23 The Effect of Therapeutic Modalities on Tendinopathy

Jason D. Leadbetter

Degenerative tendon problems often prove recalcitrant to many forms of non-operative care [1]. Frequently, optimal functional outcomes and patient goals are not attained due to the persistence of chronic pain, loss of motion, and weakness. Ideally, rehabilitative goals should rely upon evidence-based clinical practice applied at appropriate intervals to facilitate healing and repair of injured tendons. In practice, understanding when and how to use therapeutic modalities to aid in healing and the recovery of function can often be unclear. For the therapist, modalities serve as an adjunct to directed exercise and have historically been utilized in the treatment of soft tissue injuries to decrease pain, inflammation, and edema, or to increase tissue extensibility [2]. In the era of evidence-based practice, the challenge is to relate the use of therapeutic modalities to demonstrate a healing response or the advancement of a specific functional goal. Recent histopathological studies of degenerated tendons have demonstrated varying underlying pathologies; the role of inflammation in intratenonous injury may be overstated [3]. The diagnosis of "tendonitis" often overshadows the histopathological evidence of degenerative tendinosis [3–5]. However, paratenonitis clearly has an inflammatory pathobiology. Therefore, the clinician must have an understanding of the mechanism of tendon injury and underlying pathology in order to deliver the most appropriate care. At question is whether the current accepted practice of employing modalities in tendon injury treatment is valid given the cellular pathology associated with tendinopathy and can their use be matched with a quantitative functional outcome measure. This chapter will examine the best available evidence on biological and functional efficacy of therapeutic modalities.

Classification of Modalities

Therapeutic modalities generally fall under four main categories: heat, cold, electricity, and manual therapy. Alternative modalities such as cold lasers, low energy extracorporeal shock wave treatments, and acupuncture are used widely throughout Europe and Asia and are gaining wider acceptance in clinical practice in the United States. In a general sense, clinicians utilize each classification because they generate a specific physiological effect upon an injury site that in theory can aid the recovery process. For example, heating modalities are most often used to increase tissue extensibility prior to stretch, decrease pain or to increase blood flow to an injured area. In a healing tendon, induced hyperemia may allow for increased removal of waste products, synthesis of new collagen, and increased production of fibroblasts [6,7]. By impacting functional impairments such as stiffness and pain, the appropriate use of heat by therapists and trainers can speed up the recovery phase of treatment and prevent the onset of new injury or chronic dysfunction. In theory, the correct use of an applied heating modality can directly impact both the rate and quality of return to function without limitation. This methodology of care holds true for the use of any physical agent, but difficulty arises for many clinicians trying to understand the mechanism by which their use is able to impact tissue pathology and affect outcome. Understanding the basic science helps explain the physiological affects of each therapeutic modality and serves as a foundation for clinical practice.

Basic Science

It is currently unknown whether the use of physical agents upon tendinopathy should be distinguished from other soft tissue injuries. The following is a discussion of the known biophysical effects of the main therapeutic agents.

Heat: Therapeutic heating modalities are generally separated into 2 categories: superficial and deep. Superficial agents involve the external application of heat by means of hot packs, infrared lamps, whirlpools, paraffin baths, and fluidotherapy. Deep heating modalities include

Table 23-1. Physiologic effects of heat application.

	Short heat application (30 min or less)	Prolonged heat application
Skin capillaries	Dilatation	Continued dilation
Skin texture	Smooth	Smooth
Skin color	Pink, then red	Dusky
Skeletal muscle	Relaxed	Irritated
Cell tissue size	Expanded	Less expanded but still above normal
Tissue pressure	Increased	Levels off
Tissue metabolism	Increased	Levels off
Pulse	Slow	May increase
Respiration	Slow and deep	May increase
Heart stroke volume	Decreased	Increased
Blood pressure	Increased then decreased	Decreased
Pain sensation	Decreased	Effect depends on extent of heating

Source: Reprinted from Rivenburgh DW (1992). Physical modalities in the treatment of tendon injuries. Clin Sports Med 11:645–659

ultrasound and diathermy. Table 23-1 illustrates the physiologic effects of heat application, which are generally considered to be the following: increases in tissue temperature, cellular metabolism, nerve conduction velocity, vasodilation, and decreases in pain, joint stiffness, and muscle tone and spasticity [2,6,8]. Clinical research supports changes in tissue extensibility with applied heat, and the effect of temperature on cellular activity is well documented [6,9,10]. Increases in thermal bond strength after tendon repairs with controlled heating and cooling has been demonstrated, while other research indicates degradation of different collagen types in tendon with elevated temperatures above 41 degrees C [11,12]. The lack of controlled studies of thermal modalities suggests the effect of heat upon tendinopathy is not well understood.

Superficial heating modalities accomplish the transfer of heat energy primarily through processes of conduction, convection and radiation. Most studies of the application of superficial heating modalities indicate that increases to local tissue temperature occur only to a depth of a few millimeters, do not exceed a peak of 104 degrees Fahrenheit, and can only be sustained for short periods [2]. According to the first law of thermodynamics, energy can neither be created nor destroyed but transformed into different states. The movement of atoms and molecules within an object is called kinetic energy and is a representation of an objects internal thermal energy. Thermal conductivity involves the transfer of this energy from an object of higher energy to an object of lower energy when two objects are in direct contact [10]. The use of hot packs and paraffin baths follows this principle. In general, the flow of energy from heating modalities goes from the higher energy modality source to the tissues of the body, which contain lower internal kinetic energy. In physical agents involving therapeutic cold, this flow is reversed with higher energy in the form of heat being drawn away from the body causing soft tissue cooling. Substances in the human body vary in their ability to act as efficient conductors of thermal energy based upon differing specific heat capacities. Bone, blood, and muscle are relatively good conductors compared to fat, which does not contain as much water fluid content and is considered a more efficient insulator [2,10].

Instruments such as infrared lamps utilize a slightly different process of heat energy transfer known as radiation. All objects can emit or receive radiant energy based upon the characteristics of the electromagnetic waves being produced by a certain object. The base unit of radiation is the photon, a measure of high-velocity molecular movement and the release of kinetic energy from molecular collisions. Photons travel along electromagnetic waves and energy is transmitted along varying frequencies. Higher frequencies are associated with shorter wavelengths along the electromagnetic spectrum, creating an inverse relationship between intensity of energy transmission and size of wavelengths. The energy contained in an infrared wavelength causes an increase in the molecular kinetic energy of the absorptive surface thereby increasing its thermal energy [8].

Fluidotherapy and whirlpools utilize a combination of convection and conduction as the mode of thermal energy transfer. Convection involves the movement of heated molecules from areas of high density to areas of low density. Thermally charged molecules display greater movement secondary to increased kinetic energy and thus require more space. Lower density heated regions are lighter and rise to replace higher density cooler regions moving in the opposite direction. This process creates circulating temperature gradients that continue until all the thermal energy is equally distributed throughout the entire substance. Heat is then conducted to or drawn away from soft tissue immersed in a bath of water or sand kept at a unified temperature through mode of convection [2,8].

There are 2 types of deep heating modalities used clinically: diathermy and ultrasound. Ultrasound and diathermy are unique in that both have thermal and nonthermal properties. By using a pulsed rather than continuous setting, a clinician can stimulate mechanical cellular events that are critical in the stages of inflammation and repair. Although the literature is inconclusive, some effects that are thought to occur include: increases in fibroblast and macrophage activity, increases in microperfusion and cell permeability related to acoustic streaming and cavitation, increases in mast cell degranulation and release of chemotactic factor and histamine [2,6,13–15].

Thermal properties of ultrasound and diathermy are generally elicited when using a continuous mode. Both ultrasound and diathermy have been popular choices for many clinicians over the past several decades due their capacity to safely heat deeper structures. Deep heating modalities are generally considered indicated when one is trying to increase the temperature of tissues 2 to 5 cm beneath the surface of the skin [2]. The basic physiological responses to this mode of heating are the same as for superficial heating agents but are more penetrating. Although both ultrasound and diathermy accomplish the transfer of heat energy, the mode of transfer is completely different. Diathermy utilizes the properties of electromagnetic waves generated by highly conductive metal coils whereas ultrasound relies on acoustical energy.

There are 3 main types of diathermy: longwave, shortwave, and microwave. Theoretically, diathermy is able to effect heating of deeper connective tissues due to utilization of longer wavelengths and lower frequencies along the electromagnetic spectrum. The kinetic energy carried along these wavelengths is not refracted or absorbed as much at the surface level as is infrared energy, but is instead transmitted to a deeper level where the conversion to thermal energy occurs [16]. Of the different types of diathermy, short wave is most commonly used, followed by microwave. The use of longwave diathermy is no longer in accepted clinical practice due to the potential for serious burns and mechanical disruptions caused by frequency type.

Shortwave diathermy has two modes of application referred to as condenser field and induction field. Condenser field diathermy involves positioning a part into a magnetic field generated by separate capacitor plates where induction field diathermy utilizes physical contact of the capacitor plates on the patient to complete a circuit and generate the electrical field in line with the body. Although there are slight variances in the heating effect between the two types of electrodes, general thermal effects on soft tissue have been demonstrated to occur at depths of between 2 and 3 cm.

Microwave diathermy has a different application utilizing a shorter wavelength and higher frequency (2450 mHz) and follows laws governing the absorption of radiated energy. Studies have shown that microwave diathermy is less effective than shortwave because of reflected energy into fatty tissue [16]. Regardless of the type of diathermy being used, it is hard to locate correlative information in the literature describing impact on tendon healing properties.

Ultrasound differs from diathermy in that it uses acoustical energy to generate heat. An ultrasound machine utilizes common house current and converts it to an ultrasonic wavelength by means of the reverse piezoelectric effect. As AC current is passed through a crystal, the crystal becomes deformed in the direction of the current. A process of compression and elongation causes mechanical vibrations of the crystal resulting in oscillatory pressure waves in the frequency of the electric current being applied to the crystal [2]. Ultrasound waves are transmitted from a transducer or sound head to the patient through means of a homogenous coupling medium typically either a gel or water. Ultrasound energy can be attenuated, refracted, or reflected, depending upon the type of biologic tissue being impacted and the wave frequency. Clinically, a 1-MHz continuous mode setting is used to accomplish thermal effects at a depth of 2 to 5 cm whereas a 3-MHz frequency is used superficially for depths less than 2.5 cm [2]. Measurable tissue temperature increases have been documented using continuous mode ultrasound [2,9]. Pulsed low-intensity settings are reserved to generate the nonthermal effects described earlier.

Another unique application of ultrasound is phonophoresis. Phonophoresis utilizes the low-level force generated by ultrasonic waves to assist the transdermal delivery of medication. Different types of medications can be applied locally to effect inflammation, pain, and wound healing, but there is little evidence in the literature to support any significant effect [17].

Cold: The effects of therapeutic cold modalities are predicated on the same thermodynamic laws as heat. The application of a colder object upon a warmer surface affects a transfer of thermal energy flowing in the opposite direction. The internal thermal energy of the warm contact surface (e.g. soft tissue) flows to the lower energy and temperature source in the form of a cold pack for example [10]. The rate of cooling upon soft tissue is dependent on several factors such as the thermal conductivity of a particular tissue type, area size, tissue thickness, and difference between cold modality and the outer skin. As with any treatment modality, care must be taken to avoid inducing tissue damage such as ischemic cell

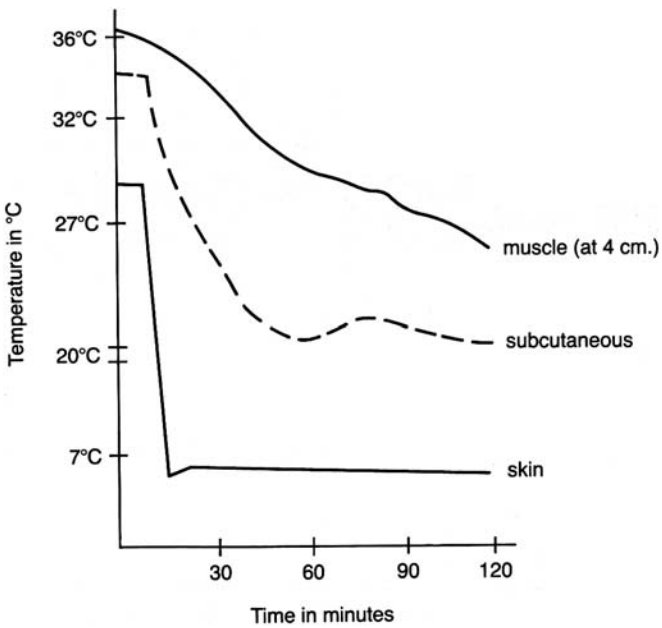

FIGURE 23-1. Tissue temperature changes during application of ice pack to the calf. (From Michlovitz, S [1986]: Thermal Agents in Rehabilitation. Philadelphia, F.A. Davis, p.75. as reprinted in Harrelson GL, Weber MD, Leaver-Dunn D. (1998) Use of Modalities in Rehabilitation. In: Andrews JR, Harrelson GL, Wilk KE, eds. *Physical Rehabilitation of the Injured Athlete.* 2nd edn. Philadelphia: W.B. Saunders; 82–145.)

death and nerve palsy [2]. The varying rates at which different biological tissues react when cold is applied are illustrated in Figure 23-1.

The physiological effects elicited by cold are generally considered to be the following: decreases in tissue temperature, pain, edema, nerve conduction velocity, muscle spasm, cellular metabolism, inflammation, tissue extensibility, and joint proprioception [2,6]. A review of the literature yields varying evidence as to the effectiveness of cryotherapy. Clinical research has supported the benefit of cryotherapy in controlling inflammation and cell metabolism after acute injury, but not as much is known about the use of ice to treat tendinopathy [4–6,18,19]. Numerous studies have demonstrated the impact of cold application at the cutaneous level but cannot support significant decreases in tissue temperature at greater than 2 cm below the surface of the skin. Deeper structures such as tendons may be affected by a hemodynamic interchange that occurs with the more superficial layers [19].

Some physiologic responses to cold, such as cold-mediated vasoconstriction and vasodilation responses, appear to be influenced by time of the exposure. Cold-induced vasodilation (CIDV) is a phenomenon that is purported to occur only after exposure times that are far longer than the 15 to 30 minutes that cold is commonly applied in the clinical setting [2]. There is also some evidence to suggest that the use of cold induces an increase in isometric muscle strength that is measurable for a few hours post-treatment. Concentric and eccentric muscle strength appear to decrease for a 10- to 20-minute period post-application after which no significant change from baseline strength occurs [20] (see Table 23-2).

Methods of therapeutic cold application include: conventional cold pack (chipped ice/bag), commercial cold pack (gel, chemical), ice baths (whirlpools, contrast baths), and ice massage.

Electricity: Therapeutic electricity is used to generate an action potential in excitable tissue. The type of physi-

TABLE 23-2. Physiologic Effects of Cold

	Short cold application (30 min or less)	Prolonged cold application
Skin capillaries	Constriction followed by dilation	Constriction (to prevent heat loss)
Skin color	White, then red	Rough, even more pronounced ("goose bumps")
Skin texture	Rough (due to action of the erector pilar), then smooth	
Cell tissue size	Little change	Slightly decreased
Tissue pressure	Decreased	Decreased
Tissue metabolism	Decreased	Decreased
Pulse	Quick, then rapid	Slow
Respiration	Gasp, then increased rate and depth of breathing	Decreased respiration rate
Heart stroke volume	Increased	Increased
Blood pressure	Increased	Decreased
Pain sensation	Decreased	Decreased

Source: Application as reprinted from Rivenburgh DW (1992). Physical modalities in the treatment of tendon injuries. Clin Sports Med 11:645–659

TABLE 23-3. Suggested uses of electrical stimulation

Re-education of muscle
Strengthening of muscle after injury
Control of pain in numerous acute and chronic syndromes
Control of postoperative pain
Control of labor pain
Treatment of urinary incontinence
Control of edema
Healing of wound
Healing of delayed or nonunion fractures
Functional electrical stimulation (orthotic)
Introduction of medications transcutaneously
Improvement or maintenance of range of motion
Stimulation of denervated muscle
Inhibition of spasticity
Relief of muscle spasms
Temporary increase of blood flow to an area
Treatment of neurovascular disorders involving vasospastic and pseudovasospastic disorders

Source: Reprinted from Harrelson GL, Weber MD, Leaver-Dunn D (1998). Use of modalities in rehabilitation. In: Andrews JR, Harrelson GL, Wilk KE (ed) Physical Rehabilitation of the Injured Athlete, 2nd edn. W.B. Saunders Co., Philadelphia, pp 82–145

ologic effect caused by an action potential can be varied by several parameters such as polarity, frequency, pulse duration, waveform, intensity, cycle type, electrode configuration, and treatment time [21]. The general indications of therapeutic electricity are given in Table 23-3.

The main units when considering applied therapeutic electricity are current, voltage, and resistance. The relationship between these variables is defined by Ohm's law: $I = V/R$. I = current, V = voltage, R = resistance. Voltage is the measure of the force which causes ions to move whereas current is the rate of electron movement in response to the applied force (voltage). Different types of materials (biological, chemical, physical) can either facilitate or inhibit the movement of ions. Resistors are materials with high impedance to ion flow. Examples of biological resistors include skin, fat, and bone. Materials in the body such as electrolyte solutions, water, and blood, act as good conductors and are characterized by low resistance [2,21].

Three types of current are used clinically: direct (DC), alternating (AC), and pulsed. Direct current involves the uninterrupted flow of charged ions in one direction. Direct current is typically utilized to stimulate denervated muscle or to drive different types medication transcutaneously during iontophoresis. Iontophoresis uses the repellant force generated by like charges to induce localized absorption of various medications into soft tissue. The efficacy of iontophoresis on tendinopathy is questionable [22].

Alternating current is defined by continuous ion flow in two directions, whereas pulsed currents involve either direct or alternating ion flow packaged into cyclically occurring waveforms. A clinician can choose between different waveform types such as monophasic, biphasic, polyphasic, symmetrical, asymmetrical, balanced or unbalanced, to produce different physical effects [21]. Examples of different waveforms are pictured in Figure 23-2.

Electromyographic units are used frequently in the clinic to measure the amount of electrical activity in skeletal muscle through either surface or implanted electrodes. Although EMG units do not involve applied electricity, biofeedback provides the patient and therapist useful information to facilitate neuromuscular control and relaxation of agonist or antagonist muscle groups during rehabilitation. This can be important when addressing the abnormal biomechanical stress that is either causing or impeding tendon healing.

Manual therapy: Manual techniques are generally used to increase range of motion (ROM), aid in the recovery of neuromuscular control and strength, decrease spasm and edema, and break adhesions that build around muscles, ligaments, capsular structures, and tendons [7]. Examples of manual therapy techniques include: friction massage, augmented soft tissue mobilization (ASTM), myofascial release, and active release technique. Tendon injuries involve changes in the cellular matrix [5]. This often results in a disruption of the normal longitudinal collagen fiber orientation of a tendon or ligament and a corresponding decrease in the ability to distribute mechanical load without strain. During the remodeling phase of healing, fibroblasts play a significant role in the synthesis of collagen, proteoglycans, and proteins important to the development of normal cellular matrix of a healthy tendon [5,7,25]. The proliferation of fibroblasts has been related to the type of load and stress placed upon a healing tissue [3,7]. Theories regarding the use of TFM (transverse friction massage) and ASTM (augmented soft tissue mobilization) suggest that new collagen synthesis results from the hyperemic response caused by the massage [23,24,26]. These forms of manually applied controlled trauma to a tendon performed at the right time in the healing process and with the correct intensity may actually induce the production of the fibroblasts and specialized proteins necessary for regeneration [23,24].

Other types of manual therapies involving active-assisted exercises and PNF techniques involve the application of an eccentric load. Some studies have indicated that a gradual and controlled eccentric loading component applied to a healing tendon also stimulates fibroblastic activity and aids in the recovery of parallel collagen fiber alignment [3,4].

Alternative modalities: There are numerous alternative therapeutic modalities currently undergoing closer

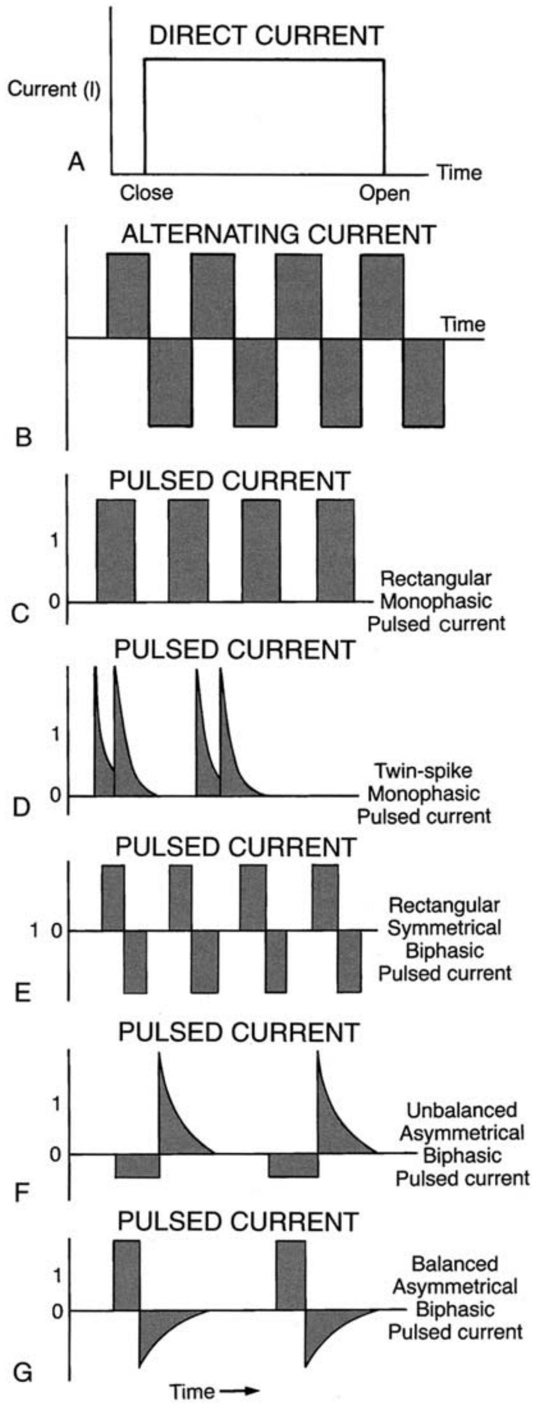

FIGURE 23-2. Graphic representation of the three types of electrical current. (A), Direct current. (B), Alternating current. (C) through (G), Pulsed currents. (Modified from Robinson A J. (1989) Basic concepts and terminology in electricity. In: Snyder-Mackler L, Robinson AJ, eds. *Clinical Electrophysiology.* Baltimore: Williams & Wilkins; 9,11,13. as reprinted in Harrelson GL, Weber MD, Leaver-Dunn D. (1998) *Use of Modalities in Rehabilitation.* In: Andrews JR, Harrelson GL, Wilk KE, eds. *Physical Rehabilitation of the Injured Athlete.* 2nd ed. Philadelphia: W.B. Saunders; 82–145.)

scientific review for effectiveness in treating soft tissue disorders. Extracorporeal shock wave therapy, cold lasers, and acupuncture are 3 treatments that are practiced more readily throughout Europe and Asia, but are gaining wider acceptance in the US through clinical trials approved by the FDA.

Extracorporeal shock waves can be generated utilizing electrohydraulic, electromagnetic, or piezoelectric devices. Treatments usually involve doses of either low-energy or high-energy waves that are then transmitted into biological soft tissue via an ultrasonic medium. Possible physiologic effects that are suggested to occur include the disintegration of calcifications, as well as cellular and circulatory changes associated with the regeneration of a healing tendon [25–31]. Efficacy studies on the use of extracorporeal shock wave therapy (ESWT) in the treatment of tendinopathy have shown mixed results. Loew et al. demonstrated improved patient responses to both pain and function after using shock wave therapy to treat insertional tendinopathies of the shoulder [27]. Another study evaluated the use of low-energy extracorporeal shock wave application to treat recalcitrant cases of plantar fasciopathy, with similar results [28]. Wang conducted a 2-year case series study on patients with lateral epicondylopathy of the elbow and showed positive results with respect to pain [32].

However, a double-blind, randomized controlled trial by Speed et al. on the effects of ESWT on lateral epicondylopathy purported to demonstrate a significant placebo effect with no positive effects compared to a sham therapy [33]. Buchbinder et al. showed similar results in their study on the use of shock waves for treatment of plantar fasciopathy [34]. Finally, findings by Haake et al. directly contradict reports of positive outcomes of ESWT as being flawed by inappropriate study designs [35]. At this time, further investigation needs to be conducted in order to substantiate positive clinical outcome.

Low-intensity “cold” lasers are purported to emit a form of electromagnetic energy that stimulates the production of fibroblasts, macrophages, and ATP. There does not seem to be a clear mechanism by which these effects occur although it is suggested that photochemical reactions drive the regulation and output of intercellular communication. A few studies have shown reductions in pain and dysfunction when using cold laser therapy to treat lateral epicondylopathy, trigger points, lumbalgia, and chronic pain. However, there is also conflicting evidence suggesting that there is no therapeutic benefit when compared to a sham treatment [36]. It appears difficult at this time to determine the true effectiveness of laser use until more empirical data is collected.

Acupuncture is an ancient Chinese healing art that proposes to utilize the body’s nervous system to affect pain and dysfunction. Acupuncture points are stimulated electrically through needles to induce biophysical signals that allow for healing responses to occur. Some controlled studies have indicated altered pain responses, but the mechanism by which acupuncture is believed to affect different types of healing and pain response in the body remains unclear [37].

Evidence-Based Medicine and Therapeutic Modality Use

As in other areas of medicine, the rehabilitation sciences are rapidly evolving through advanced clinical trials and the trend towards evidence based practice. The randomized controlled trial (RCT) is currently the gold standard for evaluating the significance of an intervention and its relative importance along a critical pathway. The best available evidence is typically analyzed using one of four types of guidelines: expert consensus, outcome based, meta-analysis and cost-effectiveness, and a combination of patient preference and evidence based [38]. Clinicians must demonstrate the effectiveness of their interventions using these guidelines and then correlate their findings with patient responses to pain and dysfunction. This approach has fostered controversy among many rehabilitation specialists as long held beliefs concerning the use of physical modalities in treating soft tissue injuries are coming into question.

In October 2001, an independent group of medical professionals, therapists, and researchers, collectively known as the Philadelphia Panel, released their findings based on a comprehensive review of the interventions used to treat various musculoskeletal conditions in the neck, shoulder, low back, and knee [39,40]. Randomized controlled, cohort, case control, and nonrandomized studies were collected and statistically analyzed utilizing the MEDLINE, EMBASE, Current Contents, Cochrane Controlled Trial Register, and CINAHL databases. The goal of this panel was to establish evidence-based treatment parameters regarding the use of exercise, traction, manual therapy, heat and ice, electrical modalities (E-stim, TENS, biofeedback), and ultrasound on soft tissue disorders ranging from arthritis to tendinopathy. Studies were allotted grades for clinical importance based on statistical significance and study design. For example, a RCT (single or meta-analysis) with a $P < 0.05$ was given a grade A, while a C grade was given to observational studies with low significance factors and low clinical importance (see Table 23-4). The results concerning the effect of physical agents upon the rehabilitation of tendon in the knee and shoulder were both revealing and inconclusive. Only 2 randomized controlled trials (one for ultrasound, one for therapeutic massage) were discovered for the treatment of tendinopathy of the knee. Of these 2, the study involving therapeutic massage was given a grade of C for affecting pain. For all other treatments, including ultrasound, the panel deemed there was either no data or insufficient data to attribute any clinical significance [39]. Concerning treatment of calcific tendinopathy, general tendinopathy, capsulitis, and bursitis of the shoulder, 4 randomized controlled trials and 3 controlled clinical trials were found. These studies involved the use of therapeutic ultrasound but only one study for treatment of calcific tendinitis received grade A for pain, function, and global patient assessment. All other treatments were classified as either having low clinical importance or having no or insufficient data to contribute to evidence based guidelines [40]. A full description of inclusion and exclusion criteria as well as general determinations of the Philadelphia Panel can be found in the journal *Physical Therapy.*

Robertson and Baker presented a meta-analysis of all studies concerning the effectiveness of therapeutic ultrasound on soft tissue healing [41]. A total of 35 RCTs were identified in a search of MEDLINE and CINAHL databases dating from 1975 to 1999. Exclusion criteria eliminated all but ten of these studies. Only 2 studies dealing with calcific tendinopathy and carpal tunnel syndrome

Table 23-4. Details of Philadelphia Panel Classification System

	Clinical importance	Statistical significance	Study design[a]
Grade A	>15%	$P < .05$	RCT (single or meta-analysis)
Grade B	>15%	$P < .05$	CCT or observational (single or meta-analysis), with a quality score of 3 or more the 5-point Jadad methodologic quality checklist
Grade C+	>15%	Not significant	RCT or CCT or observational (single or meta-analysis)
Grade C	<15%	Unimportant[b]	Any study design
Grade D	<0% (favors control)		Well-designed RCT with >100 patients

Source: Reprinted from Albright J, Allman R, Bonfiglio RP, Conill A, Dobkin B, Guccione AA (2001) Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for shoulder pain. Phys Ther. 81:1719–1730

[a] RCT = randomized controlled trial, CCT = controlled clinical trial.

[b] For grade C, statistical significance is unimportant (i.e., clinical importance is not met; therefore, statistical significance is irrelevant).

could demonstrate an effect beyond that of a placebo [41]. Although definitive conclusions are not possible at this time, it does appear that a lack of evidence contributes to the confusion on the best way to treat tendinopathies.

An independent search of MEDLINE from 1970 to 2001 conducted by this author yielded similar results for effectiveness of physical agents upon tendon healing and regeneration. Keywords that were used either alone or in combination included: tendon, fibroblast, rehabilitation, repair, randomized controlled trial, and therapeutic modality. Although there are many descriptive studies concerning the use of heat, cold, electricity, etc., the literature is lacking in controlled studies correlating the specific use of a physical agent and the return of human tendon to normal function.

Recommendations for Future Use of Therapeutic Modalities

The dilemma facing rehabilitation specialists in today's evidenced-based climate is to relate clinical experience to clinical research. The specific use of a physical agent should correlate with the stimulation of tendon healing and have objective and quantifiable markers to guide the return to full function. The best and most timely care would be available to the patient if a clinician were to use cryotherapy, for example, and know that if it was applied at the right time, amount, duration, and intensity, measurable cellular events could occur in a tendon facilitating repair and return to premorbid function. However, efforts to improve clinical practice may also serve to inhibit this process if varying human inferences are made upon information gathered in databases that is either incomplete or irrelevant [42]. Functional outcome measures and quality-of-life indexes must continue to be emphasized as much as focusing on the singular tissue effect of any one treatment. Meanwhile, on going scientific investigation will be integral in guiding the use of therapeutic modalities.

References

1. Curl WW. (1990) Clinical relevance of sports-induced inflammation. In: Leadbetter WB, Buckwalter JB, Gordon SL, eds. *Sports-Induced Inflammation.* Park Ridge, IL: American Academy of Orthopaedic Surgeons;149–154.
2. Harrelson GL, Weber MD, Leaver-Dunn D. (1998) Use of modalities in rehabiltation. In: Andrews JR, Harrelson GL, Wilk KE, eds. Physical Rehabilitation of the Injured Athlete. 2nd ed. Philadelphia: W.B. Saunders;82–145.
3. Almekinders LC. (1998) Tendinitis and other chronic tendinopathies. *J Am Acad Orthop Surg.* 6:157–164.
4. Khan KM, Mafulli N, Coleman BD, Cook JL, Tauton JE. (1998) Patellar tendinopathy: some aspects of basic science and clinical management. *Br J Sports Med.* 32:346–355.
5. Leadbetter W. (1992) Cell-matrix response in tendon injury. *Clin Sports Med.* 11(13):533–576.
6. Rivenburgh DW. (1992) Physical modalities in the treatment of tendon injuries. *Clin Sports Med.* 11:645–659.
7. Hammer WI. (1999) The effect of soft tissue techniques at the cellular level. In: Hammer WI, ed. *Functional Soft Tissue Examination and Treatment by Manual Methods.* 2nd ed. New York: Aspen Publishers; 461.
8. Hecox B. (1994) Superficial heat modalities. In: Hecox B, Mehreteab TA, Weisberg J, eds. *Physical Agents: A Comprehensive Text for Physical Therapists.* Stamford, CT: Appleton & Lange;125–141.
9. Knight CA, Rutledge CR, Cox ME, Acosta M, Hall SJ. (2001) Effect of superficial heat, deep heat, and active exercise warm-up on the extensibility of the plantar flexors. *Phys Ther.* 81:1206–1214.
10. Hecox B. (1994) Thermal physics. In: Hecox B, Mehreteab TA, Weisberg J, eds. *Physical Agents: A Comprehensive Text for Physical Therapists.* Stamford, CT: Appleton & Lange; 65–77.
11. Drew PJ, Watkins A, McGregor AD, Kiernan MN, Clement M. (2001) The effects of temperature and time on thermal bond strength in tendons. *Lasers Med Sci.* 16:291–298
12. Palotie A. (1983) Effect of elevated temperature on the intracellular degradation of different collagen types. *Coll Relat Res.* 3:105–113.
13. Ramirez A, Schwane JA, McFarland C, Starcher B. (1997) The effect of ultrasound on collagen synthesis and fibroblast proliferation *in vitro. Med Sci Sports Exerc.* 29:326–332.
14. Jackson BA, Schwane JA, Starcher BC. (1991) Effect of ultrasound therapy on the repair of Achilles tendon injuries in rats. *Med Sci Sports Exerc.* 23:171–176.
15. Frieder S, Weisberg J, Fleming B, Stanek A. (1998) A pilot study: the therapeutic effect of ultrasound following partial rupture of Achilles tendons in male rats. *J Orthop Sports Phys Ther.* 10:39–46.
16. Ebenbichler GR, ErogmusCB, Resch KL, Funovics MA, Kainberger F, Barisani G. (1999) Ultrasound therapy for calcific tendinits of the shoulder. *N Engl J Med.* 340: 1533–1538.
17. Cameron MH, Perez D, Otano-Lata S. (1999) Electromagnetic radiation. In: Cameron MH, ed. Physical Agents in Rehabilitation. Philadelphia: W.B. Saunders;303–344
18. Oziomek RS, Perrin DH, Herold DA, Denegar CR. (1991) Effect of phonophoresis on serum salicylate levels. *Med Sci Sports Exerc.* 23:397–401.
19. Fernandez-Palazzi F, Rivas S, Mujica P. (1990) Achilles tenditis in ballet dancers. *Clin Orthop.* 257:257–261.
20. Enwemeka CS, Allen C, Avila P, Bina J, Konrade J, Munns S. (2002) Sort tissue thermodynamics before, during, and after cold pack therapy. *Med Sci Sports Exerc.* 34:45–50.
21. Ruiz DH, Myrer JW, Durrant E, Fellingham GW. (1993) Cryotherapy and sequential exercise bouts following cryotherapy on concentric and eccentric strength in the quadriceps. *Athl Train.* 28:320–323.
22. Selkowitz DM. (1999) Electrical Currents. In: Cameron MH, ed. *Physical Agents in Rehabilitation.* Philadelphia: W.B. Saunders;345–400.
23. Perron M, Malouin F. (1997) Acetic acid iontophoresis for the treatment of calcifying tendinitis of the shoulder: a

randomized control trial. *Arch Phys Med Rehabil.* 78:379–384.
24. Hammer WI. (1999) Friction Massage. In: Hammer WI, ed. *Functional Soft Tissue Examination and Treatment by Manual Methods.* 2nd ed. New York: Aspen Publishers; 463–464.
25. Davidson CJ, Ganion LR, Gehlsen GM, Verhoestra B, Roepke JE, Sevier TL. (1997) Rat tendon morphologic and functional changes resulting from soft tissue mobilization. *Med Sci Sports Exerc.* 29:313–319.
26. Chamberlain GJ. (1982) Cyriax's friction massage: a review. *J Orthop Sports Phys Ther.* 4:16–22.
27. Loew M, Daecke W, Kusnierczak D, Rahmanzadeh M, Ewerbeck V. (1999) Shock-wave therapy is effective for chronic calcifying tendinitis of the shoulder. *J Bone Joint Surg*. (Br) 81(5):863–867.
28. Rompe JD, Schoellner C, Nafe B. (2002) Evaluation of low-energy extracorporeal shock-wave application for treatment of chronic plantar fasciitis. *J Bone Joint Surg.* 84:335–341.
29. Rompe JD, Hopf C, Kullmer, Heine J, Burger R. (1996) Analgesic effect of extracorporeal shock-wave therapy on chronic tennis elbow. *J Bone Joint Surg.* (Br) 78-B:233–237.
30. Rompe JD, Kirkpatrick CJ, Kullmer K, Schwitalle M, Krischek O. (1998) Dose-related effects of shock waves on rabbit tendo Achillis. *J Bone Joint Surg.* (Br) 80-B:546–552.
31. Spindler A, Berman A, Lucero E, Braier M. (1998) Extracorporeal shock wave treatment for chronic calcific tendinitis of the shoulder. *J Rheumatol.* 25:1161–1163.
32. Wang C-J, Chen H-S. (2002) Shock wave therapy for patients with lateral epicondylitis of the elbow. *Am J Sports Med.* 30:422–425,
33. Speed CA, Nichols D, Richards C, Humphreys H, Wies JT, Burnet S, Hazelman BL. (2001) Extracorporeal shock wave therapy for lateral epicondylitis-a double blind randomized controlled trial. *J Orthop Res.* 20:895–898.
34. Buchbinder R, Ptasznik R, Gordon J, Buchanan J, Prabaharan V, Forbes A. (2002) Ultrasound-guided extracorporeal shock wave therapy for plantar fasciitis—a randomized controlled trial. *JAMA*. 288:1364–1372.
35. Haake M, Konig IR, Decker T, Riedel C, Buch M, Muller H-H. (2002) Extracorporeal shock wave therapy in the treatment of lateral epicondylitis. *J Bone Joint Surg.* 84(11): 1982–1991.
36. Dreyfuss P, Stratton S, Herring SA. (1993) The low-energy laser, electro-auscope, and neuroprobe—treatment options remain controversial. *Phys Sports Med.* 21:47–57.
37. LaRiccia PJ. (2000) Acupuncture and physical therapy. *Orthop Phys Ther Clin N Am.* 9:429–442.
38. Scalzitti DA. (2001) Evidence-based guidelines: application to clinical practice. *Phys Ther.* 81:1622–1628.
39. Albright J, Allman R, Bonfiglio RP, Conill A, Dobkin B, Guccione AA. (2001) Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for knee pain. *Phys Ther.* 81:1675–1700.
40. Albright J, Allman R, Bonfiglio RP, Conill A, Dobkin B, Guccione AA. (2001) Philadelphia Panel evidence-based clinical practice guidelines on selected rehabilitation interventions for shoulder pain. *Phys Ther.* 81:1719–1730.
41. Robertson VJ, Baker KG (2001) A review of therapeutic ultrasound: effectiveness studies. *Phys Ther.* 81:1339–1350.
42. DiFabio RP. (1999) Myth of evidence-based practice. *J Orthop Sports Phys Ther.* 29:632–634.