15 (3) (2026) 1498-1505

Journal of Physical Education, Sport, Health and Recreations

http://journal.unnes.ac.id/journals/peshr

Physiotherapy Management in Post ACLR Phase III with a Combination of NMEs and Exercise Therapy

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Keywords

Anterior Cruciate Ligament Reconstruction; Electrical Stimulation; Exercise therapy

History Dates

Received: *August 4, 2026*
Revised: *August 9, 2026*
Accepted: *September 1, 2026*
Published: *November 6, 2026*

DOI

https://doi.org/10.15294/active.v15i3.62138

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Abstract

Anterior Cruciate Ligament Reconstruction (ACLR) is a surgical procedure aimed at restoring knee joint stability following an Anterior Cruciate Ligament (ACL) injury. Phase III post-ACLR conditions often cause several problems, including decreased muscle strength, limited range of motion, balance disorders, and reduced functional activity. This study aimed to determine the effectiveness of Neuromuscular Electrical Stimulation (NMES) and exercise therapy in phase III post-ACLR patients at ABR Physiotherapy Bojonegoro. The method used was a case study on an 18-year-old male patient, Mr. V, diagnosed with phase III post-ACLR who received physiotherapy intervention for four treatment sessions. Evaluations were conducted using Manual Muscle Testing (MMT), a goniometer, the Lower Extremity Functional Scale (LEFS), and the Y-Balance Test. The results showed improvements in muscle strength, an increase in range of motion from 120° to 135°, as well as improvements in functional activity and dynamic balance. The combination of NMES and exercise therapy proved to have a positive effect in improving knee function in phase III post-ACLR patients. Therefore, physiotherapy interventions using NMES and exercise therapy can be used as an effective rehabilitation method to support recovery in post-ACL reconstruction patients.

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p-ISSN 2460-724X
e-ISSN 2252-6773

INTRODUCTION

Exercise is a physical activity performed regularly to improve health, physical fitness, and athletic performance. Exercise offers numerous benefits for the body, such as improving cardiorespiratory endurance, muscle strength, flexibility, and motor coordination. (Okta Arya Prabowo & Rohman Hakim, 2023). However, despite these benefits, sports activities also carry the risk of injury, especially in high-intensity sports that involve running, jumping, sudden changes of direction, pivoting, and physical contact. One common sports injury to the lower extremities is anterior cruciate ligament injury (Halim Mardianto et al., 2022).

The anterior cruciate ligament (ACL) is one of the main ligaments in the knee joint, located within the knee joint and serves as the primary stabilizer of the knee. The ACL plays a role in preventing anterior translation of the tibia against the femur, controlling knee rotation, and maintaining dynamic stability of the knee joint during functional activities (Shom et al., 2023) . ACL injuries can occur due to contact or non-contact injury mechanisms. Non-contact injury mechanisms are more common, such as pivot movements, sudden changes in direction, incorrect positioning when landing after a jump, or sudden deceleration while running (Made et al., 2023). ACL injuries are often found in athletes in soccer, basketball, futsal, badminton, volleyball, and other sports that involve explosive movements of the lower extremities (Montalvo et al., 2019).

ACL injuries can cause impaired knee joint stability characterized by pain, swelling, decreased range of motion, decreased muscle strength, impaired proprioception, and limitations in functional activities (Santoso et al., 2018). In grade II and grade III ACL injuries, surgery in the form of Anterior Cruciate Ligament Reconstruction (ACLR) is often performed to restore mechanical stability of the knee and help patients return to daily activities and sports activities (Khairunnisa et al., 2024). ACL reconstruction is a surgical procedure using a graft to replace the ruptured ACL ligament (Diermeier et al., 2020).

Although ACL reconstruction surgery aims to improve knee stability, post-operative patients still often experience various functional problems. Some common problems found in post-ACL reconstruction patients include pain, edema, limited range of motion, decreased quadriceps and hamstring muscle strength, muscle atrophy, muscle inhibition, decreased proprioception, impaired balance, and limited functional activities (Santoso et al., 2018). Decreased quadriceps muscle strength is one of the most common problems caused by arthrogenic muscle inhibition, a condition where muscle activation is disrupted due to changes in sensory impulses after injury or surgery to the knee joint (Lepley, 2015) . This condition can cause gait disturbances, decreased knee stability, and increase the risk of re-injury if not properly managed (Van Wyngaarden et al., 2021).

Physiotherapy plays a crucial role in the rehabilitation process for patients following ACL reconstruction. Physiotherapy rehabilitation programs aim to reduce pain and edema, increase joint range of motion, enhance muscle strength, improve proprioception, enhance balance, and restore the patient's functional abilities (Ministry of Health of the Republic of Indonesia, 2015). Post-ACL reconstruction rehabilitation is generally divided into several phases. In phase III, therapy focuses on increasing muscle strength, dynamic knee stability, neuromuscular control, balance, and preparing for a return to functional activities and sports.

One physiotherapy modality that can be used in post-ACL reconstruction rehabilitation is Neuromuscular Electrical Stimulation (NMES). NMES is an electrical stimulation modality used to generate muscle contractions through motor nerve stimulation. NMES works by increasing motor unit recruitment, thereby helping to increase muscle activation, particularly in the quadriceps muscle, which experiences muscle inhibition post-surgery. Furthermore, NMES can also help prevent muscle atrophy, increase muscle strength, and improve neuromuscular control in the knee joint (Moran et al., 2019).

In addition to the use of NMES, exercise therapy is also a key component in the rehabilitation of patients after ACL reconstruction. Exercise therapy, administered in a gradual and controlled manner, can help improve muscle strength, flexibility, joint stability, proprioception, balance, and functional activity. Exercises such as squats, lunges, calf raises, bridges, balance boards, single-leg balances, planks, and gait training are among the exercises frequently used in phase III of ACL reconstruction rehabilitation. Closed kinetic chain exercises

such as squats and lunges are considered safer for ACL grafts because they can improve knee joint stability and reduce shear forces on the tibia (Wilk et al., 2017).

The combination of NMES and exercise therapy is expected to provide more optimal rehabilitation results in patients after phase III ACL reconstruction. Increasing muscle activation through NMES combined with strengthening and proprioceptive exercises can help increase muscle strength, increase joint range of motion, improve dynamic balance, and enhance patient functional activity. Thus, patients are expected to be able to return to daily activities and sports more optimally while minimizing the risk of re-injury. (Karimijashni et al., 2023).

Based on the description, the author is interested in knowing the effect of Neuromuscular Electrical Stimulation (NMES) and exercise therapy on increasing muscle strength, joint range of motion, dynamic balance, and functional activity in patients undergoing post-anterior cruciate ligament reconstruction phase III at ABR Physiotherapy Bojonegoro.

METHODS

This study employed a case study design to evaluate the physiotherapy management and clinical changes following a structured rehabilitation program in a single patient with phase III post-Anterior Cruciate Ligament Reconstruction (ACLR). The study was conducted in January 2026 at ABR Physiotherapy Bojonegoro. The subject was an 18-year-old male patient, identified as Mr. V, who was diagnosed with phase III post-ACLR of the right knee following a futsal-related injury. The patient presented with right lower-extremity weakness, limited knee joint range of motion, impaired single-leg balance, and difficulty performing functional activities such as running, stair climbing, and squatting.

Clinical assessment was performed before and after the physiotherapy intervention. Muscle strength was evaluated using Manual Muscle Testing (MMT), knee joint range of motion was assessed using a goniometer, functional activity was measured using the Lower Extremity Functional Scale (LEFS), and dynamic balance was evaluated using the Y-Balance Test (YBT). These outcome measures were selected to assess changes in muscle strength, joint mobility, functional activity, and dynamic postural control following the intervention.

The physiotherapy program consists of a combination of Neuromuscular Electrical Stimulation (NMES) and exercise therapy delivered over four therapy sessions. Each session included NMES, strengthening exercises, balance training, flexibility and mobility exercises, and gait training. NMES was applied to the quadriceps muscle for approximately 15 minutes, with the intensity adjusted according to the patient's tolerance. The intervention was intended to facilitate quadriceps muscle activation and support improvements in muscle strength following ACL reconstruction. The exercise therapy component consists of strengthening, balance, flexibility and mobility, and gait training. Strengthening exercises included squats, lunges, calf raises, bridges, and single-leg deadlifts. Each strengthening exercise was performed for 3 sets of 10 repetitions, with the exercise intensity adjusted according to the patient's tolerance. The exercises were administered progressively to improve lower-extremity muscle strength and knee joint stability.

Balance training consisted of single-leg balance and balance-board exercises and was performed for approximately 10–15 minutes per therapy session. The balance component was intended to improve proprioception, neuromuscular control, and dynamic balance. Flexibility and mobility training consisted of stationary cycling and stretching, while gait training was provided to improve walking pattern and functional performance. The intervention was progressed according to the patient's tolerance and clinical response. Progression was directed toward improving muscle activation, strength, knee mobility, dynamic balance, and functional performance. Closed kinetic chain strengthening exercises such as squats and lunges were included as part of the rehabilitation program to support knee stability. The intervention was adjusted based on the patient's ability to perform the exercises safely and with appropriate movement control.

Table 1. Rehabilitation program

Week	Intervention	Objective
Week1	NMES, Plank, Squat, Stationary bike, Bridge, gait activities	To improve lower-limb muscle strength, postural control, flexibility and knee mobility, as well as good gait function.
Week2	NMES, Plank, Squat, Single leg balance, Bridge, Calf raise	To improve motor control, stability, balance, knee coordination and functional ability.
Week3	NMES, Plank, Balance board, Lunges, Calf raise, Single leg deadlift	Improves balance, muscle strength, movement control and knee stability.
Week4	NMES, Plank. Balance board, Stationary bike, Calf raise, Single leg deadlift	Optimising muscle strength, balance, stability, knee mobility and the ability to perform functional activities without compensation.

FITT: 3 sets, 15 repetitions each with 1 minute rest between sets.

The intervention was conducted over four therapy sessions. Each session consists of a combination of NMES and exercise therapy, with therapy parameters adjusted based on the patient's tolerance and clinical condition. Available clinical records listed the duration of NMES, the volume of strengthening exercises, and the duration of balance exercises. However, specific rest intervals between sets and measurable exercise intensities, such as percentage of one-repetition maximum (1RM) or rating of perceived exertion (RPE), were not documented in the original case records. Therefore, these parameters were not estimated retrospectively.

Evaluations were conducted before and after the intervention to determine changes in muscle strength, knee joint range of motion, dynamic balance, and functional activity. The final results were then compared with the initial conditions to determine the clinical response to the combination of NMES and exercise therapy. In the original manuscript, an increase in knee flexor and extensor muscle strength was reported from MMT 4 to 5, an increase in knee flexion ROM from 120° to 135° in the results table, an increase in LEFS from 68/80 to 74/80, and an increase in Y-Balance ability from 79.6% to 92.6%.

RESULTS AND DISCUSSION

This study was conducted to determine the effectiveness of Neuromuscular Electrical Stimulation (NMES) and exercise therapy in patients after Phase III Anterior Cruciate Ligament Reconstruction (ACLR). The physiotherapy interventions provided included NMES, strengthening exercises, balance training, and functional activity training during six therapy sessions. To determine the effectiveness of the physiotherapy intervention, the measurement tools used were Manual Muscle Testing (MMT), Range of Motion (ROM), Lower Extremity Functional Scale (LEFS), and Y-Balance Test (YBT).

Patient Characteristics

An 18-year-old male patient, identified as V, was diagnosed with post-phase III anterior cruciate ligament reconstruction (ACLR) of his right knee following a futsal injury. He complained of right leg weakness, limited knee range of motion, impaired balance when standing on one leg, and difficulty performing activities such as running, climbing stairs, and squatting.

Manual Muscle Testing (MMT)

Table 2. Evaluation of Muscle Strength with MMT

Movement	Mark	Mark
Knee Flexor	4	5
Knee Extensor	4	5

Table 2 shows an increase in muscle strength after physiotherapy intervention. At the initial examination, knee flexor and knee extensor muscle strength was still decreasing, with a score of 4. After four sessions of NMES and exercise therapy, muscle strength increased to a score of 5. This improvement indicates that the combination of NMES and exercise therapy is effective in increasing muscle activation and strength in patients undergoing phase III ACL reconstruction.

Joint Range of Motion (ROM)

Table 3. LGS Evaluation with Goniometer

Movement	Mark	Mark
Knee Extension/Flexor	S 0°–0°–120°	S 0°–0°–135°

Table 3 shows an increase in knee joint range of motion after physiotherapy intervention. The initial examination revealed limited knee flexion of 120°, which increased to 135° at the final examination. The increase in ROM indicates improved joint mobility and flexibility of the tissues surrounding the knee.

Lower Extremity Functional Scale

Table 4. Evaluation of Functional Activities with LEFS

Lower Extremity Functional Scale	Mark	Mark
Total value	68/80	74/80

Table 4 shows an improvement in the patient's functional activity after physiotherapy intervention. At the initial examination, the patient still experienced limitations in activities such as walking long distances, climbing stairs, squatting, and running. After four sessions of therapy, the LEFS score increased from 68/80 to 74/80, indicating an improvement in the patient's functional activity ability.

Y-Balance Test

Table 5. Dynamic balance evaluation with Y-Balance Test

Direction of movement	Mark	Mark
Anterior, Postero medial, Postero lateral	79.6%	92.6%

Table 5 shows an improvement in the patient's dynamic balance scores after physiotherapy intervention. At the initial examination, the patient still had poor balance. After four sessions of therapy, the Y-Balance Test score increased from 79.6% to 92.6%, indicating improved dynamic balance.

Neuromuscular Electrical Stimulation (NMES)

Electrical stimulation intervention using Neuromuscular Electrical Stimulation (NMES) is administered to the quadriceps muscle to increase neuromuscular activation, improve muscle strength, and help reduce muscle inhibition after ACL reconstruction surgery. NMES is

administered for approximately 15 minutes with an intensity according to patient tolerance. According to Moran et al. (2019), NMES effectively increases quadriceps muscle activation and helps increase muscle strength in post-ACL reconstruction patients. Bustam (2023) also states that electrical stimulation can help increase motor unit recruitment and accelerate the rehabilitation process of musculoskeletal patients.

Exercise Therapy

Strengthening exercises are given to improve lower leg muscle strength and knee stability. These exercises include squats, lunges, calf raises, bridges, and single-leg deadlifts. Exercises are performed in stages with 3 sets of 10 repetitions, depending on patient tolerance. According to Kisner and Colby (2017), gradual and repeated strengthening exercises can improve muscle strength, joint stability, and functional activity ability in musculoskeletal patients. Furthermore, closed kinetic chain exercises such as squats and lunges are considered safer for ACL grafts because they can improve knee joint stability.



Figure 1. Example of Strengthening exercise

Balance training is given to improve proprioception, neuromuscular control, and dynamic balance. The exercises provided include single-leg balance and balance board exercises. Each therapy session lasts approximately 10–15 minutes. According to Hertel and Corbett (2019), balance training effectively improves proprioception and postural control in patients with knee instability. Karimijashni et al. (2023) also stated that balance training can improve dynamic stability and functional ability in patients after ACL reconstruction.

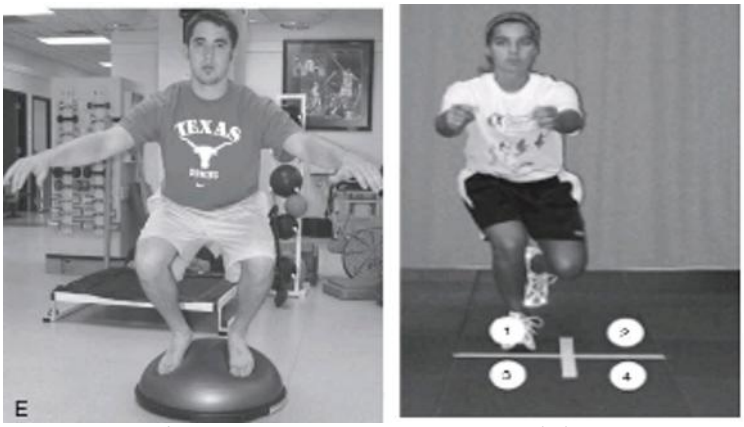


Figure 2. Example of balance training

CONCLUSION

The conclusion obtained after therapy was carried out on a patient named Mr. V aged 18 years with a diagnosis of *Post-op Anterior Cruciate Ligament Reconstruction phase 3* , using a combination intervention of *Neuromuscular Electrical Stimulation* (NMES) and exercise therapy for 4 times of therapy, the following results were obtained: The provision of a combination of *Neuromuscular Electrical Stimulation* (NMES) and exercise therapy with results from T1–T4 was able to increase muscle strength using *Manual Muscle Testing (MMT) measurements.* The provision of a combination of *Neuromuscular Electrical Stimulation* (NMES) and exercise therapy with results from T1–T4 was able to increase the value of functional activity and

dynamic balance using measurements of *the Lower Extremity Functional Scale and Y-Balance Test.* The provision of a combination of *Neuromuscular Electrical Stimulation* (NMES) and exercise therapy with the results from T1–T4 being able to increase the range of joint motion by measuring using a goniometer.

AUTHOR CONTRIBUTION STATEMENT

All authors contributed equally to the conceptualization, methodology, data collection, analysis, and drafting of the manuscript. All authors have read, revised, and approved the final manuscript for publication.

FUNDING STATEMENT

This research received no specific grant or financial support from any funding agency in the public, commercial, or not-for-profit sectors.

AI USAGE STATEMENT

The authors used Grammarly solely for grammar checking and language refinement during the preparation of this manuscript. No generative AI tools were used for data collection, analysis, or content creation. All scientific findings and conclusions were generated and verified entirely by the authors.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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