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# IMPACT OF NEUROMUSCULAR ELECTRICAL STIMULATION (NMES) COMBINED WITH THERAPEUTIC EXERCISE ON POSTOPERATIVE ACL REHABILITATION

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## Abstract

**Background:** Anterior cruciate ligament ACL injuries among athletes and other physically active people usually develop into surgeries, which are followed by intensive post-operative rehabilitation. This is aimed at successful recovery of muscular strength and functional stability. NMES has appeared to be a promising adjuvant modality that might enhance neuromuscular activation and accelerate the recovery process. The main objective of the study is to assess the impact of NMES coupled with a structured therapeutic exercise program on muscle strength, functional outcomes, and overall recovery in patients undergoing postoperative ACL rehabilitation.

**Methods:** This randomized controlled trial (RCT) involved 16 patients who had undergone ACL reconstruction surgery. Participants were randomly assigned to either the intervention group, receiving NMES combined with therapeutic exercises, or the control group, receiving therapeutic exercises alone. The intervention lasted 10 weeks, with assessments conducted at baseline and at 10 week. Primary outcomes included quadriceps muscle strength, measured using an isokinetic dynamometer, and knee function, evaluated through Lysholm Knee Scoring Scale.

**Results:** the results showed significant improvement in strength of quadriceps and knee function in group receiving NMES and therapeutic exercises as compared to therapeutic alone group with a mean difference of a mean difference of 8.75 (p=0.04) and 5.50 (p=0.047) for quadriceps strength and knee function respectively.

**Conclusion:** NMES is considered to substantially enhance the recovery of muscle strength and function during post-ACL reconstruction rehabilitation programs compared to therapeutic exercises alone. Such results suggest that NMES could be a valuable addition to traditional rehabilitation

protocols, possibly even further improving the treatment outcomes for patients undergoing ACL reconstruction surgery.

**Keywords:** Anterior cruciate ligament repair, Neuromuscular Electrical Stimulation, therapeutic exercises, Quadriceps

## Introduction

Anterior cruciate ligament injuries are among the commonest and most debilitating musculoskeletal injuries, especially among athletes and physically active individuals. Most high-impact activities that involve landings promoting sudden stops, pivoting, or abrupt changes of direction lead to oversights or tearing of the ligament. The ACL is highly important for knee joint stability, and its injury often leads to severe functional deficits in the form of instability, reduction of movement, and diminished muscle strength. These are further pronounced in the muscles of the quadriceps, which during this period of recuperation are frequently subjected to atrophy due to disuse 2-3. One population-based survey from Canada, within a period of 17 years in total, reported 28,401 primary ACLR and 2085 ACLR revision ACLR from 2002-2018 4. As the surgical reconstruction of the ACL is usually inevitable to re-establish the stability and function of the knee, an important role of postoperative rehabilitation becomes decisive for ensuring optimum recovery 5. Conventional rehabilitation protocols combine various therapeutic exercises to achieve strength, range of motion, and proprioception 6-7. Only recently, though, have there been reports on the inclusion of neuromuscular electrical stimulation in rehabilitation schemes as an adjunct to standard therapeutic exercises 8-9.

Neuromuscular electrical stimulation is a technique of applying electrical impulses to muscles, thus inducing contractions that are accepted as somewhat comparable to voluntary muscle contractions. This modality has been catching interest in rehabilitation medicine for its promise in enhancing muscular strength, preventing atrophy, and improving neuromuscular function, especially during the early phase of recovery when a minimal voluntary muscle contraction can be elicited. NMES may provide a synergistic effect when used in combination with therapeutic exercise, thereby improving the rehabilitation process and outcomes in patients with ACL reconstruction. 10-11.

Despite promising results, NMES has not yet gained wide acceptance in clinical use, and some debate still exists about how best to apply this modality. A number of factors, such as patient compliance, cost of NMES devices, and specialized training for clinicians are relevant factors to consider in the application of NMES in routine postoperative care. Further studies are necessary to determine the ideal guidelines on the use of NMES in ACL rehabilitation, including the stimulation parameters and exercise modalities. In light of the complexity surrounding the restoration of quadriceps strength post-ACL surgery, NMES is a highly promising solution. NMES can elicit contractions in muscles by the direct application of electrical impulses and hence helps in maintaining the mass and strength of the muscle when active movement is not possible. In this regard, this is particularly essential at the initial stages of the rehabilitation process, inasmuch as patients during this stage may not be able to engage in high-intensity exercise due to postoperative pain or swelling. Hence, the study is aim to assess the impact of NMES coupled with a structured therapeutic exercise program on muscle strength, functional outcomes, and overall recovery in patients undergoing postoperative ACL rehabilitation.

## Methodology

### Target Population

The study targeted the population of patients who had undergone anterior cruciate ligament reconstruction surgery. All the patients were invited prior to the surgery. Postoperative patients who were considered in the early to mid-rehabilitation phase had been the focus of attention.

### Sampling Technique

Purposive sampling technique was used to select participants who meet the specific criteria for the study. This technique ensures that participants have undergone ACL reconstruction and are at a

similar stage of postoperative recovery, which is critical for consistent and valid results. Then randomization was performed using computer generated method of simple random sampling technique and participants were allocated into two of the treatment groups. The participants were blinded to the intervention group.

**Study Setting**

The study was conducted at [hospital name], where ACL reconstruction surgeries and postoperative rehabilitation are regularly performed. The setting was equipped with the necessary facilities for both NMES and therapeutic exercise interventions.

**Selection Criteria**

The inclusion criteria encompasses the patients age between 18-40 years who had unilateral ACL reconstruction surgery using ipsilateral autologous bone-patellar tendon-bone graft performed by the same surgeon. The knee range of motion in flexion to be 90 degree within 2 weeks post-surgery. Patients who were diagnosed with hypertension, or history of knee surgery/ injury, suffering with neurological disorders, pregnant or lactating women were exclude from the study.

**Study Protocol**

Sixteen patients were invited before the scheduled surgery to participate in the rehabilitation program. The patients wore post-operative immobilizer to stabilize the knee joint immediately after knee surgery and weight bearing on 2$^{nd}$ post-operative day. An informed consent with details of the rehab protocol along with risks and benefits was provided to the participants. Once the signed document was received, the intervention protocol was initiated. During the first 2 weeks, the rehabilitation programme consisted of continuous passive mobilizations combined with low frequency and high volume neuromuscular electrical stimulations of the quadriceps muscles to counteract activation failure 12.

Patients were randomly divided into group A which received NMES plus therapeutic exercises and Group B which received therapeutic exercises only. The details of each protocol is given below. The treatment lasted for 10 weeks with 5 sessions/ week under the supervision of three trained physical therapist.

**Intervention**

**Group A: NMES Combined with Therapeutic Exercise**

The training ran from the third week to the tenth week, five sessions a week. NMES was administered through a wireless, portable, battery-operated stimulator (Chattanooga cordless Professional) producing a rectangular, symmetrical mono-phasic pulse following a voluntary contraction of the muscle. Electrodes Self-adhesive, Compex Dura-Stick plus, were inserted on the operated limb above the motor sites of the vastus lateralis and vastus medialis muscles, which are the two most affected from the postoperative muscle atrophy. Two NMES frequencies, 35 Hz and 50 Hz, were alternately applied during each session. These frequencies were selected to target both slow and fast-twitch muscle fibers while ensuring maximal comfort for the patient 13. The stimulation intensity was gradually increased by the trainer with each repetition and across all sessions, based on the patient's tolerance, to optimize motor unit recruitment (14).Therapeutic Exercise Protocol: In addition to NMES, patients participated in a structured therapeutic exercise program that includes range-of-motion exercises, strengthening exercises for the quadriceps and hamstrings, and functional training exercises.

**Group B: Therapeutic Exercise Only**

Therapeutic Exercise Protocol: Patients in Group B followed the same therapeutic exercise program as Group A, consisting of range-of-motion exercises, strengthening exercises, and functional training. The program was tailored to each patient's needs and monitored for adherence and progress. Isometric

straight leg lifts were carried out till the end of first month. Squats and water activities, including cycling, walking, and stepping, were carried out with the first 3-4 weeks. Strengthening activities were initiated during the second month of therapy. The muscle building, power training, and relearning specific sport skills were rehabilitated during 4-10 weeks 11.

**Assessment**

***Lysholm Knee Scoring Scale***

The Lysholm Knee Scoring Scale is used clinically in the assessment of knee function and symptoms, particularly after knee injuries or surgery. It is an 8-item tool assessing limp, support, locking, instability, pain, swelling, stair climbing, and squatting, with scores ranging from 0 to 100; the higher the score, the better the knee function 15.

***Isokinetic dynamometer***

The strength of quadriceps was asses using The Commander™ Muscle Tester dynamometer in a seated position. It permits assessment of muscle strength through a given range of motion at uniform speed and provides precise data regarding peak torque, muscle power, and endurance. This piece of equipment is used extensively in rehabilitation and sports medicine for the analysis of muscle performance and in the monitoring of muscle recovery 16.

**Ethical Considerations**

All the participants were fully informed about the purpose of the study and then gave their written consent accordingly. The research was performed by following standards that could be considered in keeping with the principles described in the Belmont Report as those related to research with human subjects. All participants in this study received a statement of confidentiality related to privacy and personal safety. Any participant had the right to withdraw from this research at any time.

**Results**

A total of sixteen post-operative patients with ACL reconstruction were included in the study which were allocated into group A and B receiving NMES combined with therapeutic exercise and therapeutic exercises only. The mean age of participants was 25.5±7.19 in group A and 23.62±5.47 in group B. out of 16 participants 5 were females and 11 were males. The most affected knee was reported to be right knee with 10 participants. The baseline value for quadriceps strength in group A and B was 92.87±5.56 and 91.50±6.94 respectively. The details are provided in table 1.

**Table 1 showing demographic characteristics of participants at baseline**

| **Variable** | | **Group A (n=8)** | **Group B (n=8)** |
|---|---|---|---|
| **Age in years** | | 25.5±7.19 | 23.62±5.47 |
| **Gender** | **Male** | 6 (75%) | 5 (62.5%) |
| | **Female** | 2 (25%) | 3 (37.5%) |
| **Affected side** | **Right** | 6 (75% | 4 (50%) |
| | **Left** | 2 (25%) | 4 (50%) |
| **Quadriceps strength** | | 92.87±5.56 | 91.50±6.94 |
| **Knee score** | | 59.37±3.88 | 59.50±6.05 |

Skewness and kurtosis test was applied to check the normality of data. The findings were within the normal distribution hence independent sample t test was applied for between group analyses. The findings showed significant improvement for quadriceps muscle strength and knee score in group A vs. group B with a mean difference of 8.75 (p=0.04) and 5.50 (p=0.047) respectively. The details are mentioned in table 2

| Table 2 depicting Group comparison of quadriceps strength and knee score | | | | | |
|---|---|---|---|---|---|
| **Variable** | **Post mean ±SD (Group A)** | **Post mean ±SD (Group B)** | **Mean difference** | **df** | **P value<0.05)** |
| **Quadriceps strength** | 108.37±6.92 | 99.62±8.72 | 8.75 | 14 | 0.04 |
| **Knee score** | 76.0±4.40 | 70.50±5.63 | 5.50 | 14 | 0.047 |

## Discussion

This study aimed to evaluate the impact of Neuromuscular Electrical Stimulation (NMES) combined with therapeutic exercise on postoperative ACL rehabilitation, compared to therapeutic exercise alone. Our results revealed that while NMES combined with therapeutic exercise led to a significant improvement in knee score with a mean difference of 5.50 (p=0.047), quadriceps strength showed no significant difference between the two groups, with a mean difference of 1.87 (p=0.679). The significant improvement in knee score in Group A suggests that NMES combined with therapeutic exercise may enhance functional outcomes and subjective measures of knee health more effectively than therapeutic exercise alone. The findings of our study are consistent with the findings of the other study like reported in a study by Labanca et al that NMES along with functional exercises is more affected in improving flexors and extensor muscle strength, higher loading symmetry during stance to sit[11]. Furthermore, NMES has also proven to be effective in the restoration of fiber size and muscle contractility followed ACLR when provided in early phase of rehabilitation 17-18. In a systematic review on assessing the role of NMES in improving quadriceps strength, a total of 20 studies were included. Of the 20 articles used, 16 said NMES was effective in the regaining of quadriceps strength after ACLR, while the remaining four stated that NMES, although it would not hurt a patient, wasn't necessary for the strengthening after ACLR 19. Similar results were reported in the study by ___ in which forty patients with ACLR were provided with NMES + conventional exercises and conventional exercises only. After 12 weeks of intervention, the NMES group showed the Lysholm score of $93.18 \pm 3.67$ points ($p<0.05$) as compared to control group 20. While the benefits of NMES are clear, its implementation in clinical practice requires careful consideration. Factors such as the timing of NMES application, the appropriate intensity and duration of stimulation, and patient compliance are all critical to achieving optimal outcomes. Additionally, clinicians must be trained in the proper use of NMES devices and protocols to ensure that they are used effectively and safely. The study has some limitations: the relatively small sample size (16 participants) may limit the generalizability of the findings, variations in NMES protocols (e.g., intensity, frequency) between studies may affect comparability. Future studies should involve larger sample sizes to improve the statistical power and generalizability of the findings. Extended follow-up periods could provide insights into the long-term effects of NMES combined with therapeutic exercise on both functional outcomes and muscle strength.

## Conclusion

NMES combined with therapeutic exercise showed significant improvement in knee function and quadriceps strength. These findings contribute to the ongoing debate regarding the efficacy of NMES in postoperative ACL rehabilitation and underscore the need for further research to optimize rehabilitation strategies and protocols.

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