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A Functional Training with Neurokinetic Control Exercises for ACL Reconstruction in Restoring Movement Efficiency and Injury Prevention: A Single Case Study with 6-Month Follow-up

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Abstract

Anterior Cruciate Ligament (ACL) injuries are common in active individuals and often require surgical reconstruction, followed by structured rehabilitation to restore function and prevent reinjury. This case report presents the rehabilitation journey of a 28-year-old male who sustained an ACL tear in a motorcycle accident and underwent ACL reconstruction using Semitendinosus and Gracilis grafts. Rehabilitation commenced three weeks post-surgery, emphasizing pain management, range of motion (ROM) recovery, and muscle strengthening in the early phases. As the patient progressed, advanced training integrated functional exercises, plyometric drills, differential learning, and visual-motor training to enhance neurokinetic control and movement efficiency. Over six months, the patient demonstrated substantial improvements, including pain reduction (NPRS score from 9 to 1), ROM flexion gain (30° to 130°), quadriceps strength increase (50 Nm to 200 Nm), and hamstring strength recovery (40 Nm to 170 Nm). Gait mechanics also improved, with enhanced step length and cadence. Statistical analysis confirmed a large effect size in pain reduction and ROM gains, highlighting the potential of multimodal rehabilitation for effective recovery. This approach may reduce reinjury risk by enhancing neuromuscular control and movement efficiency. Further research is recommended to explore long-term functional outcomes and the potential role of blood flow restriction training in ACL rehabilitation.

Keywords: ACL Reconstruction, Differential Learning, Functional Training, Neurokinetic Control, Plyometric Training, Rehabilitation.

Introduction

The anterior cruciate ligament (ACL) is a key stabilizing structure of the knee joint, connecting the femur to the tibia and preventing excessive forward movement of the tibia and rotational instability of the knee. The term 'anterior' indicates the front, while 'cruciate' refers to the cross-like arrangement with the posterior cruciate ligament. ACL injuries are among the most common musculoskeletal injuries, particularly in physically active populations, such as athletes involved in cutting, pivoting, and jumping. These injuries can range from partial tears to complete ruptures and are often accompanied by pain, swelling, and joint instability (1). Diagnosis of an ACL tear is often made clinically using special tests. Among these, the Lachman's test is considered the most accurate for detecting acute ACL injuries. In this test, the knee is flexed between 15 to 30 degrees, and the tibia is gently pulled forward while stabilizing the femur. Anterior translation of the tibia with a soft endpoint typically indicates a positive result. Other clinical tests such as the anterior drawer and pivot shift test are also used to confirm diagnosis and assess functional instability (2). Conventional rehabilitation following ACL injury or surgery includes phases of pain reduction, range of motion restoration, muscle strengthening, and neuromuscular training. Despite well-structured rehabilitation programs, many patients experience prolonged deficits in neuromuscular control, proprioception, and coordination. These residual impairments may affect return-to-sport readiness and increase the risk of reinjury. Long-term complications, including joint instability and early osteoarthritis, have also been reported in some patients who resume activity prematurely or follow insufficient rehab protocols (3). Over the past two decades, researchers have explored the

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efficacy of different physiotherapy approaches for ACL rehabilitation. Myer et al. emphasized the role of neuromuscular training in injury prevention among adolescent female athletes, where the incidence is notably higher (4). A study compared traditional physiotherapy protocols with neuromuscular- focused rehabilitation, reporting improved dynamic stability and functional performance in the latter group (5). Such findings have encouraged the integration of balance, proprioceptive, and dynamic movement training into standard ACL rehab programs. However, several limitations persist in the current literature. Many protocols apply generalized proprioceptive and balance training without identifying or addressing the underlying compensatory movement patterns that patients develop post-injury. The persistence of maladaptive motor behaviour suggests a central neurological component that is often overlooked. Furthermore, few studies incorporate tools such as motion analysis systems, force platforms, or electromyography to quantify movement impairments or detect subtle deficits in joint control (6).

Another limitation is the lack of standardization in outcome measures and failure to stratify data according to population subgroups such as elite athletes, recreational individuals, adolescents, and sedentary patients. Studies also vary widely in their rehabilitation timelines, making it difficult to compare findings or develop uniform guidelines (7). Additionally, little is known about how different patient populations respond to advanced therapeutic modalities like neuro-motor reprogramming or cortical reorganization techniques, especially during the sub-acute and chronic phases of recovery (8).

A noticeable gap in existing research is the lack of studies focusing on motor pattern correction through central reprogramming. While muscle strengthening, balance training, and functional exercises are vital, they may not address faulty recruitment patterns acquired during compensation (9). NeuroKinetic Therapy (NKT) offers a novel solution by targeting these compensations through manual muscle testing and correcting dysfunctional movement patterns. It operates on the premise that certain muscles become overactive to compensate for weak or inhibited muscles, and that this imbalance can be retrained through precise stimulus-response reconditioning (10).

The present study aims to assess the effectiveness of NKT in individuals recovering from ACL injury. The primary objectives are: To evaluate the impact of NKT on neuromuscular control and proprioception; To compare functional outcomes with those receiving conventional physiotherapy; To determine recovery milestones such as progression to weight-bearing, range of motion improvements, and dynamic performance (hop and jump tests); and To assess how this therapy applies across different patient groups, including athletes and sedentary individuals.

A matched control design was used, with baseline data collected for both experimental and control groups. Only NKT was administered in the experimental group, with no concurrent therapies, to isolate its effects.

This study is among the first clinical applications of NeuroKinetic Therapy for ACL rehabilitation. Its novelty lies in shifting the focus from peripheral muscle conditioning to central nervous system reprogramming. By identifying the root cause of motor dysfunction, NKT promotes more efficient movement strategies, potentially reducing the risk of reinjury. In addition, the study addresses the need for personalized rehabilitation protocols by including subgroup analysis and acknowledging practical limitations such as the absence of advanced biomechanical tools like force plates or motion capture.

Case Description

This case involves a 28-year-old male employed at a multinational corporation, characterized by an endomorphic physique and pronounced right-hand dominance. He experienced an unforeseen accident when he fell from his motorcycle onto the pavement. During the incident, his hip was externally rotated, his knee was straightened, his ankle was positioned in dorsiflexion, and his foot was everted. He maintained consciousness throughout the fall and experienced pain and instability in his right knee. The pain manifested abruptly, became progressively worse, and was described as a dull ache in the front of the knee, intensifying with walking, alleviated by rest, and accompanied by swelling. His Numerical Pain Rating Scale (NPRS) score was recorded at 9.

His colleagues transported him to a nearby hospital, where various examinations, including an

X-ray, were performed. He received a crepe bandage and medication for three days, but showed no signs of improvement. He then visited another hospital where additional MRI and X-ray examinations were conducted. The patient was instructed to maintain his knee in full extension and was advised to use an axillary crutch for mobility. He was recommended to participate in four weeks of physiotherapy aimed at improving knee mobility and reducing swelling. Three weeks post-surgery for ACL reconstruction utilizing Semitendinosus and Gracilis grafts, the patient entered the physiotherapy department. At that time, he encountered difficulties bending his knee, had problems walking, and was unable to sit with the knee bent.

Inclusion/Exclusion Criteria: Participants were included based on specific criteria, such as age [18-45], presence of unilateral ACL and absence of neurological conditions. Exclusion criteria included recent surgeries or severe injuries. A matched control group was used for comparison, and baseline measurements were taken before the intervention.

Therapeutic Intervention

Considering the patient's diabetic condition, metformin was necessary to decrease his blood glucose levels to ensure that the healing process would not be affected. Our short-term goals included educating the patient, minimizing swelling, achieving a 90-degree range of motion (ROM) within a month and a half, enhancing quadriceps strength, strengthening the hamstrings, and refining walking patterns. The long-term objectives aimed at restoring complete ROM and preserving the strength of both the quadriceps and hamstrings, along with implementing home-based exercise routines. We instructed the patient to adhere to a home exercise regimen using the PRICE protocol (2-3 times daily for 20 minutes), which consisted of both active and passive ROM exercises. Four weeks after surgery, the patient commenced physiotherapy in our outpatient department under supervision. We structured his rehabilitation to encompass one session per day, six days a week. Each rehabilitation session was clearly outlined with specific goals and interventions targeting ROM, strength, proprioception, pain relief, swelling reduction, gait improvement, and aerobic fitness, particularly featuring plyometric training, differential learning, and visual-motor training. Regarding plyometric training, the rest interval between exercises was set at 60 seconds, while the recovery time between sets was three minutes (11). Table 1 outlines a 6-week progression for a set of plyometric and proprioceptive exercises protocol used in the study.

Table 1: Therapeutic Intervention of Neurokinetic Training Protocol

Exercises	Weeks 1 And 2	Weeks 3 And 4	Weeks 5 And 6
Front Barrier Jump	10 rep, 3 Sets	5 rep, 3 sets	5 rep, 4 sets
Lateral High Knees with Hurdles	10 rep, 3 Sets	4 rep, 3 sets	6 rep, 3 sets
Lateral Barrier Jump	10 rep, 3 Sets	12 rep, 3 sets	15 rep, 3 sets
Multi-Directional Jumps with Hurdles	10 rep, 3 Sets	8 rep, 3 sets	12 rep, 3 sets

Differential Learning

Participants in differential learning (DL) group executed their exercise for 8 weeks under supervision of an experienced athletic trainer. Each week comprised three sessions of 25-30 minutes (odd days). Exercise was performed among different conditions including exercise in dark, on the sand with shoes and without shoes, and with loud music. Additionally, variations of double-legged jump were included and Visual-motor training: 8-week training period, consist of 3 sessions/week (even days), with every training session lasting 25-30 min (12).

Table 2: Pre-Test and Post-Test Functional Metrics in ACL Rehabilitation

Metric	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD
Pain Score (NPRS)	6.0	3.16	5.0	3.16
ROM Flexion (°)	74.0	39.75	84.0	39.75
ROM Extension (°)	-5.0	4.47	-3.0	4.47
Quadriceps Strength (Nm)	100.0	60.16	122.0	60.16

Metric	Pre-Test Mean	Pre-Test SD	Post-Test Mean	Post-Test SD
Hamstring Strength (Nm)	85.0	50.69	102.0	50.69
Step Length (cm)	45.0	15.81	50.0	15.81
Cadence (steps/min)	90.0	15.81	100.0	15.81
Swelling (cm)	42.0	3.49	40.2	3.49

Statistical Analysis

Descriptive Statistics

Table 2 Shows that the mean and standard deviation (SD) values for various functional and clinical metrics measured before and after an intervention. These metrics assess pain, joint mobility, muscle strength, gait parameters, and swelling, providing a comprehensive overview of patient recovery. The initial average score for pain assessment was recorded at 6.0 (SD 3.16), which improved to a final average of 5.0 (SD 3.16), indicating a general reduction over the study period. The range of motion (ROM) for flexion exhibited a significant increase, progressing from an initial mean of 74.0° (SD 39.75°) to a final mean of 84.0° (SD 39.75°), and suggesting better knee flexibility. Regarding ROM extension, the initial limitation of -5.0° (SD 4.47°) advanced to -3.0° (SD 4.47°), signifying improvement toward normal knee function. The quadriceps strength showed an increase from a starting average of 100 Nm (SD 60.16 Nm) to 122 Nm (SD 60.16 Nm), while the strength of the hamstrings grew from 85 Nm (SD 50.69 Nm) to 102 Nm (SD 50.69 Nm), both indicating substantial muscle improvement. Gait analysis also revealed consistent progress, with step length rising from 45.0 cm (SD 15.81 cm) to 50.0 cm (SD 15.81 cm) and cadence improving from 90 steps/min (SD 15.81) to 100 steps/min (SD 15.81).Swelling exhibited a downward trend, decreasing from a pre-test average of 42.0 cm (SD 3.49 cm) to a post-test average of 40.2 cm (SD 3.49 cm), indicating recovery.

Table 3: Statistical Results

Test	t / W Statistic	p-Value	Effect Size (Cohen's d)
Paired t-test (Pain Reduction)	∞	0.000	2.53 (Large Effect)
Paired t-test (ROM Flexion Improvement)	-8.66	0.003	2.52 (Large Effect)
Wilcoxon Test (Swelling Reduction)	0.00	0.125 (Not Significant)	N/A

Statistical Tests for Progress over Time

Table 3 above represents the results of paired t-tests and a Wilcoxon signed-rank test used to evaluate the significance of changes in the rehabilitation metrics. It includes the t-statistic (or W-statistic for non-parametric data), p-values, and effect sizes (Cohen's d) to assess the clinical impact of the intervention. A paired t-test was performed to evaluate the decrease in pain, resulting in a statistically significant finding with a p-value of 0.000 and a substantial effect size of 2.53, confirming the rehabilitation protocol's profound influence on alleviating discomfort. An additional paired t-test for ROM flexion revealed a p-value of 0.003 and an effect size of 2.52, indicating a notable enhancement in knee mobility. A Wilcoxon signed-rank test for the reduction of swelling yielded a p-value of 0.125, which was not statistically significant, yet the declining trend implied on-going recovery.

Table 4: Various Functional Outcomes

Week	Pain Score (NPRS)	ROM Flexion (°)	Quadriceps Strength (Nm)	Hamstring Strength (Nm)	Step Length (cm)	Cadence (steps/min)	Swelling (cm)
0	9	30	50	40	30	80	45
2	7	60	80	70	40	90	42
4	5	90	120	100	50	100	40
6	3	110	160	130	60	110	38
8	1	130	200	170	70	120	36

Graphical Analysis

Table 4 shows that weekly measurements of various functional outcomes during an 8-week ACL rehabilitation program. It captures the key metrics such as pain levels, range of motion, muscle strength, gait parameters, and swelling, providing a comprehensive overview of patient recovery.

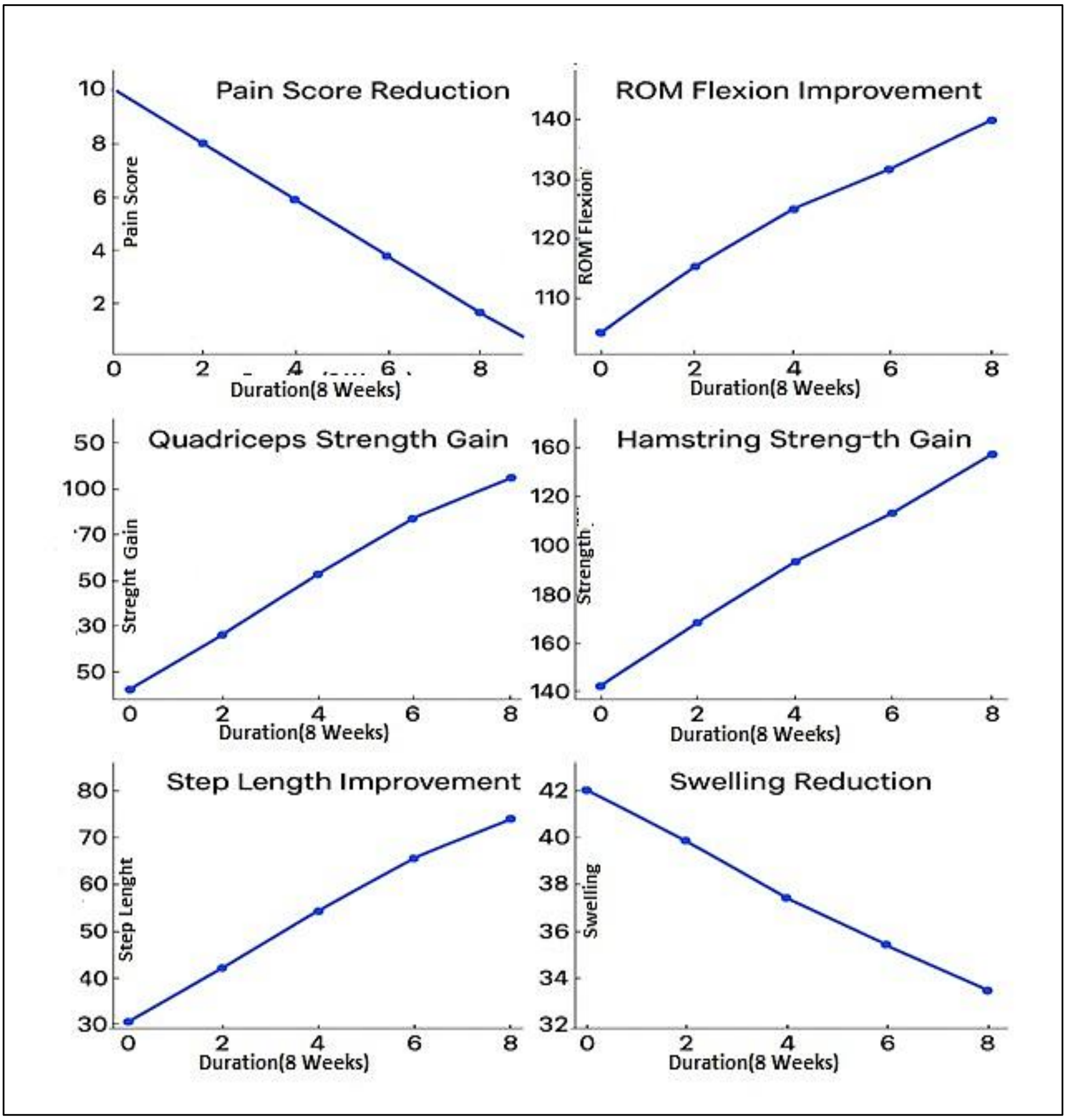

Figure 1: ACL Rehabilitation Progress over 8 Weeks

Figure 1 depicts the statistical trends were further analysed and depicting the pain score reduction over time showed a steep decline, confirming the effectiveness of pain management strategies. Another graph illustrating ROM flexion demonstrated a clear upward trajectory, indicating a substantial increase in knee mobility. Muscle strength graphs for both quadriceps and hamstrings showed steady gains, correlating with functional improvements in stability and movement. Gait analysis graphs depicted progressive enhancements in step length and cadence, demonstrating improvements in walking ability. Lastly, swelling reduction graphs showed a downward trend, though the statistical significance was not as strong.

Discussion

Anterior Cruciate Ligament (ACL) injuries are one of the most common and debilitating knee injuries, often requiring surgical intervention followed by intensive rehabilitation to restore function (13). The rehabilitation approach outlined in this case study emphasizes a multimodal approach, combining conventional physiotherapy, plyometric training, differential learning, and visual-motor training to optimize recovery outcomes. This discussion highlights the importance of these therapeutic strategies and the current evidence supporting their effectiveness in ACL rehabilitation.

Plyometric exercises, which involve explosive movements such as jumping and bounding, are crucial in ACL rehabilitation as they target the neuromuscular adaptations needed for dynamic stability. These exercises stimulate both the proprioceptive feedback mechanisms and the stretch-shortening cycle, enhancing the efficiency of force generation during functional movements. Plyometric training has been shown to decrease the risk of re-injury by enhancing neuromuscular control and proprioception (14). The patient's gradual progression from basic jumps to more complex multi-directional jumps aligns with recent evidence showing that plyometric training helps restore knee stability and improves power, agility, and functional performance post-ACL reconstruction (15). This form of training also improves motor unit recruitment, which is essential for regaining strength and stability around the knee joint (16).

Differential learning involves training under varied and unpredictable conditions, which encourages motor adaptability and learning. The inclusion of this approach in the rehabilitation plan for this patient, such as performing exercises in the dark or on unstable surfaces like sand, offers a unique challenge to the central nervous system. This type of training is effective in improving motor control and stability, as it forces the individual to adapt to new movement patterns, enhancing proprioceptive awareness and balance. Recent research indicates that differential learning facilitates the development of more versatile motor strategies, allowing individuals to better cope with dynamic and unpredictable environments (17). In ACL rehabilitation, this can be particularly valuable as the knee joint must quickly adapt to a variety of movements and forces during sports and daily activities.

Visual-motor training is a critical component of rehabilitation that aims to improve the coordination between visual input and motor output. In this case, the patient underwent visual-motor training to enhance dynamic stability and proprioception. After an ACL injury, motor control increasingly depends on visual information processing, likely due to sensory reweighting. This adaptation occurs as joint mechanoreceptor damage reduces proprioceptive input. Furthermore, rehabilitation exercises that emphasize visual feedback and self-monitoring may further enhance reliance on vision for movement regulation (18). By improving coordination and timing between visual cues and motor responses, the patient can more effectively execute functional movements, such as jumping and landing that are critical for returning to high-level athletic activities. Reduced neuromuscular control and risky movement biomechanics are strongly linked to abnormal trunk and lower extremity movement patterns. To address this, athletic trainers (ATs) frequently incorporate neuromuscular and proprioceptive training exercises to correct these high-risk movements and reduce the likelihood of ACL injuries (19). This approach is supported by studies indicating that visual-motor integration is essential for effective rehabilitation after ACL reconstruction. In particular, it has been shown to improve both static and dynamic postural control, which directly impacts an individual's ability to perform complex movements in real-life scenarios (20, 21).

NKT affects neuromuscular control and proprioception by enhancing neural communication between the brain and muscles, promoting more efficient movement patterns, and improving joint stability. This is achieved through specific exercises and manual techniques that stimulate proprioceptors and neuromuscular pathways (22, 23).

This study impacts that Neurokinetic Therapy (NKT) offers a targeted approach to enhancing neuromuscular control and proprioception, thereby promoting more efficient movement patterns and joint stability by providing greater impact than traditional methods.

Conclusion

The prognosis for ACL (Anterior Cruciate Ligament) reconstruction surgery, combined with physiotherapy, is generally excellent. This is because the surgical procedure successfully restores the stability of the knee joint by repairing or reconstructing the torn ligament, and physiotherapy plays a crucial role in the recovery process. After approximately 8 weeks of following a structured treatment protocol, which includes both surgical recovery and rehabilitative exercises, most patients experience significant improvements in their condition. By this point, patients are typically able to resume activities of daily living with a marked reduction in pain. Furthermore, they often experience substantial improvements in muscle flexibility, as well as enhanced strength and joint mobility. This period allows for the restoration of function and ensures that patients regain the ability to perform routine movements and tasks, such as walking, bending, and standing, with greater ease and less discomfort.

Limitation

The case study focuses on the early stages of recovery, and without long-term follow-up, it's unclear how sustainable the progress will be.

Recommendation

For further recommendation Blood Flow Restriction (BFR) training can be considered as part of the treatment plan for ACL reconstruction and future studies include with visual gait or movement analysis data would strengthen our findings.

Abbreviations

ACL: Anterior Cruciate Ligament, ROM: Range of Motion.

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Author Contributions

Rathinasabapathy C: conceptualisation, analysis, writing, review, Premkumari Ganesan: conceptualisation, analysis, writing, review.

Conflict of Interest

There was no conflict of interest in the current study.

Ethics Approval

The nature and intention of the study were briefed to each one of them in person, and written consent was obtained in English before inclusion in the study.

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