

# Clinical Application of Electrotherapy

MICHAEL G. DOLAN, MA, ATC, CSCS • Canisius College

FRANK C. MENDEL, PhD • State University of New York at Buffalo

Using electrotherapy in the management of athletic injuries is standard practice for most athletic trainers and therapists. Electrical stimulation (ES) is applied to relieve pain, to elicit muscle contractions for strength

and reeducation after trauma or immobilization, in iontophoresis, and to manage edema and chronic wounds. Although use of ES is common clinical practice, and athletic training students typically receive extensive instruction in its application, there is little evidence from randomized clinical trials clearly demonstrating positive “treatment” effects on functional outcomes or return to play for athletes. Many clinicians and educators are firm proponents of the clinical benefits of electrotherapy in the management of athletic injuries, and they might be justified, but

until more definitive research is completed ES should be considered as just one component of a comprehensive rehabilitation program. Like all modalities, however, ES should not be used in certain circumstances. Contraindications include, but are not limited to, cardiac pacemakers, pregnancy, infections,

neoplasms, and peripheral vascular disease. If in doubt, clinicians should err on the side of caution and consult with the referring physician before initiating treatment.

## Overview

Clinicians struggle with the terminology used to describe electrotherapy. For example, transcutaneous electrical neural stimulation (TENS) is an acronym familiar to all athletic trainers and therapists. When the term *TENS* is used, many clinicians envision a small, portable unit that evokes sensory-level stimulation to manage pain. The electrical parameters of a TENS unit, such as waveform, pulse width, and duration, might be very comparable to those of large ES units used in clinical settings, but some clinicians would not consider the latter to be TENS units. Technically, any device that produces electrical current sufficient to produce sensory-level stimulation and transmits that current to patients via electrodes is considered a TENS unit. Rather than focus on the name of the electrical stimulator, which is driven by marketing strategies of the manufacturers, clinicians should focus on the stage of the inflammatory or healing process and the desired treatment outcome. Then, if applicable, choose the appropriate electrical parameters to achieve the treatment goal for the individual patient.

Electrical currents are classified as direct current (DC), alternating current (AC), or pulsed current (PC). DC, or galvanic current, is defined as current that flows uninterrupted in one direction. DC is indicated for stimulating long-standing

## KEY POINTS

▶ Although electrical stimulating currents are everyday practices and athletic training students typically receive extensive instruction, little evidence from randomized clinical trials supports the effectiveness of some of these “treatments” on functional outcomes or influencing return to play for athletes.

▶ High-voltage pulsed current, if applied immediately after trauma, is as effective as some forms of cryotherapy and nonsteroidal anti-inflammatory drugs in curbing edema formation in animal models.

▶ High-level electrical stimulation is effective in recovering quadriceps strength during early rehabilitation after ACL reconstruction.

▶ Of all the proposed indications of electrical stimulation, their use in wound management is supported by basic science and controlled clinical trials.

▶ Key Words: electrical stimulation, athletic injuries, modalities

denervated muscles, in iontophoresis, and, in some cases, for wound healing. AC, or faradic current, is also continuous but alternates equally between the positive and negative poles and therefore creates no net charge. PC is interrupted current that is on and off for specific periods. For example, high-voltage pulsed current is characterized by short monophasic twin-spiked pulses followed by long interpulse intervals. Clinicians choose either positive or negative polarity for this type of electrical therapy, depending on the desired outcome. Because the duty cycle, which is calculated by dividing the time current is actually on by the total treatment time, is so short (typically 1–2%),

little to no skin irritation typically occurs. Conversely, dermal injuries are a concern when using DC, which by definition has a duty cycle of 100%. Russian, biphasic, and interferential currents are classified as PC because they do not fit the strict definition of either DC or AC. The major applications of electrotherapy addressed in this article are outlined in Table 1. The information in the table should be viewed as suggested starting points, not as strict protocols. These suggestions are based on current theory and clinical experiences but should be modified according to specifications of the electrical generator and the individual needs of the patient.

**TABLE 1. GENERAL SETTINGS FOR ELECTROTHERAPY**

Outcome	Waveform	Polarity	Pulse Setting	Electrodes	Output
Pain relief (gate control)	PC or AC	NA	High (100+ pps)	Electrode over painful area	90% of visible motor threshold or tingle
Pain relief (opiate)	PC or AC	NA	Low (1–5 pps) for muscle contraction and acupuncture	Small electrodes or probe over motor point or acupuncture point	Muscle contraction or noxious
Muscle strengthening <sup>5</sup>	AC 2500 Hz; PC (Russian, HVPC, biphasic, inferential, NMES)	NA	Moderate (50–75 pps)	Motor points	Maximal contraction within patient tolerance; 10 s on, 50 s off
Long-standing denervated muscle	DC	NA	NA	Over muscle	Motor threshold
Edema control <sup>6</sup>	HVPC	Negative	120 pps	Underwater or large surface	90% of visible motor threshold
Iontophoresis <sup>7</sup>	DC	Based on charge of molecule to be driven	NA	Over targeted tissue	Low current
Wound management <sup>10</sup>	HVPC	+ to attract macrophages, – to attract fibroblasts	100	Active electrode in wound or adjacent to wound edges	Tingle

*Note.* See references for specific set-up. PC = pulsed current; AC = alternating current; pps = pulses/s; HVPC = high-voltage pulsed current; NMES = neuromuscular electrical stimulation.

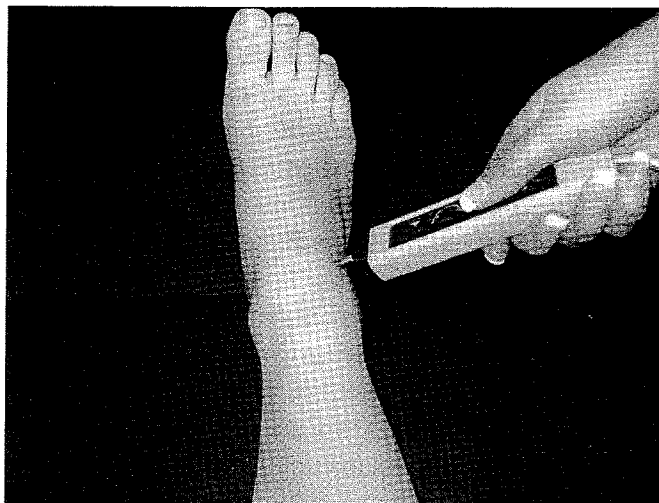
## Pain Management

Acute pain management is often a goal for certified athletic trainers who use electrotherapy. Clinicians are keenly aware that managing pain and swelling is an essential starting point in all rehabilitation programs. Unchecked pain leads to further inflammation and delays implementation of exercise that restores range of motion, strength, balance, neuromuscular control, and functional activity. Electrotherapy is well established as a safe and effective method of managing musculoskeletal pain. Historically, Melczak and Wall's gate-control theory has served as the primary model for pain relief. Sensory but submotor ES is thought to influence pain perception by stimulating large-diameter afferent fibers, which in turn reduce pain by inhibiting transmission of pain stimuli to the brain. Exact parameters for waveform, pulse rate, and phase duration have not been established experimentally, but most treatments based on gate-control theory consist of sensory-level stimulation (perceived as tingling) applied at high pulse rates (100+ pulses/s) for extended periods of time (hours or days) via small portable stimulators. Most TENS units produce biphasic waveforms and therefore are classified as PC or AC stimulators.

Sensory-level TENS effectively reduces muscle inhibition after laboratory-induced knee effusion.<sup>1</sup> TENS might reduce muscle inhibition by decreasing function of Ib-inhibitory interneurons or by stimulating Ia-excitatory interneurons, both of which might be plausible mechanisms for decreasing muscle inhibition that accompanies joint swelling.

Interferential currents are also used to manage pain, but no more effectively than traditional TENS.<sup>2</sup> Interferential-current stimulators produce two sine waves that are slightly out of phase. These two waves summate and create a resultant wave, referred to as an amplitude-modulated wave. Theoretically, this resultant wave penetrates deeply into tissues. Electrodes are usually arranged in an X pattern over the targeted tissue or pain site.

Clinicians can also choose from a variety of techniques collectively known as opiate-mediated pain control. Strong electrical stimulation of motor points, trigger points, acupuncture points, or painful tissue can also be used to treat pain by inducing the release of endogenous opiates. Current theory suggests that pain relief is attributable to chemical inhibition of noxious



**Figure 1** Application of noxious stimulation using a probe for opiate pain relief.

input at the dorsal horn of the spinal cord. Electrical current is applied by a probe to a very small area, at low pulse rates (1–5 pulses/s), and at amplitudes sufficient to elicit motor contractions. Alternatively, clinicians can apply focused stimulation over trigger or acupuncture points until the patient perceives a noxious effect for 30–60 s (see Figure 1). Athletes often report significant pain reduction and a sense of mild anesthesia after treatment. The physiological mechanisms underlying such effects are elusive and not fully understood. Enkephalins inhibit transmission of painful stimuli along neural pathways, and there is some evidence that ES, as just described, might stimulate enkephalin production. Some clinicians use both the gate-control and the opiate-mediated pain-control theory on the same patient at different stages of the rehabilitation process. For example, during early stages of an injury when pain is intense and muscle contractions are unwanted, clinicians might choose typical gate-control settings (i.e., amplitude sufficient to produce a strong tingle, high pulse rate, 100 or greater, applied continuously for long periods). After acute pain has decreased they could implement opiate-based pain relief, which generally includes amplitudes that minimally cause muscle contraction or noxious sensation, typically at much lower pulse rates ranging from 1–80 pulses/s.

### Electrically Induced Muscle Contractions

Athletic trainers and therapists have a long history of using ES to elicit muscle contractions. Pain, swelling,

immobilization, and surgery commonly cause surrounding musculature to “shut down.” Improved surgical techniques, including more arthroscopic techniques, and a movement toward early mobilization after injury have reduced the need for electrically induced muscle contraction over the past 10–15 years. Even with these advances, however, patients still present with decreased muscle strength postsurgery. Specifically, pain, swelling, and immobilization after ACL-reconstructive surgery result in reduced strength of quadriceps muscle. Snyder-Mackler et al.<sup>3</sup> established that high-level electrical stimulation was effective in recovering quadriceps strength during early rehabilitation after ACL reconstruction. Generally, the current is 2,500 Hz AC delivered at 50–75 pulses/s for 10- to 15-s intervals, followed by a rest cycle of 50 s. The stimulus intensity is sufficient to invoke muscle contraction and is increased up to patient tolerance.

### Denervated Muscle

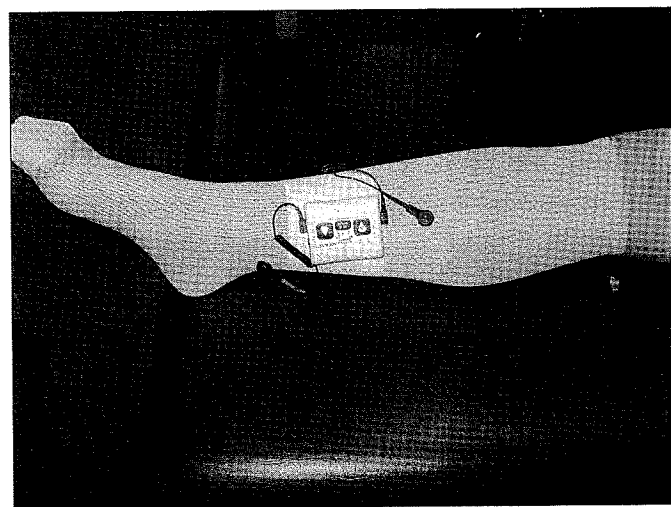
Occasionally, athletic trainers might treat patients who cannot perform a volitional muscle contraction because of denervation. Some forms of TENS that produce pulses of exceptionally long duration can cause denervated muscle to contract. Most clinicians, however, choose DC, or galvanic, stimulation to invoke muscle contractions for these patients. Because the nerve is damaged or not functioning, DC stimulators are designed to provide a constant flow of current to directly depolarize muscle.

### Edema Management

Edema, a natural part of the inflammatory process, is initiated by virtually any trauma including athletic injuries. Uncontrolled edema can increase pain, prolong immobilization, reduce range of joint motion, and inhibit ligament healing, all of which can extend time to recovery. Swelling, or edema, is formed as inflammatory mediators released after injury cause gapping of endothelial cells lining the blood vessels. Such gapping allows plasma proteins, leukocytes, and water to leave blood vessels and move into intercellular space, causing edema. Reed<sup>4</sup> demonstrated that one form of ES, high-voltage pulsed current (HVPC), limits permeability of microvessels, thereby reducing the amount of fluid that escapes into tissue spaces. The mechanism of action remains unknown. Output from HVPC generators is

typically in the form of short (8–10  $\mu$ s) monophasic twin peaks delivered at 100–120 pulses/s. Such output is characterized by high peak voltage but low average current. High-voltage stimulators enable clinicians to choose either positive or negative polarity, but because of low average current and duty cycles, skin injuries caused by changes in skin pH are unlikely.

Recent work has established that cathodal HVPC delivered at 120 pulses/s at 90% of visible motor threshold curbs edema formation as effectively as some forms of cryotherapy<sup>5</sup> or nonsteroidal anti-inflammatory drugs (M.G. Dolan et al., unpublished data, 2004). Clinicians should be aware of two key factors: (a) Electrical stimulation and other interventions should be applied as soon as practically possible because it appears that acute edema formation can be curbed but, once formed, cannot be reduced, and (b) duration of treatment is critical. It seems that these treatments are effective only while the current is actively applied. This suggests that near-continuous treatment is needed throughout the acute inflammatory response.<sup>6</sup> If so, the common clinical practice for acute athletic injuries might need revision. Currently, we are applying electrical stimulation as a primary first-aid treatment to athletes who have sustained inversion ankle sprains. This is in addition to the traditional ice, compression, and elevation. ES is applied via sock electrodes and small portable electrical stimulators, which allow near-continuous treatment (23+ hr/day) while the inflammatory process is ongoing (see Figure 2).



**Figure 2** Use of electrode sock and portable stimulator for continuous application of high-voltage pulsed current for edema management after an acute ankle sprain.

## Iontophoresis

Iontophoresis uses bipolar electric fields to propel molecules through intact skin and into underlying tissue. Analgesics and anti-inflammatory medication are “driven” into tissue using electrical charges delivered by DC generators specifically manufactured for iontophoresis. For example, dexamethasone, a negatively charged anti-inflammatory medication, is placed under the cathode, which is placed over the targeted tissue. Because like charges repel, the cathode forces (repels) the negatively charged medication into the tissue. Iontophoresis is sometimes considered “injection without a needle,” but its clinical efficacy remains in doubt. Evans et al.<sup>7</sup> reported that iontophoresis of lidocaine into myofascial trigger points was statistically significant. Small effect size, however, which indicates the clinical meaningfulness of the treatment, suggests that iontophoresis had little clinical effect. Depth of penetration and the ability of electrical generators to deliver appropriate dosages of medication are commonly debated among clinicians and researchers. Recent work in this area suggests that diffusion, not the magnitude of the repelling current, determines the depth of penetration of the drug molecules.<sup>8</sup>

## Augmenting Wound Management

Of all the proposed applications of ES, none is better supported by basic science and controlled clinical trials than its use in chronic-wound management.<sup>9</sup> Most athletic trainers have limited clinical experience in managing wounds such as decubitus ulcers or wounds caused by systemic diseases such as diabetes or peripheral vascular disease. As athletic trainers expand their practice into nontraditional settings such as hospitals and clinics, however, they will encounter these clinical conditions.

The transepidermal electrical potential, or epidermal battery, is an electrical potential that normally exists between the epidermis and deeper body fluids. Wounds in skin allow current to flow from inside to outside damaged tissue as long as the wounds remain open and moist. The “wound current” is what is thought to “inform” inflammatory cells to migrate to or alter their behavior to effect wound healing. For reasons still unknown, this wound current fails to materialize in some wounds, and, presumably as

a consequence, these wounds fail to heal. By inducing “artificial wound currents” with low-current ES systems, many researchers and clinicians have closed wounds that had remained open for months or years. Note that *wound closure* and *wound healing* are often used as synonymous phrases. In the context of chronic wounds, wound closure might not mean full healing of deeper tissues, but in some instances, it can mean the difference between amputation and sparing a limb.

Kloth<sup>10</sup> suggests two methods of applying HVPC for wound management. Using sterile techniques, one electrode is placed directly in a wound and the other is placed nearby on healthy tissue. The second technique involves placing two electrodes of the same polarity adjacent to wound edges and a dispersive electrode on nearby skin. In either case, the active electrodes (in or adjacent to wound) are set to positive to attract negatively charged neutrophils and macrophages. To facilitate wound closure, the active electrodes are negative to attract positively charged fibroblasts. HVPC is delivered at 100 pulses/s at sub-motor levels 1 hr/day until the skin closes. ES should be considered an adjunct to moist-wound healing and should be performed by health-care professionals with specialized training and clinical experience in this area.

## Summary

Electrical modalities are integral components of athletic training education and clinical practice. Electrotherapy will continue to evolve, we hope, based on its efficacy and cost effectiveness, and not on testimonials and claims by clinicians and manufacturers. As athletic trainers continue to strive for recognition as more autonomous health-care professionals, we must insist that our clinical practices and education be guided by sound research. ■

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**Michael Dolan** is the Peter Canisius Distinguished Teaching Professor in the Department of Sports Medicine, Health & Human Performance, at Canisius College in Buffalo, NY. His research interests include acute trauma management, foot orthotic devices, and efficacy of ankle bracing.

**Frank Mendel** is an associate professor and vice chairman of the Department of Pathology and Anatomical Sciences at the State University of New York at Buffalo. His research interests include efficacy of various treatments for sprains and contusions.

## UPCOMING THEMES

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|---------------------|-------------------------------------------------------------------------------------------------------------------------------|
| <b>November</b>     | <b>Applied Clinical Research</b><br><i>Thomas W. Kaminski, PhD, ATC/R, University of Delaware</i>                             |
| <b>January 2005</b> | <b>Sports-Medicine Pharmacology</b><br><i>Gary L. Harrelson, EdD, ATC, DCH Regional Medical Center, Tuscaloosa, AL</i>        |
| <b>March</b>        | <b>Emergency Care in Athletic Training</b><br><i>Marisa A. Colston, PhD, ATC/L, University of Tennessee at Chattanooga</i>    |
| <b>May</b>          | <b>Emergency Preparedness</b><br><i>Katie Walsh, EdD, ATC-L, East Carolina University</i>                                     |
| <b>July</b>         | <b>Core Stabilization</b><br><i>Gary L. Harrelson, EdD, ATC, DCH Regional Medical Center, Tuscaloosa, AL</i>                  |
| <b>September</b>    | <b>Management of Lumbar Spine Dysfunction</b><br><i>Marisa A. Colston, PhD, ATC/L, University of Tennessee at Chattanooga</i> |
| <b>November</b>     | <b>Professional Work Satisfaction</b><br><i>Gary L. Harrelson, EdD, ATC, DCH Regional Medical Center, Tuscaloosa, AL</i>      |