N94- 28371

510-52
207619
P. 9

Electrical Stimulation in Exercise Training

Walter Kroll, Ph.D.
Department of Exercise Science
University of Massachusetts
Amherst, Massachusetts

Introduction

Electrical stimulation has a long history of use in medicine dating back to 46 A.D. when the Roman physician Largus found the electrical discharge of torpedo fishes useful in the treatment of pain produced by headache and gout. A rival Greek physician, Dioscorides, discounted the value of the torpedo fish for headache relief but did recommend its use in the treatment of hemorrhoids. In 1745, the Leyden jar and various sized electrostatic generators were used to treat angina pectoris, epilepsy, hemiplegia, kidney stones, and sciatica. Benjamin Franklin used an electrical device to treat successfully a young woman suffering from convulsive fits. In the late 1800's battery powered hydroelectric baths were used to treat chronic inflammation of the uterus while electrified athletic supporters were advertised for the treatment of male problems.

Fortunately, such an amusing early history of the simple beginnings of electrical stimulation did not prevent eventual development of a variety of useful therapeutic and rehabilitative applications of electrical stimulation. Over the centuries electrical stimulation has survived as a modality in the treatment of various medical disorders with its primary application being in the rehabilitation area. Recently, a surge of new interest in electrical stimulation has been kindled by the work of a Russian sport scientist who reported remarkable muscle strength and endurance improvements in elite athletes. Yakov Kots reported his research on electric stimulation and strength improvements in 1977 at a Canadian-Soviet Exchange Symposium held at Concordia University in Montreal. Since then an explosion of new studies has been seen in both sport science [9] and in medicine [13].

Based upon the reported works of Kots and the present surge of new investigations, one could be misled as to the origin of electrical stimulation as a technique to increase muscle strength. As a matter of fact, electric stimulation has been used as a technique to improve muscle strength for over a century. Bigelow [3] reported in 1894, for example, the use of electrical stimulation on a young man for the purpose of increasing muscle strength. Employing a rapidly alternating sinusoidal induced current and a dynamometer for strength testing, Bigelow reported that the total lifting capacity of a patient increased from 4328 pounds to 4639 pounds after only 25 minutes of stimulation. In 1965, Massey *et al.* [11] reported on the use of an Isotron electrical stimulator that emitted a high frequency current. Interestingly enough, the frequencies used by Massey *et al.* and the frequencies used by Bigelow in 1894 were in the same range of frequencies reported by Kots a being the most effective in strength development. It would seem the Russian secret of high frequency electrical stimulation for strength development, then, is not a modern development at all.

Strength Improvement by Electrical Stimulation

Kots claimed that electrical stimulation could produce a stronger muscular contraction than that possible via a maximal volitional effort. Such a claim attracted great attention in the exercise science community where optimal strength development is believed to be produced by overload training; that is, the muscle contraction must exceed some critical tension level for strength improvement to occur. If electrical stimulation could indeed produce a supernormal maximal contraction and activate more muscle fibers than a volitional contraction, it could constitute a super strength training technique. And, indeed, Kots presented data that 20 10-minute electrical-stimulation sessions increased strength by 40 percent in athletes and also resulted in a decrease of subcutaneous fat under the stimulated area. Such results were clearly in the realm of spectacular and researchers hurried to study the new super training technique.

But, alas, the almost unbelievable claims made for electrical stimulation as a super training technique were not reproduced by other researchers. As Nelson and Currier [13] noted in their review of electrical stimulation as a strength development technique, peak torque developed by electrical stimulation of muscle was consistently less than that produced by a maximal voluntary contraction. If electrical stimulation was combined with a voluntary contraction, the torque developed was less than that produced by the voluntary contraction alone. Although Nelson and Currier did not identify the cause of the latter effect, it would be described by Russian neurophysiologists as the well known Wedenski inhibition that occurs when two high-intensity stimuli occur simultaneously. Certainly the notion of a supermaximal contraction and an enhanced overload training effect simply was not seen.

An earlier review by Kramer and Mendryk [9] made note of the fact that different kinds of electrical stimulators were being employed with different wave forms, pulse frequencies, and maximum current capabilities. Many of the electrical stimulators lacked conformity with Kots' specifications for a sine wave pulse, high-frequency pulse rate to produce an anesthetic effect allowing high current flow for maximum activation of muscle tissue, number of stimulations administered, and single stimulation duration and rest interval. Specific details about the methodology employed were not provided in many of the electrical-stimulation strength studies. It might also be added that several electrical-stimulation strength studies employed incorrect statistical analysis techniques making their reported results subject to question. Notwithstanding such acknowledged limitations to any review of research findings, Kramer and Mendryk drew the only conclusion possible: "...the available literature does not support claims made for the Russian technique of electrical stimulation."

Concern about the proper application of the Russian technique a well a use of a proper electrical stimulator is justified before any final disposition can be valid of Kots' claims for electrical stimulation. It is interesting to note, however, that Kots was involved in a study in which he personally applied the electrical stimulation using his own stimulator [18]. The short-term effects over seven sessions with proper protocols and proper stimulator showed that isokinetic knee extension strength declined 13.6 and 17.6 percent in three female volleyball players and 16.7 and 3.1 percent in seven male football players at 24 deg/s and 126 deg/s, respectively. Only the difference at 24 deg/s for males was statistically significant although it must be noted that the small sample sizes of three and seven constitutes a serious deficiency for any statistical contrasts. Significant atrophy of fast twitch muscle fiber area occurred in the males. Thus, the Kots regimen not only failed to increase strength, it also failed to maintain strength in trained athletes. Both of these failures refute specific claims Kots had made for the Russian electrical-stimulation technique. The results of the Kots' involved study fail to provide any challenge to the conclusion that Russian claims of electrical stimulation as a super training technique are dubious.

Tonic Sensory Function of Electrical Stimulation

It would seem clear that the utilization of electrical stimulation as a means to increase strength is an interior substitute for simple voluntary muscle contraction. As the Russian M. A. Cherepakhin [5] noted back in 1977, electrical stimulation combined with physical exercise—isometric or dynamic—was no better than the physical exercise alone. And the same is true for deconditioned subjects (i.e., voluntary exercise is better than electrical stimulation for disuse atrophy). However, electrical stimulation might serve a function as a deconditioning preventive when used as tonic sensory protocol rather than as a strength training protocol.

Boris B. Yegerov [20] believed electrical stimulation might be used to combat some weightlessness effects not confined to muscle strength loss. Noting that low-voltage impulses could reduce vestibular vegetative reactions he stated that "...skeletal muscle under electrostimulation becomes the source of a strong stream of afferent impulses to the central nervous system. We are entitled to assume that the periodic repetition of such stimuli may counteract the vegetative reaction which takes place under conditions of weightlessness."

Rehabilitation specialists know that the speed with which muscle atrophy occurs is so rapid that a neural factor must be operative [10, 4, 17]. And it is also known that simple isometric contractions in a casted limb significantly deters muscle atrophy [15]. But it has also been shown that electrical stimulation, whether in combination with isometric contractions or alone, has a significant effect upon disuse atrophy [16, 6]. Perhaps the most instructive study might be that conducted by Gould *et al.* [8] who compared isometric contraction, control, and electrically stimulated groups of ten subjects each who wore long-leg casts from groin to toes for 2 weeks. The electrically stimulated group suffered significantly less thigh muscle volume loss than the other groups, retained its calf volume (loss of 0.98 percent, nonsignificant) and actually increased in ankle dorsiflexion strength. These results may be related to the beneficial effects electrical stimulation has been shown to have upon muscle protein synthesis and quadriceps atrophy due to immobilization [7].

Thus, high intensity electrical stimulation may not be essential to prevent a significant portion of disuse atrophy. There is even some limited evidence that electrical stimulation used as a tonic sensory protocol could maintain performance quality of some kinesthetic sense tasks [2]. In our own work using patterned electrical stimulation on stroke paralysis, thrice weekly sessions have produced return of somesthetic sense in hemiplegic limbs as well as return of significant movement capability in paralysis lasting up to 23 years. It would seem, therefore, that the investigation of electrical stimulation as a tonic sensory protocol has been neglected in disuse atrophy studies and may warrant closer scrutiny.

References

[1] ANDERS, F. F. AND S. ULLA. Transient decrease in number of motor units after immobilization in man. *J. Neurol. Neurosurg. Psychiat.* 41:924-929, 1978.

[2] BENNETT, K. AND A. DICKINSON. The effects of low intensity electrical current during immobilization on proprioceptive function. *Med. Sci. Sports Ex.* 4:119, 1982.

[3] BIGELOW, H. R. *An International System of Electro-Therapeutics.* London: F. J. Rebman, 1894.

[4] BUCHTHAL, F. AND A. MADSEN. Synchronous activity in normal and atrophic muscle. *Electoenceph. Clin. Neurophysiol.* 2:425-444, 1950.

[5] CHEREPAKHIN, M. A., YE. KAKURIN, I. IL'INA-KAKUYEVA, AND G. T. FEDERENKO. Evaluation of effectiveness of muscular electrostimulation for the prevention of disorders related to prolonged restriction of motor activity in man. *Kosm. Biol. Med.* 2:64-68, 1977.

[6] ERIKSSON, E. AND T. HAGGMARK. Comparison of isometric muscle training and electrical stimulation supplementing isometric muscle training in the recovery after major knee ligament surgery. *Amer. J. Sports Med.* 7:169-171, 1979.

[7] GIBSON, J. N. A., K. SMITH, AND M. J. RENNIE. Prevention of disuse muscle atrophy by means of electrical stimulation: maintenance of protein synthesis.

[8] GOULD, N., D. DONNERMEYER, M. POPE, AND ASHIKAGA. Transcutaneous muscle stimulation as method to retard disuse atrophy. *Clin. Orthop.* 164:215-220, 1982.

[9] KRAMER, J. F. AND S. W. MENDRYK. Electrical stimulation as a strength improvement technique: a review. *J. Orthop. Sports Phys. Ther.* 4:91-98, 1982.

[10] LIPPMAN, R. K. experimental study of muscle atrophy. *Surg. Gynec. and Obst.* 47:512-522, 1928.

[11] MASSEY, B. H., R. C. NELSON, B. J. SHARKEY, T. COMDEN, AND G. C. OTTOT. Effects of high frequency electrical stimulation on the size and strength of skeletal muscle. *J. Sports Med. Phys. Fit.* 5:136-144, 1965.

[12] MCNEAL, DONALD R. 2000 years of electrical stimulation. In: *Functional Electrical Stimulation*, edited by F. Terry Hambrecht and James B. Reswick. New York: Dekker, 1977, p.3-35.

[13] NELSON, ROGER M. AND DEAN P. CURRIER (eds.). *Clinical Electrotherapy.* Norwalk, CT: Appleton & Lange, 1987.

[14] PATEL, A. N., Z. A. RAZAK, AND D. K. DASTUR. Disuse atrophy of human skeletal muscle. *Arch. Neurol.* 20:413-421, 1969.

[15] ROZIER, C. K., J. D. ELDER, AND M. BROWN. Prevention of atrophy by isometric exercise of a casted leg. *J. Sports Med.* 19:191-194, 1979.

[16] STANISH, W. D., G. A. VALIANT, A. BONEN, AND A. N. BELCASTRO. The effects of immobilization and of electrical stimulation on muscle glycogen and myofibrillar ATPase. *Can. J. Appl. Spt. Sci.* 7:267-271, 1982.

[17] STOBOY, H. AND G. FRIEDEBOLD. Changes of electrical activity, of actual circumference of thigh during contraction and of strength-endurance product during isometric training in functional and organic muscle atrophy. *Med. Sport* 8:492-496, 1973.

[18] ST. PIERRE, DIANE, ALBERT W. TAYLOR, MARCEL LAVOIE, W. SELLERS, AND YAKOV M. KOTS. Effects of 2500 Hz sinusoidal current on fibre area and strength of the quadriceps femoris. *J. Sports Med.* 26:60-66, 1986.

[19] WENZEL, BERNICE M. AND H. PHILIP ZEIGLER (eds.). Tonic functions of sensory systems. *Annals NY Acad. Sci.*, Vol. 290, 1977.

[20] YEGEROV, B. B. Soviet space M.D. advises stimulation by electricity for weightlessness. *Med. Trib.* 9:2, 1968.

[21] WOLF, E., A. MAGORA, AND B. GONEN. Disuse atrophy of the quadriceps muscle. *EMG* 11:479-489, 1971.