Original Article

Comparison of electrical stimulation and isometric training on isokinetic strength of knee extensors: A randomized clinical trial

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ABSTRACT

Objective: The purposes of this study were (1) to investigate and (2) to compare effects of isometric exercises and electrical stimulation on isokinetic strength for healthy quadriceps femoris muscle.

Methodology: Twenty healthy volunteers (range, 20-25; mean age, 20.9±1.1 yr) participated in the study. All participants were divided into two groups (Group I and Group II). Each group consisted of 10 subjects. While Group I received electrical stimulation with Russian current, Group II trained with maximal volunteer isometric exercises (10s contraction and 50 s relaxing periods with 10 repetitions) for three days per week for six weeks. Before and after the training program, each subject was evaluated using the following tests; anthropometrical measurements, fixed weight repetition, step-up, decline squat, single leg hop, and isokinetic assessments (peak torque, work per repetition, initial peak torque, fatigue index, total work done, %BW).

Results: After a 6-week training program, significant differences in terms of physical functioning and isokinetic parameters in the two groups were found (p<0.05). Physical functioning and isokinetic strength of quadriceps femoris muscle were seen to be increased in two group after training programs (p<0.05). There were no significant differences between the groups (p>0.05). Quadriceps femoris hypertrophy was only found in electrical stimulation group (p<0.05).

Conclusion: The results obtained from this study show that the two strengthening techniques just used in the study can be used to improve muscle strength, performance and isokinetic parameters in healthy quadriceps femoris muscle (p<0.05). But, there is no superiority on each other. In conclusion, these results indicate that electrical stimulation and maximal volunteer isometric exercises can be used to increase isokinetic strength as an alternative for isokinetic dynamometer in clinical setting.

KEY WORDS: M. Quadriceps Femoris, Electrical Stimulation, Isometrical Exercises, Isokinetic Testing, Strength, Endurance.

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INTRODUCTION

Quadriceps femoris (QF) muscle frequently trained in physical therapy clinics. Muscle strength is a complex phenomenon to characterize because of its wide range of normal variability and the fact that strength is affected by many factors, such as sex, age, test position, and type of contraction. The ability to measure changes in muscle strength.[1] Well con ditioned muscle and muscular balance are needed to attenuate impact loads and provide joint stability.[2] QF muscle strength is important for human body stability, movements and sports activities. Therefore, to protect and improve QF muscle strength is vital.

Following injuries to joints and muscles the injured parts of the body are often immobilized for some time to allow the damaged joints and muscles to heal. While immobilization is usually necessary, it has deleterious consequences on the function of muscles, and recovery is often slow because muscles have deteriorated during the period of immobilization. It is in these cases that electrical stimulation (ES) of muscles during the period of immobilization and afterwards is beneficial and speeds up recovery.[3,4] Electrical stimulation devices have been advertised to increase muscle strength, to decrease body weight and body fat, and to improve muscle firmness and tone in healthy individuals. It produce more muscle contraction than voluntary contraction.[5,6] Isometric exercise is a static form of exercise in which a muscle contracts and produces force without an appreciable change in the length of the muscle and without visible joint motion. Based on the early research it was reported that isometric strength gains of 5% per week occurred when healthy subjects performed a single, near-maximal isometric contraction everyday over a 6-week period.[7]

The purposes of this study were to investigate and to compare the effects of isometric training and electrical stimulation on functional and isokinetic strength of knee extensors in healthy subjects.

METHODOLOGY

Twenty healthy volunteers (mean±SD age 20.9±1.1 yrs) participated in the study. All participants were divided into two groups of 10 subjects. Group I received electrical stimulation of the quadriceps femoris muscle on the dominant side without voluntary effort associated with Russian current (2500Hz). The current was increased to provide tethanical contraction (10 repetitions of 10s contraction with 50s rest periods in between) for three days per week for six weeks. Group II trained with maximal voluntary isometric knee extensions (10 repetitions of 10s with 50 s relaxing periods in between) for three days per week for six weeks. Subjects in both groups trained at 60° knee flexion angle.

Before and after both training programs, each subject was evaluated using the following tests: (1) Anthropometrical tests; quadriceps circumference measurements (5cm and 15cm above the kneecap) were used to assess muscle hypertrophy on dominant side.[8] (2) Fixed weight repetition test (seated with back support with hip and knee at 90º flexion position) was used. The subjects examined with constant 10p weight until fatigue came out and the number of repetitions was recorded.[9] (3) Step up test; subjects were asked to stair up and down 45cm height step on dominant leg. The number of repetitions was recorded.[10] (4) Decline squat test; subjects performed single-leg eccentric squats at decline angles of 25° on a board for decline squat test. All performed the decline squat standing on their dominant leg and flexing their knee, starting from complete extension to maximal flexion. The contralateral leg was kept forward during the downward movement. Subjects came back to starting position by placing the contralateral leg. They were instructed to keep their trunk in an upright position and to avoid lateral weight shift.[11] (5) Single leg hop test; subjects performed a single leg hop for distance with dominant leg. After demonstration, each subject was allowed one trial dominant leg. Beginning with the toes immediately behind the starting line, subjects performed one hop to complete a trial. The hop was measured from the starting line to the end of the toes after completion of a trial. Dominant leg was tested three times with the average distance scored for each subject.[12] (6) Isokinetic tests; isokinetic muscle measurements were performed using the Biodex System dynamometer (Cybex II) with the knee attachment on. Orientation of the dynamometer was kept at 0°, tilt at 0°, and seat orientation at 0°. Before the testing procedure, all the subjects performed conditioning exercises and stretching of the lower extremities to warm up. They then exercised on a bicycle for 10 minutes. They were seated and secured to the apparatus with straps across the chest and thigh. Each time, the attachments of the dynamometer were readjusted accordingly, so that the centre of motion of the lever arm was aligned as accurately as possible with the slightly changing flexion-extension axis of the joint. The resistance pad was placed on the distal tibia.

The range of motion of the knee joint was set at 0–90°. Dominant leg isokinetic (concentric/ concentric) knee flexion and extension studies within the protocol of 60°/s (five repetitions), 180°/s (15 repetitions) were accomplished. Between the two sessions, subjects rested for 20 seconds. Vocal encouragement during the tests was consistent and standardized. Flexion and extension peak torque and work per repetition values, total work done, %BW

Table-I: ES Test Values.

Isokinetic Test Values	Before Training Mean ± SD	After Training Mean ± SD	Wilcoxon Z	P
Peak Torque(Nm)	117.1 ± 50.0	136.8± 44.0	-2.805	0.005
WPR (Nm)	117.5 ± 55.7	141.8 ± 52.1	-2.803	0.005
Initial Pek Torque	43.5 ± 27.4	70.5 ± 28.6	-2.803	0.005
Fatique Index	-37.9 ± 60.5	23.6 ± 8.8	-2.701	0.007
Total Work Done	823.1 ± 441.9	1024.8 ± 484.6	-2.599	0.009
Peak Torque %BW	1299.9 ± 693.6	1668.9 ± 670.3	-2.803	0.005

and fatigue ratios automatically calculated by the device were noted.

All participants gave informed consent and the study was approved by the ethical board committee of Pamukkale University Medical Faculty (Ref no: 06.2; date, 03.06.2009). This study was supported by Pamukkale University Scientific Research Projects Foundation (Grant no: 2009SBE004).

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS version 13.0). Mann–Whitney U Test was used for comparing the groups. Wilcoxon test was used to detect improvements within groups. The $p<0.05$ level was used to denote statistical significance.

RESULTS

After a 6-week training program, significant differences in terms of physical functioning and isokinetic parameters in the two groups were found ($p<0.05$). There were no significant differences between the groups ($p>0.05$). Although quadriceps femoris hypertrophy was only found in electrical stimulation group, ($p<0.05$) this difference was not significant statistically when the groups were compared. On anthropometrical measurements was found hypertrophy on 15cm above the kneecap on electrical stimulation ($p<0.05$), fixed weight repetition significantly increased ($p<0.05$), step up test significantly increased ($p<0.05$), decline squat ($p<0.05$), single leg hop ($p<0.05$) significantly increased on both groups. On isokinetic tests peak torque ($p<0.05$), work per repetitions ($p<0.05$), total work done ($p<0.05$), %BW ($p<0.05$) and fatigue index ($p<0.05$) were increased on both groups. In other saying, physical functioning and isokinetic strength of quadriceps femoris muscle were seen to be increased in two group after training programs ($p<0.05$) (Table I and II).

DISCUSSION

There is general agreement in the literature that isometric strength training and electrical stimulation develops strength and are beneficial for both preventing and treating many types of therapeutic injuries. However there are few studies which investigated effects of electrical stimulation and maximal voluntary isometric contraction (MVIC) on isokinetic strength on literature.[13] Most studies indicate that ES

Table--II: MVIC Test Values.

Isokinetic Test Values	Before Training Mean ± SD	After Training Mran± SD	Wilcoxon Z	P
Peak Torque(Nm)	142.8 ± 51.9	157.5± 52.5	-2.805	0.005
WPR (Nm)	135.7 ± 46.6	162.0 ± 56.5	-2.705	0.007
Initial Pek Torque	47.4 ± 31.8	81.8 ± 36.97	-2.701	0.007
Fatique Index	-86.6 ± 179.5	22.0 ± 52.0	-2.091	0.037
Total Work Done	857.9 ± 416.3	1269.8± 520.1	-2.803	0.005
Peak Torque %BW	1314.8 ± 495.8	1898.6 ± 505.7	-2.803	0.005

is more effective in preventing muscle atrophy when compared to no exercise, isometric exercise of the quadriceps muscle group, isometric co-contractions of both hamstrings and quadriceps groups and combined isometric exercise.[14] Examination of the literature reveals certain common characteristics among studies of electrical stimulation for augmentation of muscular strength. On the other hand many investigators have used electrical stimulation to produce tetanic muscular contractions.[15]

According to Delitto, patients in an electrical stimulation regimen can achieve higher individual thigh musculature strength gains than patients in a voluntary exercise regimen when simultaneous contraction of thigh muscles is prescribed during an early phase of postoperative rehabilitation.[16] Mohr et al investigated comparison of isometric exercise and high volt galvanic stimulation on quadriceps femoris muscle strength. The Isometric Exercise Group was found to have an increase in strength significantly greater 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.[17] Ogino et al designed study for MRI quantification of muscle activity after volitional exercise and neuromuscular electrical stimulation. They found volitional muscle contractions were several times stronger than those induced by neuro muscular electrical stimulation (NMES) in this study and their findings support the idea that MRI can provide a noninvasive way to quantitative and localize volitional and electrically stimulated muscle activation.[18] Baskan investigated effects of MVIC at different knee angels (15º, 60º) on healthy QF muscle. After six week training periods strength and endurance improved statistically significant on QF muscle on both groups. But 60º knee angles are more effective than 15º.[19]

In our study after ES and MVIC training improved the muscle strength and performance ($p<0,05$) but there were no differences between the groups ($p>0,05$). Perez et al investigated the effects of electrical stimulation (ES) on oxygen uptake (VO_2) kinetics and delta efficiency (DE) during gradual exercise. The hypothesis was that ES would attenuate the VO_2-workload relation and improve DE. After the study they explained ES could be used as a supplementary tool to improve two of the main determinants of endurance capacity, namely VO_2 kinetics and work efficiency.[20] Some authors proposed to determine skeletal muscle structure and function in response to electrical stimulation in moderately impaired COPD patients. NMES may promote a modest degree of type II muscle fibre hypertrophy in COPD patients with well-preserved functional status. These micro-structural changes, however, were not translated into increased volitional strength in this sub-population.[21] We found that after the strength training program fatigue values decreased on both groups ($p<0,05$). Hypertrophy appeared on ES group ($p<0,05$) but there was no differences on MVIC group ($p>0,05$). The results obtained from this study show that the two strengthening techniques used in the study can be used to improve muscle strength, performance and isokinetic parameters in healthy quadriceps femoris muscle ($p<0.05$). However, there is no superiority on each other. These results indicate that electrical stimulation and maximal volunteer isometric exercises can be used to increase isokinetic strength.

Currier et al investigated effects of electrical stimulation and isometrical exercises on healthy subjects for quadriceps femoris muscle. Five weeks later they found isokinetic strength improvement at all groups but there were no differences between the training groups.[15] Another study investigated electrical stimulation's effectiveness even in improving quadriceps strength in healthy subjects and compared interferential and low-frequency current in terms of the effects on quadriceps strength and perceived discomfort. Group A received electrical stimulation with bipolar interferential current while group B received electrical stimulation with low-frequency current. Group C served as the control group. Statistically significant increase in isokinetic strength was observed after training in two groups. Increase in strength did not differ between the stimulation groups. No significant change in strength occurred in group C.[22] We also found that ES and MVIC improved the QF muscle performance and strength ($p<0,05$) but the differences between the two groups were not significant ($p>0.05$). Isokinetic parameters significantly increased on both groups ($p<0.05$). Moreover, QF hypertrophy associated with increased formation with isokinetic strength and endurance ($p<0.05$). The results obtained from this study indicate that electrical stimulation and maximal voluntary isometric exercises can be used to improve the functional outcomes assessed by performance tests and dynamic isokinetic strength in healthy subjects. These results indicate that electrical stimulation and maximal volunteer isometric exercises can be used to increase isokinetic strength as an alternative for isokinetic dynamometer in clinical setting.

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Authors' Contributions:

EB completed the study design, manuscript writing, and statistical analysis.
UC did study management, editing of the manuscript, review and final approval of manuscript.
HHY did data collection and analysis of the data.

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