

Comfort In Electrical Stimulation

Alon G., Kantor G., and Ho H.S. (1994) Effects of electrode size on basic excitatory responses and on selected stimulus parameters. *J. Orthop. Sports Phys. Ther.* 20, 29-35.

Abstract: Recent data have implicated the size of surface electrodes as an important factor affecting peripheral nerve excitation. Therefore, we studied the effects of electrode size on the basic excitatory responses and on stimulus characteristics. Four different sizes of self-adhesive surface electrodes were applied over the medial and lateral gastrocnemius muscle of 20 healthy subjects. The excitatory levels were sensory threshold, motor threshold, pain threshold, and maximally tolerated painful stimulation. Stimulus parameters included a symmetric biphasic waveform, 200 microseconds phase duration, and a pulse repetition rate of 50 pps. Amplitude was increased until the appropriate excitatory response was achieved. At this amplitude level, the computerized recording system collected data of stimulus peak current, peak voltage, and phase charge as well as isometric plantar flexion force. Repeated measure analysis of variance and Newman-Keuls post hoc tests revealed that increasing electrode size significantly decreased voltage but increased current and phase charge magnitudes. With increasing electrode area, the ratios of voltage/current decreased nonlinearly, while the ratios of charge/voltage increased nonlinearly. The comfort of stimulation for the same amount of plantar flexion force improved significantly as electrode size became larger. We concluded that electrode size affects the stimulus parameters, comfort, and force generation associated with electrically induced excitatory responses. Electrode size should be considered an integral part of the attempt to improve subject response to transcutaneous electrical stimulation

Baker L.L., Bowman B.R., and McNeal D.R. (1988) Effects of waveform on comfort during neuromuscular electrical stimulation. *Clin. Orthop.* 75-85.

Abstract: Electrical stimulation is a commonly used clinical tool, but subject and patient comfort is still a major problem retarding its widespread application. Stimulus waveform in combination with pulse duration can play a major part in subject comfort. An asymmetric balanced biphasic square waveform was perceived as comfortable and was clinically effective in stimulating wrist flexor and extensor muscles. Subjects preferred the square waveforms over a paired spike monophasic waveform. In the larger quadriceps muscle group, a symmetric biphasic square wave was perceived as more comfortable than either a monophasic paired spike or any of three medium frequency waveforms. There seemed to be, however, a small subpopulation of subjects who consistently preferred the medium frequency waveforms. Medium frequency stimulation should be tried for those patients who have considerable difficulty adapting to the sensory input inherent with the use of surface electrical stimulation

Bowman B.R. and Baker L.L. (1985) Effects of waveform parameters on comfort during transcutaneous neuromuscular electrical stimulation. *Ann. Biomed. Eng* 13, 59-74.

Abstract: Twenty-three females between the ages of 19 and 35 were studied in order to compare the effects of variations in pulse duration, waveform symmetry, and source regulation on comfort during quadriceps surface stimulation at amplitudes necessary to produce 27 Nm torque. Stimulation parameters compared were: 1) 50 and 300 microseconds pulse durations, 2) asymmetrical and symmetrical biphasic waveforms, and 3) current and voltage source regulation. Subjects overwhelmingly

preferred the 300 microseconds pulse duration regardless of waveform or source regulation, strongly preferred the symmetrical biphasic waveform, and had inconsistent preference for either regulated voltage or regulated current sources

Campbell J.M., Meadows P.M. (1995) Electrical Stimulation in the Management of Muscle Disuse or Temporary Muscle Denervation Can Be Effective and Comfortable. *Proc RESNA Annual Conference*, Vancouver, CANADA, 393-396.

Delitto A. and Rose S.J. (1986) Comparative comfort of three waveforms used in electrically eliciting quadriceps femoris muscle contractions. *Phys. Ther.* 66, 1704-1707.

Abstract: The purpose of this study was to compare the relative comfort levels of electrical stimulation having different waveforms, but otherwise identical current characteristics, delivered percutaneously to normal quadriceps femoris muscles contracting at the same intensity level. The quadriceps femoris muscles of 20 healthy subjects were stimulated to a torque level 60% of that obtained in a maximal voluntary isometric contraction, using pulsed current with a carrier frequency of 2,500 Hz, at 50 pulses per second of 10-msec pulse duration. Three different waveforms were used: sinusoidal, sawtooth (triangular), and square. The relative comfort level of each electrically elicited contraction for each waveform was determined for each subject using a 20-cm-long visual analog scale. The results showed that no one waveform was most comfortable (least uncomfortable) and the difference was significant in what the subjects perceived to be the most comfortable contraction, regardless of waveform (p less than .01). These results indicate that a subject's perception of discomfort changes as the waveform of stimulation varies and that individual preferences exist for different waveforms. Selection of the most comfortable waveform could prove beneficial when the intensity of muscle stimulation is increased

Dumoulin C., Seaborne D.E., Quirion-DeGirardi C., and Sullivan S.J. (1995) Pelvic-floor rehabilitation, Part 1: Comparison of two surface electrode placements during stimulation of the pelvic-floor musculature in women who are continent using bipolar interferential currents. *Phys. Ther.* 75, 1067-1074.

Abstract: BACKGROUND AND PURPOSE: Electrical stimulation of the pelvic floor is used as an adjunct in the conservative treatment of urinary incontinence. No consensus exists, however, regarding electrode placements for optimal stimulation of the pelvic-floor musculature. The purpose of this study was to compare two different bipolar electrode placements, one suggested by Laycock and Green (L2) the other by Dumoulin (D2), during electrical stimulation with interferential currents of the pelvic-floor musculature in continent women, using a two-group crossover design. SUBJECTS: Ten continent female volunteers, ranging in age from 20 to 39 years (mean = 27.3, SD = 5.6), were randomly assigned to one of two study groups. METHODS: Each study group received neuromuscular electrical stimulation (NMES) of the pelvic-floor musculature using both electrode placements, the order of application being reversed for each group. Force of contraction was measured as pressure (in centimeters of water [cm H₂O]) exerted on a vaginal pressure probe attached to a manometer. Data were analyzed using a two-way, mixed-model analysis of variance. RESULTS: No difference in pressure was observed between the two electrode placements. Differences in current amplitude were observed, with the D2 electrode placement requiring less current amplitude to produce a maximum recorded pressure on the manometer. Subjective assessment by the subjects

revealed a preference for the D2 electrode placement (7 of 10 subjects).

CONCLUSION AND DISCUSSION: The lower current amplitudes required with the D2 placement to obtain recordings comparable to those obtained with the L2 technique suggest a more comfortable stimulation of the pelvic-floor muscles. The lower current amplitudes required also suggest that greater increases in pressure might be obtained with the D2 placement by increasing the current amplitude while remaining within the comfort threshold. These results will help to define treatment guidelines for a planned clinical study investigating the effects of NMES and exercise in the treatment of urinary stress incontinence in women postpartum. [Dumoulin C, Seaborne DE, Quirion-DeGirardi C, Sullivan SJ. Pelvic-floor rehabilitation, part 1: comparison of two surface electrode placements during stimulation of the pelvic-floor musculature in women who are continent using bipolar interferential currents

Kramer J.F. (1987) Effect of electrical stimulation current frequencies on isometric knee extension torque. *Phys. Ther.* 67, 31-38.

Abstract: The purpose of this study was to compare the isometric knee extension torques of male and female subjects during maximal voluntary contractions (MVCs), electrical stimulation only, and electrical stimulation superimposed onto MVCs at electrical stimulation current frequencies of 20, 50, and 100 Hz. An asymmetrical, bidirectional, nonionizing waveform of 1-msec pulse duration was delivered through the femoral nerve and the superficial quadriceps femoris muscles at maximally tolerated intensity for each subject. The male subjects (n = 20) demonstrated significantly greater absolute torques under all contraction conditions than did the female subjects (n = 20) (p less than .01); when the torques were expressed as a percentage of each subject's MVC torque, however, no significant differences were observed between the sexes. Overall, the superimposed contractions at 50 and 100 Hz and the MVCs had similar torque values, all being significantly greater than the torque values produced by electrical stimulation only at frequencies of 20, 50, and 100 Hz and by the superimposed contractions at 20 Hz. Superimposing electrical stimulation onto MVCs did not result in greater torques than those produced by the MVCs alone. The three most effective contraction conditions, in terms of subject comfort (minimal discomfort) and increased torque, were the superimposed contractions at 50 and 100 Hz and MVCs alone, all of which involved a voluntary component

Nelson H.E., Jr., Smith M.B., Bowman B.R., and Waters R.L. (1980) Electrode effectiveness during transcutaneous motor stimulation. *Arch. Phys. Med. Rehabil.* 61, 73-77.

Abstract: Four types of electrodes were evaluated for clinical effectiveness in electrically stimulating the quadriceps muscles to gain knee extension for time periods lasting up to 4 days. These electrodes included self-adhering pregelled pads, solvent-activated conductive tape, carbonized conductive silicone rubber, and felt-covered metal plates. The electrodes were compared for ability to produce knee extension torque, electrical impedance, ease of application, durability, comfort, and skin reactivity. Felt-pad electrodes soaked in tap water or saline produced the highest mean torque and lowest electrical impedance, which made them excellent choices for single session stimulation. Carbon-rubber electrodes with either gel produced slightly less torque, slightly higher impedances, and only minor skin reactions. They were relatively easy to apply, and the majority remained intact for the duration of the study period. They were found to be most suitable for prolonged functional electrical stimulation of the quadriceps. Stimulation using pregelled

electrodes produced the lowest torque, and they displayed consistently higher electrical impedance. Even though they were easiest to apply and survived better than the other electrodes, they also produced the most skin reactions. The torque and electrical impedance of the activated-tape electrodes were extremely variable and unpredictable, and the process of application was long and involved, making them clinically impractical for either long or short stimulation

Rosenberg J.N. and Turchetta J. (1993) Magnetic coil stimulation of the brachial plexus. *Arch. Phys. Med. Rehabil.* 74, 928-932.

Abstract: This study establishes a protocol and normal values for magnetic stimulation of the brachial plexus at the mid-clavicular point. We evaluated twenty normal subjects bilaterally, and determined normal latencies to the abductor pollicis brevis, abductor digiti minimi, biceps, triceps, deltoid, infraspinatus, latissimus dorsi, and rhomboid major. Our values were comparable to latency values obtained with electrical stimulation at Erb's point and reported in the literature. Patient's compared their comfort between electrical stimulation and magnetic stimulation and magnetic stimulation was found more comfortable. To demonstrate that magnetic stimulation is an easier and less painful method to study brachial plexus injuries, we report two cases where we were unable to record evoked responses with electrical stimulation at Erb's point yet easily obtained magnetic recordings