Therapeutic modality: rehabilitation of the injured athlete

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This chapter reviews traditional and alternative therapeutic modalities for the treatment of injuries commonly seen in an orthopaedic sports medicine practice. The reader is reminded that active progressive functional exercises are considered the ultimate modality and that other relatively “passive” modalities should be incorporated in a manner that best serves patient advancement toward more independent functional exercise participation.

Cryotherapy

Using an animal model, Dolan et al [1] reported that post-trauma limb volumes following blunt injury were smaller for a group that received cold water immersion (12.8°C – 15.5°C) compared with untreated control subjects. Myrer et al, [2] in comparing the effects of 20 minutes of ice pack application with those of cold whirlpool immersion (10°C) reported no differences in intra-calf muscle temperature decreases; however, ice packs decreased subcutaneous tissue temperature more than the cold whirlpool, and the cold whirlpool was superior for prolonged temperature reduction. Zemke et al [3] reported that ice massage provided more rapid deep muscular cooling than an ice pack following 15-minute applications. Kuligowski et al [4] reported that cold whirlpool and contrast therapy enabled earlier return to both baseline resting elbow flexion angle and perceived pain level following exercise-induced delayed onset muscle soreness (DOMS) than warm whirlpool or no treatment at all.

Speer et al [5] reported that shoulder surgery patients who received cryotherapy had less pain, slept better, used less pain medication, and had greater overall satisfaction than subjects in a non-cryotherapy control group. Lessard et al [6] reported that knee arthroscopy patients who received a 1-week cryotherapy
program in conjunction with exercises had increased exercise compliance, improved weight-bearing status, and reduced pain medication consumption compared with patients who received exercises alone. In comparing a combined cold and compression cryotherapy system with conventional ice packs among 44 anterior cruciate ligament (ACL) reconstruction patients, Schroder and Passler [7] reported less pain, less swelling, reduced pain medication consumption, increased active range of motion (AROM), and superior functional scores for the cold-compression system group. In a study of post-unilateral total knee replacement patients, Walker et al [8] reported that patients who used a continuous cooling pad in addition to a continuous passive motion device had decreased pain medication consumption compared with patients who received continuous passive motion either with or without transcutaneous electrical nerve stimulation. Ohkoshi et al, [9] in using implanted thermosensors, reported that ACL reconstruction patients who received cryotherapy had less pain, required less pain medication, had less blood loss, and had lower suprapatellar pouch and intercondylar notch temperatures than the control group.

In contrast to reports supporting cryotherapy, Konrath et al, [10] in studying 103 consecutive ACL reconstruction patients, failed to find objective benefits early in the postoperative course, suggesting that joint compression or a placebo effect may be the more beneficial factors. Dervin et al, [11] in assessing 78 ACL reconstruction patients, reported no differences in pain between those who received either circulating ice water or room temperature water in a cold-compression device. In assessing 131 ACL reconstruction patients for the effectiveness of postoperative cooling at 4.4°C, 7.2°C, 12.8°C, or 21°C, Daniel et al [12] reported that all of the cooling pads lowered skin temperature; however, differences were not found between groups for perceived pain, pain medication use, swelling, or AROM.

**Sonotherapy**

In a comparison of the tissue heating effects of 1 MHz and 45 kHz frequency continuous ultrasound using a non-living animal model, Ward and Robertson [13] reported that the heating provided by the 45 kHz ultrasound was very superficial, whereas 1 MHz ultrasound heated both superficial and deep tissues. In using an animal model to assess deep tissue heating differences between ultrasound with coupling gel and underwater ultrasound at 2 cm from the skin surface, Forrest and Rosen [14] reported that only the direct method using coupling gel produced therapeutic temperature increases. In using an animal model to study Achilles tendon healing, Jackson et al [15] reported that the continuous ultrasound group (1.5 W/cm², 4 min) had improved collagen synthesis and greater mechanical strength than a control group.

In assessing the effect of continuous ultrasound to the volar forearm (1.5 W/cm², 5 min) on human skeletal muscle blood flow, Robinson and Buono [16] reported no differences for up to 30 minutes post-treatment, concluding that
muscle hyperemia was probably not the primary mechanism responsible for the clinical benefits seen following ultrasound therapy. In contrast to this study, Fabrizio et al [17] reported that ultrasound (1.0 MHz, 1.0 and 1.5 W/cm²) increased triceps surae blood flow velocity. Ward and Robertson, [18] in assessing continuous 1 MHz ultrasound at three intensity levels (0.5, 1.0, and 2.0 W/cm²) when delivered underwater reported that increasing the applicator–skin surface distance resulted in progressive and significantly lower tissue temperature increases. From these data, they designed dosage correction factors to provide equivalencies for ultrasound provided away from the skin surface.

Stay et al [19] reported no differences in upper arm swelling, relaxed-elbow extension angle, strength, or soreness between female subjects with exercise-induced DOMS who were treated with pulsed ultrasound (20% duty cycle, 1 MHz, 1.5 W/cm², 7 min) and untreated control subjects. Rose et al [20] reported that 1 MHz continuous ultrasound at 1.5 W/cm² to the human calf (4°C tissue temperature increase) produced a slower thermal decay and slower deep tissue cooling than 3 MHz ultrasound. From these data they concluded that the effective stretching window following ultrasound therapy was greater for deeper tissues. Draper et al [21] reported that 3 MHz ultrasound heated tissues at 0.8 cm and 1.6 cm depths faster than 1 MHz ultrasound (2.5 and 5 cm² sound head sizes). Chan et al [22] reported that continuous ultrasound (3 MHz, 1 W/cm², 4 min) increased human patellar tendon temperature at both two times and four times the effective radiating area of a 4.5 cm² sound head, but two times the effective radiating area provided greater heating of longer duration. Draper et al, [23] in comparing the deep heating effect of ultrasound (1 MHz, 1.5 W/cm², 10 min) on human calf muscle that had been treated with either a real or sham hot pack (75°C) reported that greater temperature increases (> 4°C) could be attained with 2 to 3 minutes less total ultrasound time when preheating with a hot pack. Rimington et al [24] reported that ultrasound alone (1 MHz, 1.5 W/cm²) provided a greater heating effect at a depth of 3 cm in human calf muscle than ultrasound preceded by cryotherapy.

In assessing the effect of phonophoresis (1.5 W/cm², 1.0 MHz, 8 min) with 0.33% dexamethasone on adrenal function, Franklin et al [25] reported no evidence of systemic effects. Bare et al [26] failed to find elevated levels of serum cortisol following phonophoresis (1.0 MHz, 1.0 W/cm², 5 min) of a 10% hydrocortisone solution to the volar forearm of 16 subjects. Klaiman et al [27] failed to distinguish differences in pain level or pressure tolerance between 49 patients with soft-tissue injuries who were treated with fluocinonide phonophoresis or ultrasound. Ciccone et al [28] reported that phonophoresis with trolamine salicylate was more effective than ultrasound alone in decreasing the effects of DOMS. In an excellent review of phonophoresis, Byl [29] reported that maximal treatment effectiveness requires topical agents that transmit ultrasound, moist skin that is pretreated with ultrasound, heating or shaving, patient positioning that maximizes circulation to the treated area, continuous ultrasound within the thermal ranges (≥ 1.5 W/cm²) unless there are contraindications for heating based on patient condition (acute injury, open wound), and leaving the drug on
the skin with an occlusive dressing after treatment. For acute injury or open wound treatment, pulsed ultrasound (0.5 to 1.0 W/cm²) should be used. All patients should be monitored for systemic drug side effects, especially when a large area is treated or when there is a loss of continuity of the stratum corneum (higher diffusion rate for open wounds).

**Pulsed electrical stimulation (motor response)**

In exploring the effect of various combinations of burst and carrier frequencies of neuromuscular electrical stimulation (NMES) pain perception during 50% maximal voluntary isometric quadriceps femoris muscle contractions, Rooney et al [30] reported that burst frequencies of 50, 70, and 90 bps at carrier frequencies of 2500 and 5000 Hz did not differ in perceived pain intensity and that greater pain was reported at 10,000 Hz regardless of burst frequency. They recommended that different burst and carrier frequency combinations be tried on a client-by-client basis (to determine the most comfortable, yet greatest torque-producing stimulus). In a comparison of console and portable battery-powered NMES units for the treatment of the quadriceps femoris of 52 ACL reconstruction patients, Snyder-Mackler et al [31] reported that subjects who trained with console-style clinical stimulators (Fig. 1) had greater training intensities and quadriceps torque than subjects who used battery-powered units. Draper and Ballard [32] compared electromyographic biofeedback and portable NMES used in conjunction with quadriceps setting and straight-leg raises (3 times/day, 30-min sessions, for 4 weeks). They reported that the biofeedback group recovered to 46% of the

![Fig. 1. Console electrical neuromuscular stimulation of the quadriceps femoris.](image)
contralateral quadriceps maximal voluntary isometric contraction, whereas the portable NMES group recovered to 38%.

Transcutaneous electrical nerve stimulation

Fundamentally, transcutaneous electrical nerve stimulation (TENS) alters the pattern and frequency of nerve action potentials transmitted toward the central nervous system along the stimulated nerve fibers. [33–35] Animal studies using intracellular neurophysiological recording techniques have led to theories related to the ability of TENS to close a theoretical “gate” to nociceptive impulses associated with tissue injury. [36] TENS is also associated with theories of pain relief linked to the activation of a primitive endogenous pain relief system housed in the reticular core of the brain stem. Some investigators have reported that TENS increases endorphin levels, [37] whereas others found no change in circulating endorphins [38] following TENS application. TENS can be viewed as altering the perceptual pain component and being of little value in managing problems related to the other four components (psychological, affective, cognitive, and behavioral). [39] Patients with acute pain that produces frequent nociceptive impulses are likely to benefit more from TENS than patients with chronic pain in whom some tissue repair has occurred. TENS is likely to be more helpful for patients with localized tissue damage and pain than for patients with diffuse pain that is difficult to localize and characterize.

Jensen et al, [40] in studying the effects of TENS, placebo TENS, and no TENS on 90 patients following arthroscopic knee surgery reported that the TENS group had less pain, required less pain medication, and re-attained preoperative knee muscle strength earlier than the other two groups. Meyler, [41] in evaluating TENS use among 211 patients with differing pain syndromes, reported that TENS was associated with a favorable response in the majority of patients with pain caused by peripheral nerve damage (53%) and musculoskeletal pain due to mechanical causes (69%). Hidderley and Weinel [42] reported that TENS applied to true acupuncture points remote from the pain site of 14 patients undergoing hemiorrhaphy reduced their pain level and morphine use compared with patients who received TENS at non-true acupuncture points. Lein et al [43] reported equal increases in wrist pain threshold for auricular, somatic, and combined TENS treatment groups of nonimpaired subjects compared with a control group.

High-volt pulsed current (EDEMA CONTROL)

Whereas evidence for the efficacy of using motor level electrical stimulation (“muscle pumping”) for edema reduction is considerable, evidence for edema reduction using sensory level stimulation is less abundant. Michlovitz et al [44] reported no differences in edema control when high-volt pulsed current (HVPC)
was added to the ice, compression, elevation treatment of acute ankle sprain patients. Cosgrove et al. [45] using an animal model, reported no differences in edema reduction following blunt trauma between HVPC, symmetrical, biphasic pulsed current, and sham electrical stimulation for edema control.

Using an animal model, Taylor et al. [46] reported that cathodal and anodal HVPC, but not alternating current, decreased macromolecular leakage from microvessels following histamine treatment. Based on the results of several experiments using animal models, Mendel and Fish [47] proposed a tentative edema management protocol using cathode HVPC at 120 pps and 90% of visible motor threshold using a water immersion technique. They recommended 30-minute treatments every 4 hours beginning as soon after the injury as possible, or as long as edema is still likely to be forming. They speculated that whatever HVPC was doing to curb edema formation was induced by non-neurological factors, such as affecting microvascular permeability. These studies suggest that the effects of muscle pumping (motor response) may resolve edema once it is formed and that sensory-level cathodal stimulation with HVPC may retard edema formation.

Iontophoresis

Li et al. [48] reported that patients with rheumatoid arthritis of the knee who were treated with iontophoresis-delivered dexamethasone had less pain at rest and greater AROM than patients who received placebo treatments. Pellecchia et al. [49] reported that patients with infrapatellar tendinitis who were treated with iontophoresis-delivered dexamethasone and lidocaine had less pain, less tenderness with palpation, and better functional scores than patients who received traditional treatment modalities. Gudeman et al. [50] reported greater symptom relief and function for plantar fasciitis patients who received iontophoresis with dexamethasone in conjunction with standard modalities than patients who received standard modalities alone. Wieder [51] reported increased knee AROM and a 98.9% decrease in the myositis ossificans mass of a 16-year-old male using iontophoresis-delivered 2% acetic acid solution followed by pulsed ultrasound (three treatments for 3 weeks). Perron and Malouin. [52] in assessing the efficacy of using acetic acid iontophoresis and ultrasound (0.8 W/cm², 1 MHz, 5 min) in the treatment of patients with calcifying shoulder tendinitis failed to report differences between treatment and control groups. Lark [53] advised using the pain-relieving effects of iontophoresis-delivered lidocaine to assess whether the target painful sites are reachable by iontophoresis.

Acupuncture

Repetitive acupoint stimulation by “needling” is believed to cause repetitive neuronal firing, thereby altering the anatomic, physiological, and chemical
components of the synaptic junctions and creating neuronal memory circuits. [54] A National Institutes of Health sponsored panel reported that acupuncture produces equivocal results because of poor study designs, small sample sizes, and inherent difficulties in the use of placebo or sham controls. [55] Currently, there is a wide variation in the practice of acupuncture, with the number of points represented on various training charts ranging from 365 to more than 2000. [56] Based on reports of promising results among large and diverse patient populations, the panel concluded that acupuncture may be useful as a component of a comprehensive patient management program but strongly recommended further research.

Using animal dissections, Egerbacher and Layroutz [57] reported that acupuncture points resembled either neurovascular bundles or cutaneous spinal nerve branches penetrating fascia or dermis, respectively. Tillu and Gupta, [58] in treating 18 patients with a 25-month mean duration of recalcitrant plantar fasciitis symptoms, reported significant pain reduction following acupuncture. Based on a multicenter study of seven practitioners and 58 patients, Macpherson and Fitter [59] reported that acupuncture effectiveness started to plateau after the first seven treatments and that patients with more severe initial conditions (particularly bodily pain) tended to make more rapid improvements. They also reported that patients with “less chronic” symptoms displayed more rapid recoveries. Gaw et al [60] reported similar improvements between patients with osteoarthritis who were treated with either “real” or sham acupuncture. Johnson et al [61] reported no differences in sensation or pain threshold between nonimpaired subjects who received acupuncture at sites that were either related or unrelated to sites of electrically induced finger pain. Takeda and Wessel [62] reported that “real” and sham acupuncture produced similar pain relief for patients with osteoarthritic knee pain.

**Magnetic field therapy**

Introducing efficacious electrical changes into the cellular microenvironment may have a beneficial effect on tissue growth and repair. The anti-inflammatory effect and enhanced microcirculation of pulsed magnetic fields (PMF) and pulsed electromagnetic fields (PEMF) are believed to be due to their magnetic or electromagnetic field action, independent of any heat produced by the fields themselves, probably via the alterations they induce in cell membrane potentials and ionic fluxes. [63] Using an animal model, Lee et al [63] studied the effects of PMF (17 or 50 Hz) and PEMF (15 or 45 Hz) compared with control in treating Achilles tendon inflammation. They reported that the group treated with a 17 Hz PMF had better collagen alignment and less inflammation than groups treated with other PMF or PEMF frequencies or control by 30 days postinjury. In a study using PEMF for treating 29 patients with persistent rotator cuff tendinitis (≥ 3 months), Binder et al [64] reported that the treated group had less pain and greater AROM following 4 weeks of treatment. In a comparison of 34 patients with heel pain, Caselli et al [65] reported no differences between patients treated
for 4 weeks with either molded insoles with continuous magnetic field foil heel inserts or standard insoles. Foley-Nolan et al [66] in a study of 40 patients with acute whiplash reported less pain and greater AROM among patients who received active PEMF therapy via their soft cervical collars than patients who received collars without an active PEMF. Borsa and Liggett [67] reported no pre- or post-treatment differences between subjects who received “real” CMF, placebo CMF, or no CMF among 45 nonimpaired subjects following an exercise-induced DOMS.

**Biofeedback**

Biofeedback provides a method of bioelectrical monitoring and amplifying the physiological processes that are ordinarily not within a patient’s awareness or control. Biofeedback can be provided by console (Fig. 2) and portable devices (Fig. 3), in single and multichannel configurations. Using radiographic techniques, Ingersoll and Knight [68] reported that nonimpaired subjects who used electromyographic biofeedback in combination with vastus medialis exercises improved their patellofemoral congruence angle compared with patients who used standard exercise and with control subjects. Draper and Ballard, [32] in studying 30 ACL reconstruction patients, reported that biofeedback was superior to portable NMES for improving knee extensor torque. Levitt et al, [69] in studying 51 patients following knee arthroscopy, reported that patients treated with exercise and biofeedback had greater knee extensor torque than those treated with exercise alone. In treating three patients with volitional posterior glenohumeral joint instability who were treated with exercise and biofeedback at the posterior head of the deltoid muscle, Beall et al [70] reported decreased pain, decreased

![Console biofeedback device](image)
dislocation episodes, and a successful return to athletic activities following 4 weeks of therapy. In a case study involving a 15-year-old female with volitional posterior glenohumeral joint dislocation, Young [71] reported good results using a dual-channel biofeedback unit (anterior, posterior deltoid heads) for clinical sessions, and a single-channel unit during home program exercises, which progressed from isometric to AROM to retrain voluntary glenohumeral joint control. Reid et al [72] reported that patients with symptomatic subluxing shoulders who used biofeedback and motor control–based exercises showed greater improvement in work and sport function and had less pain over time than patients who performed an isokinetic exercise strength program. Farmer [73] reviewed the use of biofeedback in combination with visualization to enhance athletic and exercise performance.

**Massage**

Martin et al, [74] in comparing the effect of a single 20-minute lower extremity massage, active recovery (stationary cycling for 20 minutes at 80 RPM and at 40% VO2 peak) or rest in supine (20 minutes) on blood lactate clearance following maximal anaerobic leg exercise among 10 cyclists, reported that only the active recovery group had significant decreases in blood lactate measurements. Tiidus [75] reported that there is little evidence that massage has any significant effect on the physiological factors associated with the exercise recovery process, deeming light exercise of the affected muscles preferable to improve muscle blood flow (thereby enhancing healing). Shoemaker et al [76] compared the effects of forearm and thigh effleurage, petrissage, and tapotement with mild active exercise among 10 nonimpaired subjects. Active exercise increased mean blood flow velocity and vessel diameter, and massage did not. Sullivan et al [77] reported reduced triceps surae H-reflex amplitudes among subjects who received ipsilateral calf petrissage compared with control subjects.
In a comparison between massage (2 hours postexercise) and control groups following exercise-induced elbow flexor/extensor DOMS, Smith et al [78] reported reduced serum creatine kinase levels, prolonged neutrophil elevation, and diminished diurnal cortisol reduction for the massage group. Goldberg et al, [79] in assessing the effect of manual massage pressure levels on triceps surae H-reflex amplitude reported decreased amplitudes during deeper massage compared with control conditions, suggesting that inhibitory responses were pressure sensitive.

**Exercise**

Functionally relevant movements (or components thereof) should be included in the exercise prescription as early as possible with consideration for patient safety and tissue healing status. Within any exercise prescription, the clinician needs to decide what percentage of the program will concentrate on isolated deficiencies (Fig. 4) and what percentage will concentrate on integrated multiple joint and multiple neuromuscular component activities (functional tasks) (Fig 5). Clinicians also must weigh the relative client needs regarding the primary energy system demands of the task (adenosine triphosphate–creatine phosphate, anaerobic glycolysis, aerobic) by manipulating training variables (e.g., sets, repetitions, recovery time, frequency, exercise choice, exercise order). Similarly, exercise programs should combine the positive attributes of both closed kinetic chain and open kinetic chain function (particularly as they relate to position-specific joint stresses), with progressions toward performance at neuromuscular contraction.

![Fig. 4. Conventional isokinetic rehabilitation.](image)
velocities and modes that simulate performance demands). Client needs regarding the restoration of normal coordination, proprioception, and kinesthesia are of particular importance among the athletic community. Modalities other than exercise should be incorporated in a manner that is considered to be most efficacious for catalyzing specific tissue responses (e.g., control of pain, inflammation, edema, torque increases). To achieve this, clinicians must continually evaluate the effect of their interventions and manipulate all treatment modalities to effect the desired changes, facilitate patient progress, and avoid the likelihood of the patient’s “plateauing” at a point far short of the desired outcome.

References


[31] Snyder-Mackler L, Delitto A, Stralka SW, Bailey SL. Use of electrical stimulation to enhance


