Effect of Neuromuscular Electrical Stimulation Integrated with Closed Kinetic Chain Exercises on Strength of Quadriceps Muscle

Bansal S[1], Zutshi K[2], Munjal J[3]

[1]Assistant professor, Physiotherapy Department, School of Medicine & Allied Sciences, Galgotias University, [2]Assossiate Professor, F/o AHS , Jamia Hamdard University, [3]Physiotherapist, Hindurao Hospital

Abstract

Background & Objective: Electrical stimulation has been well studied in strengthening of weak muscles. Incorporating high-intensity NMES into rehabilitation program for muscle strengthening is an effective option available for restoring quadriceps strength. The clinical use of CKC has significantly increased during the past two decades as these exercises concentrates on a co-contraction of the quadriceps, hamstrings, hip flexors, soleus, and gastrocnemius muscles and are labeled as being "sport specific movements. Literature available till date has been largely inconsistent whether combining NMES with either of strength training will produce better results. Therefore, in present study we propose to integrate NMES and CKC exercises protocols in improving strength of Quadriceps Femoris.

Method: Thirty Healthy subjects were recruited, group A(n=10) combination technique, group B(n=10) NMES, group C(n=10), CKC group: were given training for 3 days/ week for 4 weeks.

Result and Conclusion: maximum improvement resulted in Group C, followed by Group A and minimum improvement in Group B.

Key words: *Neuromuscular electrical stimulation, Closed kinetic exercise, Maximum isometric voluntary contraction, Quadriceps*

Introduction

The quadriceps is the main muscle group that control knee movement and stability. Training the quadriceps muscle is an integral part of most sports strength programs. It is important to keep the quadriceps strong to allow for highest level of flexibility, as well as to prevent injury.[1]

The key to protect the knee from pain or injury is the effective strengthening of quadriceps.[6] Several rationales for CKC exercises have been presented. CKC exercises are more "functional" as it stimulates the role of lower limb muscles in daily activities, differs in proprioceptive feedback, produce less shear force between the Tibiofemoral joint.[2,9] Thus, biomechanically CKC exercise places less strain on Patellofemoral joint.[8]

NMES has a potential to override muscle activation deficits resulting from impairment in central nervous system processing. In addition, NMES activates a greater proportion of type II (fast twitch) muscle fibers when compared to volitional training exercise at a comparable intensity. Type II Fibers are essential for higher levels of force production and their activation may translate to improved functional performance.[7] In present study we propose to integrate NMES with closed kinetic chain exercises in improving strength of Quadriceps Femoris.

Corresponding Author :
Dr. Sakshi Bansal
Assistant Professor, Galgotias University,
Greater Noida,
email id- Sakshi.bansal@galgotiasuniversity.edu.in

Clinically, this study will help in successful integration of NMES as an adjunct with the sports specific activities to improve the complex dynamic movements and thus improve functional abilities of athletes.

Method

Subjects

In group A 5 physically active male & 5 female subjects (age = 23.7±1.1; height = 5.26 ± 0.24) In group B 5 physically active male & 5 female subjects (age = 23.8±1.2; height =5.55±0.33) In group C 4 physically active male & 6 female subjects (age = 22.8 ± 1.1; height =5.33±0.24) were recruited according to following inclusion & exclusion criteria. Inclusion criteria, Healthy young men and women, of 20-30 yrs of age ,who had not participated in any other form of systematic physical training for at least 4 weeks prior to the beginning of the study. Subjects were excluded if they had Significant knee injury, Participated in any other form of systematic physical training for at least 4 weeks of starting of the study. Contraindication to use of NMES, Any neurological symptoms and Hypersensitive skin. Subjects were selected randomly and divided in to 3 groups, Group A, Group B and Group C using lottery allocation system. Subjects were stratified by sex and randomly assigned to either a group A, group B, or group C. All subjects were assigned a number. The numbers were written on a small piece of paper and then placed into 2 separate boxes. The boxes contained the numbers representing female and male subjects, respectively. Numbers were drawn and returned to the boxes until all subjects were assigned to a group. All the males (n =14) were randomly assigned to the groups first, and then the females (n = 16) were assigned to the groups. This method assured a random drawing and that the number of male subjects in each group was approximately equal. Group A individuals were given NMES and CKC exercise, Individuals in Group B were given NMES and Group C individuals were given CKC exercises only.

MVIC measurements

A strain gauge (gold tech) was used with quadriceps table. The subject was positioned on quadriceps table with knee flexion of 60 degrees. The trunk was in upright position and the subject was asked to hold the arms across the chest to prevent unwanted movements. The strain gage was connected to the distal part of test leg by a non stretchable strap. The subject was asked to push the knee strap by knee extension till 60°. The subject was asked to produce maximal isometric voluntary contraction force (MVICF). Verbal cues like “more” and “more” was told so that subject applies maximal contraction. The measurements were repeated 3 times with a 1 minute rest and the maximum value was recorded as the MVICF. Then the mean of the 3 values of MVIC was taken as the MVICF value.

Electrical stimulation training protocol

The subjects in group 1 &2 received 3 electrical stimulation sessions per week. The purpose made electrical stimulator was used to deliver 10 trains of electrical stimulation over a period of 10 minutes to each subject. The electrical stimulation was on 10 seconds and off 50 seconds of each minute and had a frequency of 50 bursts per second with a carrier frequency of 5000 Hz. The electrical stimulation consisted of a sinusoidal waveform that was interrupted every 10 milliseconds. Each sine wave in the train had a cycle duration of 200 microseconds. Two surface electrodes were positioned on the anterior surface of the right thigh. The proximal electrode was positioned transversely 15 cm distal to the right anterior superior iliac spine and over a point where the rectus femoris and vastus lateralis come together. The distal electrode was placed longitudinally on the muscle belly of the vastus medialis with the distal end 4 cm proximal to the superior pole of the patella.[15] Following an initial session to familiarize subjects with NMES, each subject completed 10 isometric quadriceps contractions produced by electrical stimulation in an attempt to produce an isometric force at or above 60% of the MVIC.

Result

The Mean & SD characteristics of subjects in all 3 groups were calculated for age, height, and weight using ANOVA.(Table 1)

Between groups data analysis

The between group comparison showed that there is significant improvement between groups after 4 weeks of training. (F= 4.844, p- value= 0.016)

Table 1. Comparison of demographic data of all

3 groups

Variables	Group 1 Mean ± SD	Group 2 Mean ± SD	Group 3 Mean ± SD	ANOVA	
Age	23.7±1.1	23.8±1.2	22.8±1.1	F= 2.2	p= 0.13
Height	5.26±0.24	5.55±0.33	5.33±0.24	F=2.93	p=0.07
Weight	58.3±7.24	58.6±8.0	51±6.87	F= 3.39	p=0.04

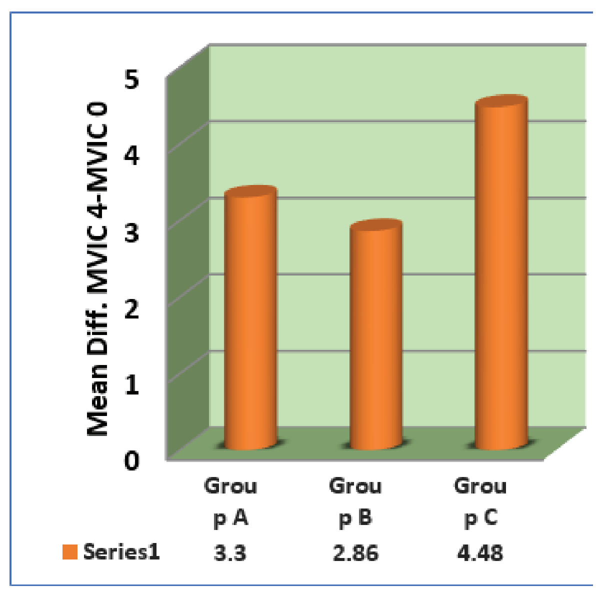
The analysis revealed that both types of training i.e. NMES and CKC, influenced isometric strength of quadriceps during study period. One – way ANOVA followed by Bonferroni's correction for multiple comparisons was applied to data collected. There was significant effect when compared between the group 2 and group 3. Post hoc analysis showed that groups improved with training i.e. from pre to post1 to post2 to post3 and to post4. Result demonstrated that maximum improvement resulted in Group C after 4 weeks of training i.e only Closed Kinetic exercises, followed by Group A i.e. combined effect and minimum improvement in Group B i.e only NMES.

Within group analysis

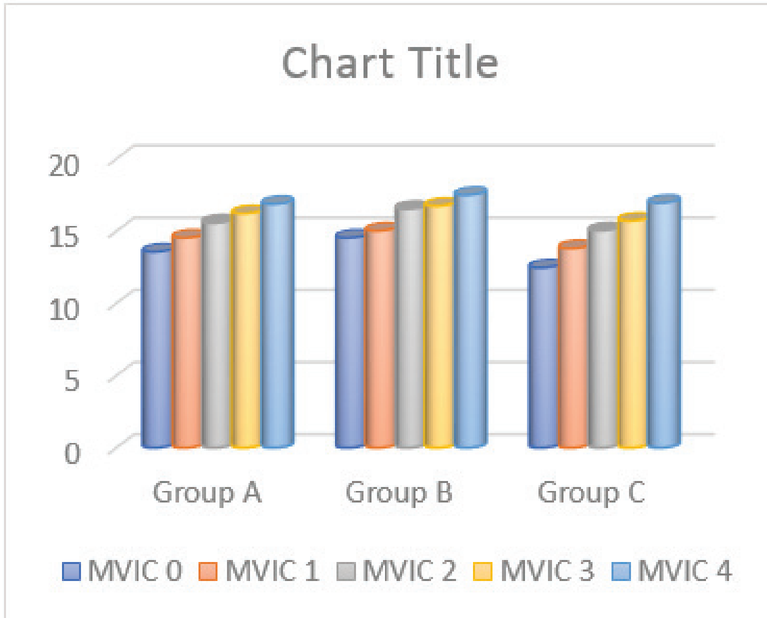
In within group analysis repeated measures ANOVA followed by Bonferroni's correction for multiple comparison was used. ANOVA shows that there was statistically significant improvement within all the 3 groups.

Discussion

The results of studies using NMES have been reported widely in the scientific literature. NMES has been shown to increase strength in healthy subjects .[3,4,11.12,14,18]. NMES in combination with voluntary exercise has also been shown significantly effective in increasing strength in healthy subjects.[13] and in those recovering from reconstructive surgery.[16,19,20] There are many possible reasons why there were less strength gains with NMES when compared with exercises alone. First explanation is that the results of previous studies mentioned could not be applied to healthy subjects as they were conducted on patients or impaired muscles. Another potential explanation for the lack of strength gains with NMES is the difference in skeletal muscle activation when achieved voluntarily versus involuntarily.



Graph 1 : Between groups comparisons of change in isometric strength of Quadriceps after training



Graph 2: Comparison of mean values for MVIC0, MVIC1, MVIC2, MVIC3, MVIC4 in all 3 Groups

Table 2 : Between groups comparisons of change in isometric strength of Quadriceps after training.

% change (MVIC4-MVIC0)	Group 1 Mean ± SD	Group 2 Mean ± SD	Group 3 Mean ± SD	ANOVA	
				F value	p- value
	3.30±1.20	2.86±1.16	4.48±1.23	4.84	0.016

With voluntary exercise muscles are recruited in an asynchronous fashion thus a greater number of fibers are involved in the training and fatigue is reduced. Whereas when training with NMES the same lower threshold fibers are recruited again and again so that fewer fibers are trained and fatigue is increased. [17] The fatigue then results in less force later in the set thus a lower training stimulus, which was the case in the present study.[10] Another reason if the intensity of electrical stimulation is not sufficiently high, then the CKC ex training is more efficient than Combined Technique to restore muscle strength.[5]

There is a consensus that the force increases induced by NMES are similar to, but not greater than, those induced by voluntary training. The rationale for the complementarity between NMES and voluntary exercise is that in voluntary contractions motor units are recruited in order, from smaller fatigue resistant (type I) units to larger quickly fatiguable (type II) units, whereas in NMES the sequence appears to be reversed. As a training modality NMES is, in nonextreme situations such as muscle denervation, not a substitute for, but a complement of, voluntary exercise of disused and healthy muscles.85 While associating NMES and exercise it therefore seems theoretically possible to completely or partially cumulate the physiological adaptations induced by each mode of muscle action performed separately.[21] This reason may explain the results of our study that superimposition of two types of contraction induced greater neuromuscular adaptations than NMES practiced alone.

Maximum strength gains were seen in only exercise group i.e CKC exercise which was carried out using the DAPRE protocol. However, the muscular strength produced by CKC is superior to that produced by NMES. Two reasons can explain this phenomenon. First, with NMES, the maximum tolerated intensity supported by subjects is generally lower than that induced by a voluntary contraction because the electrical current unrelentingly generates noxious effects that limit the optimal spatial recruitment of the MUs. Secondly, NMES only stimulates the muscle on which the electrodes are placed. CKC movement implies activation from several synergic and stabilizer muscles, which are not stimulated by NMES. Hence, NMES does not facilitate intermuscular coordination and thus it does not induce great muscle strength in a mono- or poly- articular movement. With CKC, the strength gains are specific to the muscle action (e.g. isometric vs dynamic), velocity, joint position and movement patterns used in training. The strength gains induced by Combined Technique are thought to be less specific than those induced by CKC.[21]

Result for strength gains within group subjects demonstrated a significant improvement. Strength gains achieved during the 4 weeks probably represented an increase in neural adaptation. Moritani and DeVries reported that neural factors (increased motor unit recruitment) were responsible for initial strength gains and that muscle hypertrophy became more dominant after the first 3-5 weeks of training. Direct comparison of this study with others is not possible because of the paucity of CKC training studies.[22] But in group B i.e. only NMES group there is reduction in strength gain results after 2nd week. This result may indicate short term effects of NMES on strength gains in healthy muscles. There is lack of evidences which proves minimum time duration for maintenance of strengthening effects of NMES on healthy muscles.

Limitation of the study were:

- As only healthy young adults were taken, generalization of our results on subjects of knee pathology are not possible
- Study was conducted only on dominant extremity.
- Study was conducted on sedentary subjects.
- Only isometric strength was measured.

Scope & suggestions for further research

- In future similar work can be done by taking more number of male subjects to compare the effects in male and female subjects.
- Strength training for other muscles of body can be done.
- Non dominant leg can be used or both legs strength training can be done.
- Since the study was done on a limited age group 20-30 yrs, it is advisable that similar work can be done including older or younger to included age group to allow for better generalization of the results.

Future Research

Since the present work examined the effects of 4 weeks of stimulation, it can be said that effects were mainly due to neuromuscular adaptations, In future researchers can undertake a study to examine the effects of a longer (> 4 wks) NMES program; to check for any hypertrophy caused by currents and for how long these effects are sustained i.e. the effects of detraining after cessation of current therapy.

Clinical Relevance

Clearly based on current evidence, it can be concluded that for healthy subjects and post – immobilization patients, NMES is likely to be more appropriate as an adjunct to rather than a replacement of volitional (quadriceps) strength training. For patients wearing casts, applying NMES via holes in the cast may be valuable to decrease the loss of strength.

Conclusion

The results of present study show that there is a significant improvement in strength gain by quadriceps muscles after 4 weeks training program of NMES using 5 KHz carrier frequency. But it is also seen that combining NMES with CKC ex’s is much more beneficial to improve strength rather than giving NMES alone.

So, it may be concluded from present study that NMES may act as an adjunct therapy and not a replacement therapy for strength training and the better mode for strength training remains CKC exercises or resistance training.

Ethical Clearance- Taken from...consent form's duly filled by volunteer's and by college committee

Source of Funding- Self

Conflict of Interest - NIL

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