Comparison of Isometric Exercise and High Volt Galvanic Stimulation on Quadriceps Femoris Muscle Strength

THOMAS MOHR, BARBARA CARLSON, CATHY SULENTIC, and RICHARD LANDRY

The purpose of this study was to compare the effectiveness of both high volt galvanic current (HVG) and isometric exercise to strengthen the quadriceps femoris muscles in 17 healthy subjects. The subjects were divided into three groups. The Control Group (n = 6) received no exercise or stimulation. The Isometric Exercise Group (n = 5) performed 15 sessions of maximum isometric contractions, and the Electrical Stimulation Group (n = 6) engaged in 15 sessions of electrically stimulated isometric contractions. The Isometric Exercise Group was found to have an increase in strength significantly greater ($p < .05$) than either the Control or Electrical Stimulation Group. No increase in strength was observed in either the Control or Electrical Stimulation Group. This study indicates that HVG stimulation is not as effective as isometric exercise in increasing strength in muscle.

Key Words: Electric stimulation, Exercise therapy, Muscles, Physical therapy.

Numerous articles have been published regarding the effect of electrical stimulation on strengthening skeletal muscle. Perhaps the most remarkable findings have come from the investigations conducted by Kots in Russia.1 He found electrical muscle stimulation to be an effective means of increasing strength in subjects who had experienced an injury and in subjects who were healthy; electrical muscle stimulation produced better results than an exercise regimen alone. Kots suggested that more motor units, within a given muscle, could be recruited through electrical stimulation than by a voluntary contraction of that same muscle.1 He further claimed that high intensity currents can give contractions 10 to 30 percent higher than maximal voluntary contractions. Other investigators attempting to duplicate Kots's work have apparently not had results of the magnitude found in the Russian studies.2

Although other published studies have generally found electrical stimulation capable of increasing strength in healthy subjects, it has not appeared to be more effective than exercise alone.3-8 Romero and co-workers found that electrical stimulation produced a significant increase in isometric strength of 31 percent in healthy subjects.4 Halbach and Straus reported an increased quadriceps femoris muscle strength of 22 percent with electrical stimulation, but strength gains recorded from subjects exercising isokinetically were even more marked with a 42 percent increase in strength.8

Studies on patient groups have had more positive results showing electrical stimulation to be an effective rehabilitation modality.6-13 Eriksson and Haggmark found electrical stimulation combined with exercise to be more effective in preventing atrophy than exercise alone in patients after surgery.13 Godfrey et al have found electrical stimulation as effective as a program of isokinetic exercise in patients who have had knee surgery.11 Johnson et al observed a strength increase of 25.3 percent in mild chondromalacia patellae in comparison with a marked strength increase of 200 percent in severe cases of chondromalacia patellae.12 His observation suggests that the greater the atrophy, the more effective the electrical stimulation.

Optimal stimulus characteristics such as current intensity, frequency, and the ratio of stimulus "on" time to "off" time have not yet been established. The effectiveness of the stimulation appears to be related to current tolerance, whereby the greater the delivered stimulus intensity, the greater the strength gains.1,4 Researchers have reported strength increases with stimulation frequencies ranging from 50 to 2,000 pulses per second (pps), although no single frequency has proven to be more effective than the others.4-6,8,11,12

The ratio of stimulator "on" time to "off" time is referred to as the "duty cycle." Benton et al suggest that the duty cycle ("on": "off" time ratio) be at least 1:5 to avoid fatigue.14 Researchers, however, have reported successful muscle
strengthening using duty cycles of 1:1 (4 seconds "on," 4 seconds "off"; 15 seconds "on," 15 seconds "off") and duty cycles of 1:5,8,11,12 (10 seconds "on," 50 seconds "off").

The number of electrical stimulation training sessions required to produce strength gains also is quite variable. Some investigators have reported significant strength gains in as few as 10 sessions,3,4 but other researchers found significant increases in strength in 12 to 25 training sessions.1,5-7,11 Because of differences in stimulus characteristics and training protocols, comparisons between the published studies are impossible.

High volt galvanic (HVG) current has been used in many physical therapy clinics for reducing edema, reducing pain, healing ulcers, increasing joint mobility, and preventing disuse atrophy; however, few studies have been published regarding the effectiveness of HVG in treating those conditions.13 The short duration of this current allows a high intensity stimulus and, at the same time, is relatively comfortable to the patient in comparison with conventional low volt galvanic current. High volt galvanic current, therefore, might provide an effective means of stimulating healthy muscle to increase strength. No published studies, however, have tested the effect of HVG on strengthening muscles. The purpose of this study was to compare the effectiveness of HVG with that of isometric exercise on strengthening the quadriceps femoris muscles. We hypothesized that we would find no difference between the exercise and stimulation groups in strength gains.

**METHOD**

Eighteen healthy women volunteered to participate in this study, but one subject had to drop out because of a knee injury. Ages of the subjects ranged from 21 to 29 years. All of the subjects were university students with no history of lower extremity injury. Although no attempt was made to limit daily activities, we asked all subjects not to begin any strengthening programs during the course of the experiment.

After giving their informed consent, the subjects were randomly assigned to either the Control Group or one of the two Experimental Groups. The Control Group (n = 6) subjects were allowed regular daily activity. Subjects in the Isometric Exercise Group (n = 5) performed a series of isometric exercises with the quadriceps femoris muscles (knee extensors) consisting of 10 maximal 10-second contractions with a rest period of 10 seconds between each contraction. The Electrical Stimulation Group (n = 6) received ten 10-second stimulated contractions of the quadrcipes femoris muscles followed by a rest period of 10 seconds duration between each contraction.

Strength measurements of the knee extensors were made on all subjects before and after the experiment. Isometric torque measurements were determined using a Cybex® II dynamometer.* The Cybex® II was calibrated using calibrated weights on the dynamometer lever arm before both the pretest and posttest measurements. All torque measurements and experimental procedures were performed on the right (dominant) knee of each subject. The subject was seated on the standard Cybex® II bench, which had the backrest inclined posteriorly to give a bench seat to backrest angle of 105 degrees (75° of trunk flexion). The subject's right knee was positioned and stabilized in 60 degrees of flexion.16 The subjects were stabilized in the test position by straps around the trunk, waist, thigh, and ankle. Each subject held onto the sides of the bench with both hands during the testing procedure. The subjects were positioned in this same manner for all the testing and for both the electrical stimulation and isometric exercise sessions.

Before the actual test procedure, each subject was given a brief orientation and practice session to familiarize her with the equipment and the test protocol. For the test procedure, we set the Cybex® speed control at zero and asked each subject to perform three maximal isometric contractions of 10 seconds duration. A three-minute rest period was allowed between each contraction. All subjects were verbally encouraged at the onset of each test to give a maximal contraction. The torque measurements were subsequently recorded by the Cybex® II chart recorder. We used the highest torque value for data analysis.

We gave the Control Group only a pretest and posttest torque measurement during the course of the experiment. The two Experimental Groups participated in the training sessions daily Monday through Friday for three weeks for a total of 15 training sessions. The number and duration of training sessions used in our study were similar to training regimens used in previous electrical stimulation studies.3,8,11 The isometric exercise session consisted of seating the subject on the Cybex® bench in the same position as that for the pretest torque measurement session. We set the speed control at zero, asked the subject to perform ten 10-second isometric contractions with the knee extensors, and allowed a rest period of 10 seconds between each contraction.

Subjects in the Electrical Stimulation Group were positioned on the Cybex® bench in the same manner as the Isometric Exercise Group. The stimulator used on the Electrical Stimulation Group was a Microdyne† Intellect Model 500 HVG stimulator. The Microdyne stimulator delivers a twin peak pulse of short duration (approximately 28 μsec for the first peak at one-half pulse height and 17 μsec for the second peak) with a variable current intensity of 0 to 2,500 mA peak.

We used a bipolar technique with three standard metal-sponge, electrodes consisting of two negative electrodes (cathodes, 10.2 x 10.2 cm) and one larger dispersive electrode (anode, 12.7 x 17.8 cm) to stimulate the quadriceps femoris muscles. After soaking the electrode pads in tap water, we placed one cathode over the motor point of the vastus medialis muscle and the other equally sized cathode over the motor point of the vastus lateralis muscle; the anode was placed proximal to the other two electrodes and just inferior to the inguinal ligament over the rectus femoris muscle. This electrode placement had elicited strong contractions of the quadriceps femoris muscle group in preliminary studies.

The surge mode on the HVG stimulator was used to sequence automatically the delivery of the stimulus and thus assure a consistent duty cycle during each training session. The stimulator surge controls were set for a duty cycle of 10 seconds on and 10 seconds off. The surge "on" when set at 10 seconds is actually 10 seconds at maximal intensity preceded by a 3.3-second ramp from zero to maximum intensity

---

* Cybex, Division of Lumex, Inc, 2100 Smithtown Ave, Ronkonkoma, NY 11779.
† Chattanooga Corp, PO Box 4287, Chattanooga, TN 37405.
RESULTS

The largest net change was found in the Isometric Exercise Group (14.7%); both the Control and Electrical Stimulation Groups only had strength increases of approximately 1 percent (Tab. 1).

Analysis of covariance (with pretest as covariate) results are presented in Table 2. The analysis on the adjusted means indicated a significant difference among the groups. Scheffe’s method of post hoc analysis showed that the increase in strength of the Isometric Exercise Group was significantly greater than either the Control or Electrical Stimulation Group. We found no significant difference between the Electrical Stimulation and Control Groups.

Within three stimulation sessions, all of the subjects in the Electrical Stimulation Group could tolerate a full-scale current reading of 2,500 mA. Three subjects tolerated 2,500 mA in the first stimulation session, one subject tolerated full current in two sessions, and two subjects required three training sessions for full current tolerance.

None of the subjects in either the Isometric Exercise or Electrical Stimulation Group experienced any long-lasting muscle discomfort after the training sessions. Most of the subjects in the Electrical Stimulation Group did, however, report some discomfort during the stimulation sessions. One of the subjects in the Isometric Exercise Group had to be dropped from the experiment because she incurred a knee injury unrelated to the experiment and, thus, could not complete the training sessions.

DISCUSSION

The results of this experiment indicate that three weeks (15 sessions) of HVG stimulation is not an effective method of increasing strength in healthy subjects. This finding agrees with work done on healthy subjects by Massey et al, who also found static exercise superior to nine weeks (27 sessions) of electrical stimulation in increasing strength. Similarly, Currier et al concluded that two weeks (10 sessions) of electrical stimulation combined with static exercise is of no greater benefit than static exercise alone in enhancing strength in healthy subjects.

Other investigators are in disagreement with this study, however, and have found electrical stimulation to be of benefit in increasing strength in healthy subjects over control group subjects. Training protocols in those studies involved electrical stimulation periods of three weeks (15 sessions), four weeks (16–20 sessions), five weeks (10 sessions), and five weeks (25 sessions). Comparisons between studies are impossible, however, because few studies have used the same electrical stimulation characteristics, and no other published studies have used HVG current stimulation.

Both of our experimental groups were subjected to the same total training time of 1,500 seconds (100 seconds a day for 15 days) over the course of the experiment. The significantly greater strength increase shown by the Isometric Exercise Group suggests that the training period was sufficient for strength changes to occur. Currier et al observed a significant increase in strength after only 10 daily sessions of electrical stimulation and isometric exercise (six 6-second contractions). Halbach and Straus found a 22-percent increase in strength after 15 daily sessions (ten 10-second contractions) of electrical stimulation alone. These findings suggest that the HVG stimulator used in our study did not provide an adequate training stimulus even though the contractions elicited were those maximally tolerated by the subjects.
the HVG stimulator provided a rather comfortable muscle contraction because of its short duration, the pulse duration may have been too short to serve as an adequate stimulus for muscle strengthening. Hultman and co-workers found that to produce maximal muscle force, the pulse duration should be between 0.5 and 1 msec. With pulse durations of less than 0.5 msec, the muscle tension produced by a 20-Hz stimulus was markedly decreased. Higher intensities, which may help compensate for the short duration of HVG, would not have been possible in our study because all of the subjects displayed very strong visible contractions and tolerated a full 2,500 mA of current in just a few training sessions.

The increase in strength found in the Isometric Exercise Group may reflect both a learning factor (the subjects trained on the same Cybex II used to measure pretest and posttest torque) and physiologic change in the muscle. The extent of the learning effect (if any) on the overall strength gain, however, is not possible to predict.

According to Kots, the stimulus must be maximal, yet produce minimal pain, if it is to be effective. The stimulator Kots used not only produced a maximal contraction, but it reportedly also had an anesthetic effect. Evidence of an anesthetic effect with the HVG was not apparent in our study because most of the subjects reported discomfort during the stimulation sessions.

Although few researchers have reported significant strength increases after electrical stimulation in healthy subjects, a number of investigators have found electrical stimulation to be of use in rehabilitation programs after surgery or injury. Johnson et al found electrical stimulation to be more effective in severe cases of chondromalacia patellae than in mild cases. They concluded that improvement seemed to be naturally limited and that healthy muscle showed the least improvement in strength. Similarly, untrained individuals gained strength at a greater rate than trained individuals. Even though our subjects were not participants in any organized training sessions outside of the experimental conditions, many of the subjects were occasionally involved in recreational activities. A contributing factor to the lack of significant strength increases may have been a higher level of activity of our subjects in comparison with the activity level of subjects in similar studies.

Because of the variability of electrical stimulation characteristics, subjects, and training protocols, however, comparison of published studies is impossible, and the use of electrical stimulation as an effective means of strengthening healthy muscle remains controversial.

**CONCLUSION**

This study indicated that HVG stimulation was not as effective as isometric exercise in increasing isometric strength in healthy muscle. Further investigation will be required with HVG stimulation on comparable subject samples and also on patients with muscle atrophy to establish it as an efficient modality for muscle strengthening.

**REFERENCES**

1. Babkin D, Timtsenko N (eds): Notes from Dr. Kots' (USSR) lectures and laboratory periods. Present at the Canadian-Soviet Exchange Symposium on Electrostimulation of Skeletal Muscles. Concordia University, Montreal, Quebec, Canada, December 6–15, 1977

**Commentary**

Appreciating the lack of experimental support behind the growing clinical use of high voltage stimulation (HVS), the authors have admirably set out to assess this relatively new treatment modality. Their study, including a control group, has focused on the comparative effectiveness of isometric exercise versus HVS for increasing the quadriceps muscle strength of healthy women. Although similar experimental models have been used to determine strengthening effects produced by electrical stimulation, no previous investigation has used HVS. The present authors have found that a program of HVS did not produce a significant increase in muscle strength, and they have implicated the stimulus characteristics of a specific HVS unit as the basis for this outcome. Although these conclusions may be correct, other aspects of