminous diodes (SLDs), fluorescent lamps, infrared lamps, ultraviolet (UV) lamps, diachronic lamps, and very bright incandescent light bulbs.[41] A laser, an acronym for *l*ight *a*mplification by *s*timulated *e*mission of *r*adiation, is a device that transforms electromagnetic energy of various frequencies in or near the range of visible light into an extremely intense, small, and nearly nondivergent beam of monochromatic radiation with all its waves in phase. The basic theoretical premise is that specific wavelengths of laser light, when absorbed, lead to specific physiological responses in the body. With recent advances in technology, the use of nonlaser devices, such as LEDs, SLDs, and polarized polychromic light, have been used to deliver light of a specific wavelength to the body.[41]

Although light therapy, also known as phototherapy, has been popular outside of the United States since the early 1970s, its use in the United States has recently gained in popularity since 2002 when the U.S. Food and Drug Administration (FDA) cleared specific models of LLLs, LEDs, and SLDs to treat musculoskeletal conditions, particularly for wound management, soft-tissue healing, and pain relief.[41]

To produce laser radiation, the device must have an energy source, a mechanical structure, and a lasing medium, either gas, liquid, chemical, crystal, or semiconductor. The more common LLLs use helium-neon (HeNe, a gas), gallium-aluminum-arsenide (GaAlAs, a diode or semiconductor), and gallium arsenide (GaAs, a semiconductor).[42] The effect of a laser is largely determined by the level of energy it emits. High-energy lasers (>500 mW), such as those used in surgery, are thermal in nature, meaning that they have a heating effect and may be used to destroy tissue. In contrast, LLLs, also called cold lasers or soft lasers, are athermic, meaning they do not directly heat tissues. They do, however, increase blood flow to the treatment site, thereby causing a slight measurable increase in tissue temperature with their use. Therapeutic modality lasers emit low levels of energy (<500 mW).

There is great discrepancy in the literature on the exact mechanisms by which laser light impacts tissues. It is thought that the application of a laser can increase mast cell release, promote interleukin-6 (an inflammatory regulatory substance) formation, and decrease dermal necrosis during the cellular phase of healing; increase collagen formation, degranulation, and myofibroblast conversion during the collagenization phase of healing; and promote wound contraction and tensile strength/stress during the remodeling phase of healing.[43] The literature is also split as to the effectiveness of pain relief. Overall, studies have found that laser therapy is effective at reducing pain and increasing function in acute musculoskeletal trauma,[44] carpal tunnel syndrome,[45] myofascial pain,[46,47] osteoarthritis,[48] trigger points,[46,47] neck pain,[49] and low back pain.[50]

Most lasers use a single laser probe to deliver light of a specific wavelength to tissues. More recently, cluster probes have been developed to apply multiple wavelengths to a larger area during treatment. Application involves two methods: a grid application or a scanning application. In the grid application, imagine a series of 1 cm^2 grid lines around the treatment site with the laser applied to each square for a predetermined time. In the scanning application, the probe is moved back and forth over the treatment area at a slow and steady rate, similar to an ultrasound treatment. Once the target area has been treated, a second treatment is applied with the probe moving at 90° to the first pass. The laser probe should have gentle contact with the skin surface to minimize divergence and reflection and should be perpendicular to the target area. With open wounds, the probe should be held close but not touching the wound. The use of a sterile, transparent film placed over the wound will allow the probe to be in near contact with the damaged tissue.

Lasers with shorter wavelengths have less depth of penetration than do lasers with longer wavelengths. Wavelengths in the near to middle infrared spectrum (1,000 to 1,350 nm) appear to penetrate deepest—3 to 5 mm—whereas shorter wavelengths may only penetrate <1 to 2 mm.[43]

> Laser therapy has been found to be effective in reducing pain and increasing function in acute musculoskeletal trauma, carpal tunnel syndrome, myofascial pain, osteoarthritis, trigger points, neck and low back pain.

OTHER TREATMENT MODALITIES

> ? Electrical modalities are not always available for use by athletic trainers. What other treatment modalities might be used to promote healing of the lacrosse player's upper arm contusion?

Many of the electrotherapeutic 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 some settings. As such, it becomes necessary to use other treatment modalities to achieve the same results.

Massage

Massage involves the manipulation of soft tissues to increase cutaneous circulation, cell metabolism, and venous and lymphatic flow to assist in the removal of edema; to stretch superficial scar tissue; to alleviate soft-tissue adhesions; and to decrease neuromuscular excitability (Box 12.6). As a result, relaxation, pain relief, edema reduction, 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, mineral oil) often are used. These lubricants should have a lanolin base or be alcohol-free. Massage involves five basic strokes (Table 12.2):

BOX 12.6 Application of Therapeutic Massage

Indications

Increase local circulation

Increase venous and lymphatic flow

Reduce pain (analgesia)

Reduce muscle spasm

Stretch superficial scar tissue

Improve systemic relaxation

Chronic myositis, bursitis, tendinitis, tenosynovitis, fibrositis

Contraindications

Acute contusions, sprains, and strains

Over fracture sites

Over open lesions or skin conditions

Conditions such as acute phlebitis, thrombosis, severe varicose veins, cellulites, synovitis, arteriosclerosis, and cancerous regions

TABLE 12.2 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 and 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 the 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.

1. Effleurage (stroking)
2. Pétrissage (kneading)
3. Tapotement (percussion)
4. Vibration
5. Friction

Effleurage is a superficial, longitudinal stroke to relax the patient. When applied toward the heart, it reduces swelling and aids in venous return. It is the most commonly used stroke, and it 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 the 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 and not for relaxation, it is not used in most massage treatments.

Vibration consists of finite, gentle, and rhythmic 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 (scars), aid in the absorption of an edema, and reduce localized muscular spasm. Transverse friction massage is a deep friction massage that is 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 the 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.[51] 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 physiological factors associated with the recovery process.[52] In both studies, the researchers concluded that light exercise of the affected muscles probably is more effective than massage in improving muscle blood flow (thereby enhancing healing) and in temporarily reducing muscle soreness. Because the types and duration of massage typically are 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 more commonly is used to treat small, herniated disk protrusions that may result in spinal nerve impingement, although it also may be used to treat a variety of other conditions (**Box 12.7**). 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 relaxing of the paraspinal muscles and ligamentous structures of the spinal segment.

BOX 12.7 Application of Traction

Indications

Herniated disk protrusions

Spinal nerve impingement

Spinal nerve inflammation

Joint hypomobility

Narrowing of intervertebral foramen

Degenerative joint disease

Spondylolisthesis

Muscle spasm and guarding

Joint pain

Contraindications

Unstable vertebrae

Acute lumbago

Gross emphysema

S4 nerve root signs

Temporomandibular dysfunction

Patient discomfort

A distractive force commonly is applied using 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 half 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 disk problems. In cervical traction, the patient may be either supine or seated. Again, a nonslip cervical harness is secured under the chin and back of the head to transfer the distractive force comfortably to the patient. Recommended force ranges from 10 to 30 lb. Again, there are currently no clinically or statistically significant studies that support the use of traction as a therapeutic modality.

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 is 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, the direction of the force, the magnitude of the force, or the duration of the treatment, making manual traction more flexible and adaptable than mechanical traction.

Continuous Passive Motion

Continuous passive motion is a modality that applies an external force to move the joint through a preset arc of motion. It primarily is used postsurgically at the knee, after knee manipulation, or after stable fixation of intra-articular and extra-articular fractures of most joints, such as the hand, wrist, hip, shoulder, elbow, and ankle. It also may be used to improve wound healing, accelerate the clearance of a hemarthrosis, and prevent cartilage degeneration in septic arthritis (**Box 12.8**). 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.[1,53]

BOX 12.8 Application of Continuous Passive Motion

Indications

Postoperative rehabilitation to:

- Reduce pain
- Improve general circulation
- Enhance joint nutrition
- Prevent joint contractures
- Benefit collagen remodeling

Following knee manipulation

Following joint debridement

Following meniscal or osteochondral repair

Tendon lacerations

Contraindications

Noncompliant patient

If use would disrupt surgical repair, fracture fixation, or lead to hemorrhage in postoperative period

Malfunction of device

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.

SUMMARY

1. Rehabilitation begins immediately after injury assessment with the use of therapeutic modalities to limit pain, inflammation, and a loss of ROM.

2. Therapeutic modalities, with the exception of ultrasound, fall within 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 others must be used under the direction of a physician or a licensed health care provider. Being a technician and merely applying a modality is not an acceptable athletic training practice.
5. Cryotherapy is used to decrease pain, inflammation, and muscle guarding and spasm as well as to facilitate mobilization.
6. Thermotherapy is used to treat subacute or chronic injuries to reduce swelling, edema, ecchymosis, and muscle spasm; to increase blood flow and ROM; to facilitate tissue healing; to relieve joint contractures; and to fight an infection.
7. Ultrasound produces both thermal and nonthermal effects. Thermal effects include increased blood flow, extensibility of collagen tissue, sensory and motor nerve conduction velocity, and enzymatic activity as well as decreased muscle spasm, joint stiffness, inflammation, and pain. Nonthermal effects include decreased edema; increased blood flow, cell membrane and vascular wall permeability, protein synthesis, and 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, reeducate peripheral nerves, delay denervation and disuse atrophy by stimulating muscle contractions, reduce posttraumatic edema, and maintain ROM by reducing muscle spasm, inhibiting spasticity, reeducating 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; to stretch superficial scar tissue; to alleviate soft-tissue adhesions; and to 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 commonly is used on the spine to treat herniated disk 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 primarily is used postsurgically at the knee, after knee manipulation, or after the stable fixation of intra-articular and extra-articular fractures of most joints.
14. 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.
15. 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 reevaluated to determine if the selected modality is appropriate for the current phase of healing.

APPLICATION QUESTIONS

1. You are a newly hired high school athletic trainer. As you survey the space allocated for the athletic training room, you notice that there is only one electrical outlet. What factors should you consider prior to plugging any item into that outlet?
2. A field hockey player has chronic low back pain. What type of therapy (heat or cold) treatment would you use with this athlete prior to practice? Following practice? Why?
3. An athlete has sustained an acute ankle sprain. What type of modality might you use to manage this acute injury? How might your management differ after 48 hours postinjury? Why?
4. A shot putter sustained a strain to the triceps muscle. After applying the protect, rest, ice, compression, and elevation (PRICE) principle, what other modality can be combined with PRICE to decrease pain, muscle spasms, and edema? Why?
5. An athlete sustained a hamstring strain 3 days ago. There is no swelling. The athlete reports mild discomfort when flexing and extending the knee. What modalities could be used to decrease the athlete's discomfort and increase the ROM of the hamstring muscles? Of those selected, which ones are more effective at relieving pain and muscle soreness?
6. You are the only athletic trainer at a high school. The family physician of one of the athlete's suggests massage as a strategy for breaking up soft-tissue adhesions associated with a recent shoulder surgery. The parents of the athlete ask you to perform the massage treatments right before each practice. How would you respond to their request? Why?

REFERENCES

1. Starkey C. *Therapeutic Modalities for Athletic Trainers*. 3rd ed. Philadelphia, PA: FA Davis; 2013.
2. Nolan TP Jr. Technical aspects of therapeutic modalities. In: Michlovitz SL, Nolan TP, Jr, eds.

Modalities for Therapeutic Intervention. 4th ed. Philadelphia, PA: FA Davis; 2005:41–181.

3. Kimura IF, Thompson GT, Gulick DT. The effect of cryotherapy on eccentric plantar flexion peak torque and endurance. *J Athl Train*. 1997;32(2):124–126.
4. Knight KL. *Cryotherapy in Sport Injury Management*. Champaign, IL: Human Kinetics; 1995.
5. Knight KL, Bryan KS, Halvorsen JM. Circulatory changes in the forearm in 1, 5, 10, and 15°C water.*Int J Sports Med*. 1981;4:281.
6. Ho SS, Illgen RL, Meyer RW, et al. Comparison of various icing times in decreasing bone metabolism and blood flow in the knee. *Am J Sports Med*.1995;23(1):74–76.
7. Otte JW, Merrick MA, Ingersoll CD, et al. Subcutaneous adipose tissue thickness alters cooling time during cryotherapy. *Arch Phys Med Rehabil*. 2002;83(11):1501–1505.
8. Tsang KK, Buxton BP, Guion WK, et al. The effects of cryotherapy applied through various barriers. *J Sports Rehabil*. 1997;(4):343–354.
9. Danielson R, Jaeger J, Rippetoe J, et al. Differences in skin surface temperature and pressure during the application of various cold and compression devices. *J Athl Train*. 1997;32(2):S34.
10. Bender AL, Kramer EE, Brucker JB, et al. Local ice-bag application and triceps surae muscle temperature during treadmill walking. *J Athl Train*. 2005;40(4):271–275.
11. Bélanger AY. *Therapeutic Electrophysical Agents: Evidence Behind Practice*. Baltimore, MD: Lippincott Williams & Wilkins; 2009.
12. Michlovitz SL, Rennie S. Heat therapy modalities: beyond fake and bake. In: Michlovitz SL, Nolan TP, Jr, eds. *Modalities for Therapeutic Intervention*. Philadelphia, PA: FA Davis; 2005:61–78.
13. Walsh MT. Hydrotherapy: the use of water as a therapeutic agent. In: Michlovitz SL, ed. *Thermal Agents in Rehabilitation*. Philadelphia, PA: FA Davis; 1996:139–167.
14. Kaiser DA, Knight KL, Huff JM, et al. Hot-pack warming in 4- and 8-pack Hydrocollator® units. *J Sport Rehabil*. 2004;13(2):103–113.
15. Sandqvist G, Akesson A, Eklund M. Evaluation of paraffin bath treatment in patients with systemic sclerosis. *Disabil Rehabil*. 2004;26(16):981–987.
16. Borrell RM, Parker R, Henley EJ, et al. Comparison of in vivo temperatures produced by hydrotherapy, paraffin wax treatment, and fluidotherapy. *Phys Ther*. 1980;60(10):1273–1276.
17. Hayes BT, Sandrey MA, Merrick MA, et al. The differences between 1-MHz and 3-MHz ultrasound in the heating of subcutaneous tissues. *J Athl Train*. 2001;36(2):S92.
18. Schneider NC, Walsh CT, Lemley SF, et al. 3 MHz continuous ultrasound can elevate tissue temperature at 3-cm depth. *Phys Ther*. 2001;81:A8.
19. Ramirez A, Schwane JA, McFarland C, et al. The effect of ultrasound on collagen synthesis and fibroblast proliferation in vitro. *Med Sci Sports Exerc*. 1997;29(3):326–332.
20. Houglum PA. Soft tissue healing and its impact on rehabilitation. *J Sport Rehabil*. 1992;1(1):19–39.
21. Sparrow KJ. Therapeutic ultrasound. In: Michlovitz SL, Nolan TP, Jr, eds. *Modalities for Therapeutic Intervention*. 4th ed. Philadelphia, PA: FA Davis; 2005:79–86.
22. Draper DO, Sunderland S. Examination of the law of Grotthus-Draper: does ultrasound penetrate subcutaneous fat in humans. *J Athl Train*. 1993;28(3):246–250.
23. Grant TH, Kelikian AS, Jereb SE, et al. Ultrasound diagnosis of peroneal tendon tears. *A surgical correlation*. *J Bone Joint Surg Am*. 2005;87(8):1788–1794.
24. Loudon JK, Cagle PE, Dyson M. High-frequency ultrasound: an overview of potential uses in physical therapy. *Phys Ther Rev*. 2005;10(4):209–215.
25. Klucinec B. The effectiveness of the aquaflex gel pad in transmission of acoustic energy. *J Athl Train*. 1996;31(4):313–317.

26. Draper DO, Castel JC, Castel D. Rate of temperature increase in human muscle during 1 MHz and 3 MHz continuous ultrasound. *J Orthop Sports Phys Ther*. 1995;22(4):142–150.
27. Forrest G, Rosen K. Ultrasound treatments in degassed water. *J Sport Rehabil*. 1992;1(4):284–289.
28. Merrick MA, Mihalyov MR, Roethemeier JL, et al. A comparison of intramuscular temperatures during ultrasound treatments with coupling gel or gel pads. *J Orthop Sports Phys Ther*. 2002;32(5):216–220.
29. Draper DO. Ten mistakes commonly made with ultrasound use: current research sheds light on myths. *Athl Train Sports Health Care Perspect*. 1996;2:95–107.
30. Klucinec B, Scheidler M, Denegar C, et al. Transmissivity of coupling agents used to deliver ultrasound through indirect methods. *J Orthop Sports Phys Ther*. 2000;30(5):263–269.
31. Ciccone CD, Leggin BG, Callamaro JJ. Effects of ultrasound and trolamine salicylate phonophoresis on delayed-onset muscle soreness. *Phys Ther*. 1991;71(9):666–675.
32. Cagnie B, Vinck E, Rimbaut S, et al. Phonophoresis versus topical application of ketoprofen: comparison between tissue and plasma levels. *Phys Ther*. 2003;83(8):707–712.
33. Başkurt F, Ozcan A, Algun C. Comparison of effects of phonophoresis and iontophoresis of naproxen in the treatment of lateral epicondylitis. *Clin Rehabil*. 2003;17(1):96–100.
34. Hsieh YL. Effects of ultrasound and diclofenac phonophoresis on inflammatory pain relief: suppression of inducible nitric oxide synthase in arthritic rats. *Phys Ther*. 2006;86(1):39–49.
35. Johnston TE. Muscle weakness and loss of motor performance. In: Michlovitz SL, Nolan TP, Jr, eds. *Modalities for Therapeutic Intervention*. 4th ed. Philadelphia, PA: FA Davis; 2005:41–181.
36. Jarzem PF, Harvey EJ, Arcaro N, et al. Transcutaneous electrical nerve stimulation [TENS] for short-term treatment of low back pain—randomized double blind crossover study of sham versus conventional TENS. *J Musculoskelet Pain*. 2005;13(2):11–17.
37. Butterfield DL, Draper DO, Ricard MD, et al. The effects of high-volt pulsed current electrical stimulation on delayed-onset muscle soreness. *J Athl Train*. 1997;32(1):15–20.
38. Holcomb WR. A practical guide to electrical therapy. *J Sport Rehabil*. 1997;6(3):272–282.
39. Bonacci JA, Higbie EJ. Effects of microcurrent treatment on perceived pain and muscle strength following eccentric exercise. *J Athl Train*. 1997;32(2):119–123.
40. Denegar CR, Yoho AP, Borowicz AJ, et al. The effects of low-volt, microamperage stimulation on delayed onset muscle soreness. *J Sport Rehabil*. 1992;1(2):95–102.
41. Knight KL, Hopkins T. Laser and light therapy. In: Knight KL, Draper DO, eds. *Therapeutic Modalities: The Art and Science*. 2nd ed. Baltimore, MD: Lippincott Williams & Wilkins; 2013:399–417.
42. Karu TI, Afanasyeva NI, Kolyakov SF, et al. Changes in absorbance of monolayer of living cells induced by laser radiation at 633, 670, and 820 nm. *IEEE J Select Top Quantum Electron*. 2001;7(6):982–988.
43. Baxter GD. *Therapeutic Lasers: Theory and Practice*. Edinburgh, United Kingdom: Churchill Livingstone; 1994.
44. Enwemeka CS, Parker JC, Dowdy DS, et al. The efficacy of low-power lasers in tissue repair and pain control: a meta-analysis. *Photomed Laser Surg*. 2004;22(4):323–329.
45. Naeser MA, Hahn KA, Lieberman BE, et al. Carpal tunnel syndrome pain treated with low-level laser and microamperes transcutaneous electric nerve stimulation: a controlled study. *Arch Phys Med Rehabil*. 2002;83(7):978–988.
46. Simunovic Z. Low level laser therapy with trigger points technique: a clinical study on 243 patients.

J Clin Laser Med Surg. 1996;14(4):163–167.
47. Simunovic Z, Trobonjaca T, Trobonjaca Z. Treatment of medial and lateral epicondylitis—tennis and golfer's elbow—with low level laser therapy: a multicenter double blind, placebo-controlled clinical study on 324 patients. *J Clin Laser Med Surg*. 1998;16(3):145–151.
48. Brosseau L, Welch V, Wells G, et al. Low level laser therapy for osteoarthritis and rheumatoid arthritis: a metaanalysis. *J Rheumatol*. 2000;27(8):1961–1969.
49. Chow RT, Barnsley L. Systematic review of the literature of low-level laser therapy (LLLT) in the management of neck pain. *Lasers Surg Med*. 2005;37(1):46–52.
50. Basford JR, Sheffield CG, Harmsen WS. Laser therapy: a randomized, controlled trial of the effects of low-intensity Nd:YAG laser irradiation on musculoskeletal back pain. *Arch Phys Med Rehabil*. 1999;80(6):647–652.
51. Shoemaker JK, Tiidus PM, Mader R. Failure of manual massage to alter limb blood flow: measures by Doppler ultrasound. *Med Sci Sports Exerc*. 1997;29(5):610–614.
52. Tiidus PM. Manual massage and recovery of muscle function following exercise: a literature review. *J Orthop Sports Phys Ther*. 1997;25(2):107–112.
53. Chiarello CM, Gundersen L, O'Halloran T. The effect of continuous passive motion duration and increment on range of motion in total knee arthroplasty patients. *J Orthop Sports Phys Ther*. 1997;25(2):119–127.