



Effectiveness of neuromuscular stabilisation using staggered deadlift training following ACL reconstruction with meniscus repair: A case report

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Abstract

Anterior Cruciate ligament reconstruction (ACLR) restores mechanical knee stability, yet neuromuscular and dynamic balance deficits often persist, limiting functional recovery. This single-case repeated-measures study evaluated changes in dynamic balance and unilateral functional performance in a patient undergoing phased rehabilitation augmented with a novel hinge-based stabilization exercise. A 31-year-old female underwent right ACLR with lateral meniscus repair and completed a structured rehabilitation program. ACLR rehabilitation protocol was given for 12 weeks which included a novel training of staggered deadlift with isometric holds to target hip-knee neuromuscular control. Outcome were assessed 4 weeks post-operatively and at 12 weeks post-operatively using modified-Star Excursion Balance Test(m-SEBT), single -leg hop for distance, and their limb symmetry indices (LSI). Composite m-SEBT reach on operated limb improved from 58% to 94% of limb length, with LSI improving from 63% to 95%. Single leg hop distance improved from 72 cm to 130 cm, with hop LSI increasing from 57% to 94%. These changes showed restoration of dynamic postural control and unilateral function. The findings suggest that integrating a controlled hinge-based neuromuscular exercise into early-to-mild ACL rehabilitation may contribute to improved sensorimotor control and functional symmetry. Further research is needed to confirm effectiveness in larger cohorts.

Keywords: Single case design, staggered dead lift, ACL, ACLR, rehabilitation, physical function, balance, proprioception

Introduction

Anterior Cruciate Ligament (ACL) injury is a common knee pathology associated with persistent functional limitations despite surgical reconstruction. Although ACL Reconstruction (ACLR) restores passive mechanical stability, sensorimotor deficits frequently remain, influencing gait, balance, and unilateral performance [1]. Deficits in proprioception and neuromuscular control contribute to altered movement strategies, reduced dynamic stability, and delayed return to higher-level activities [2].

Dynamic balance is a key component of post-ACLR recovery. The modified Star Excursion Balance Test (m-SEBT) is a validated measure of dynamic postural control that challenges lower-limb coordination during single-leg stance [3]. Reduced reach distances in the operated limb have been associated with neuromuscular impairments and increased injury risk [4]. Similarly, single leg hop performance reflects unilateral power generation and landing control and is widely used to evaluate functional symmetry [5]. Limb symmetry indices (LSI) derived from hop tests provide a clinically meaningful indicator of recovery progression and readiness for higher-level activity [6].

Rehabilitation following ACLR traditionally emphasizes restoration of range of motion and strengthening; however, neuromuscular retraining is increasingly recognized as essential for restoring sensorimotor function [7]. Exercises that promote hip-knee coordination under controlled loading may enhance joint stability and improve dynamic balance. Posterior chain activation, particularly through hip-dominant movement patterns, has been associated with

improved lower-limb alignment and reduced valgus stress during functional tasks [8]. The staggered deadlift, a hinge-based stabilization exercise, may provide such benefits but has not been well documented in ACL rehabilitation literature.

Single-case repeated-measures designs offer a practical method for exploring responses to novel interventions in clinical settings, particularly when preliminary clinical evidence is required [9]. Therefore, this study aimed to evaluate changes in dynamic balance and unilateral function following phased rehabilitation incorporating a staggered deadlift stabilization exercise after ACL reconstruction.

Case Description

This report was conducted after receiving permission from the TMV's Lokmanya Tilak College of Physiotherapy ethics committee at TMV is Lokmanya Tilak College of Physiotherapy. Prior to the first evaluation, a short lecture was delivered to the patient about the study and the type of interventions that she would receive. She agreed to voluntarily take part in the study and signed a consent form. The patient also signed consent to give access to her medical records to use them in this report.

Patient History

A history was taken from the patient, and all the reports and other medical information available was reviewed. The subject was a 31-year-old female homemaker by profession, mothering a daughter.

She was apparently alright fifteen months back, when she had a fall from Scooter on riding it back home. On trying to

get up her leg, got stuck under the scooter. People around helped her get up. She started feeling pain in her right knee. She had difficulty in walking and climbing stairs due to the right knee pain.

She went to the doctor and got an x-ray done, suggesting no significant changes. She also took a course of medication from which she had no relief. On visiting the doctor again and MRI was suggested which showed full thickness proximal 3rd ACL tear with small anterior intercondylar nodule formation., peripheral longitudinal tear of the posterior horn of lateral meniscus (wisberg rip tear), low to intermediate grade anterior fibers femoral attachment MCL injury, intermediate grade PLC injury, low grade femoral attachment LCL injury, moderate posterior medial and posterior lateral tibial bone marrow edema and moderate joint effusion. She was advised surgery based on the MRI scans and reports.

The medical history showed normal health status without any serious illnesses. There was no history of earlier injuries. The patient does not have any co-morbidities.

Surgical History

She underwent right knee arthroscopic ACL reconstruction + lateral meniscus repair + notchplasty + synovectomy under spinal anesthesia + right adductor block.

Synovectomy done using a 4.5mm arthroscopic shaver blade (SNN); complete ACL tear. 2cm incision taken over AM tibia, semitendinosus and gracilis graft harvest done.

Arthroscopic primary anatomic single bundle ACL reconstruction done using three stranded semitendinosus and gracilis grafts fixed on femur with adjustable loop SNN and fixed on tibia with 9 x 28mm absorbable interference screw(arthrex). Longitudinal tear seen in RR-RW zone of posterior horn of lateral meniscus.

Repair done using 2x all inside sironix + SNN stability and implant placement checked at the end of the surgery.

wounds closed in layers without drains.

no DNVD post procedure.

Examination and Evaluation

Two days after the surgery, the patient was presented with a knee brace sitting (long sitting) on the bed comfortably at her home. All her vitals were stable, and her general condition was good. No visible swelling or edema present. As it was an arthroscopic repair, there were no scars except for three small incisions taken for the surgery. Her overall posture was good, and she was ambulatory with a walker using a non-weight bearing gait pattern. On palpation, grade 1 tenderness was noted around the incisions without any edema. There were no trigger points or spasm. There were no sensory deficits as such. Reflexes came out to be normal. Gastrocnemius muscle was tight. Active range of motion of knee flexion was 0° to 30° and complete active extension was present. Rest all the ranges for other joints were normal. Adequate strength was there in the bilateral upper extremity and left lower extremity to perform transfers, ADLs, and walking with a walker independently.

Investigations

1. The patient's blood work came out to be normal.
2. Radiologic reports showed no significant changes.
3. MRI was suggested which showed full thickness proximal 3rd ACL tear with small anterior intercondylar nodule formation., peripheral longitudinal

tear of the posterior horn of lateral meniscus (wisberg rip tear), low to intermediate grade anterior fibers femoral attachment MCL injury, intermediate grade PLC injury, low grade femoral attachment LCL injury, moderate posterior medial and posterior lateral tibial bone marrow edema and moderate joint effusion.

Outcome Measures

1. Functional Performance Testing- Single leg hop for distance (ICC- 0.86 to 0.95)
2. Postural Control- Star Excursion Balance Test (ICC- 0.89 to 0.93).
3. Limb Symmetry Index for above outcomes.

Study Design

A prospective single case repeated measures design was used. Outcomes were assessed 4 week post-operatively (T1) and at 12 weeks postoperatively (T2) taking in consideration surgeon's recommendations and respecting the time of healing.

The 31-year-old female participant had sustained a right ACL tear with posterior horn lateral meniscus tear following a fall. She underwent arthroscopic ACL reconstruction using semitendinosus-gracilis autograft with meniscus repair. Post-operative recovery was uncomplicated. During the study, the participant's medications were not altered, and she stayed in good general health.

Intervention

Rehabilitation consisted of standard of care exercises delivered in phases with addition of a novel neuromuscular stabilization exercise beginning at week 4.

Measures

The SEBT has been shown to be a reliable measure and has validity as a dynamic test to predict risk of lower extremity injury, to identify dynamic balance deficits in patients with a variety of lower extremity conditions, and to be responsive to training programs in both healthy people and people with injuries to the lower extremity ¹⁰. The SEBT intrarater reliability ICC ranges from 0.89 to 0.93, showing good measurement stability ^[11].

Researchers have said that SLHTs are particularly important for measuring leg strength on a single joint, and they are commonly used to evaluate the functional states of individuals, identify asymmetries between the operated and non-operated sides, and follow developments in the limb ^[12, 13, 14].

Intraclass correlation coefficients for limb symmetry index values ranged from 0.82 to 0.93 ^[15].

Procedure

- Single leg hops for distance, SEBT and their Limb Symmetry Indices were taken 4-week post operatively and 12 weeks post-operatively.
- Staggered Squats Training
- Stand with feet staggered, operated leg slightly behind, knees slightly flexed, spine neutral chest, open shoulders back and core gently braced.
- Push hips backward (not downward), maintain neutral spine, front knee stays slightly flexed but stable, back leg assists balance.
- Lower torso until mild stretch felt in hamstrings weight shifts more into front heel and the knees stay aligned over toes.

- Hold the bottom position for three to five seconds, maintain level hips neutral spine and knee alignment. Finally return back to upright posture by driving hips forward and engaging glutes.
- Inhale during lowering, exhale slowly during isometric hold and exhale fully while returning to standing.
- 6 repetitions per side, three sets, three times per week.
- Progress by increasing the hold. Later add light dumbbell or kettlebell.
- Regress by decreasing hinge depth, reducing hold time, hold on to support or use mirror feedback for knee alignment.

Results

Outcome measures were assessed 4 weeks post-operatively and at 12 weeks postoperatively following completion of the phased rehabilitation program incorporating standard of care and staggered deadlift training.

Dynamic Postural Control (m- SEBT)

The operated limb demonstrated substantial improvement in normalized reach distances in all three directions. Operated

limb showed and increased from 58% to 94% in the SEBT score. in contrast the non-operated limb showed minimal change increasing from 92% to 95% across directions. The m-SEBT Limb Symmetry Index (LSI) improved from 63% 4 week post operatively and 95% 12 weeks postoperatively. This indicates near complete restoration of side-to-side dynamic balance symmetry.

Functional Performance (single leg Hop for distance)

The operated limb hop distance improved from 72-centimeter 4 week post-operatively to 130 centimeter 12 week post operatively reflecting and increase in unilateral propulsion capacity and landing control the non-operated limb demonstrated a smaller improvement from 126 centimeter to 137 centimeters, likely reflecting general conditioning rather than targeted recovery.

The hop LSI improved from 57% to 94% showing restoration of functional symmetry between limbs.

Overall, both dynamic balance and unilateral functional performance demonstrated marked improvements over 3 months rehabilitation period, with symmetry indices approaching normal values.

Sr. No	Outcome Measures	4 week post-operatively (T1)	12 week post-operatively (T2)
1	SEBT (Operated limb)	58%	94%
2	SEBT (non-operated limb)	92%	95%
3	LSI-SEBT	63%	95%
4	One Leg Hop Test (Operated)	72 cm	130cm
5	One Leg Hop Test (Non- Operated Limb)	126 cm	137 cm
6	LSI-One Leg Hop Test	57%	94%

Discussion

This case report examined recovery of dynamic balance and functional symmetry following ACL reconstruction with meniscus repair, using a phased rehabilitation program that incorporated in novel staggered deadlift with isometric hold beginning at 4 weeks postoperatively the improvements observed in m-SEBT and hope performance can be interpreted through several neuromuscular and biomechanics.

Restoration of Sensory Motor Control

ACL injury disrupts proprioceptive input due to damage to ligament mechanoreceptors e early rehabilitation focused on reducing swelling and establishing quadriceps activation likely improved joint afferent signals and weight acceptance mechanics as balance tasks were introduced proprioceptive demand increased p promoting improved sensory motor integration the near normalization of SEBT LSI (63% to 99%) s suggests that the operated limb regained dynamic postural control comparable to the non operated side.

Influence of Progressive Loading

The structured progression from double leg to single leg tasks ensured gradual exposure to increasing neuromuscular demand this progression likely improved hip and trunk control reducing compensatory knee loading and enhancing alignment during single limb tasks improved control of the hip abductors and extensors contributes to better control of knee valgus moments, which is crucial for safe unilateral movement

Contribution of this Staggered Deadlift

The staggered deadlift with isometrics holds was introduced at week 4 to target posterior chain activation and hip knee

coordination this exercise emphasizes a hip dominant hinge pattern which reduces anterior knee shear forces while challenging neuromuscular stability the isometric hold increases time under tension and enhances proprioceptive feedback p promoting joint position awareness and neuromuscular precision b by loading the limb in a controlled yet functional manner t the exercise likely contributed to improved control during dynamic tasks such as the m- SEBT and hope tests.

Functional Symmetry Gains

Single leg hop performance improved markedly on the operated side with hope LSI reaching 95% achieving symmetry close to 100% suggests restoration of booth force production and landing control improvements in hop distance are not solely attributable to strength gains but also reflect improved neuromuscular coordination and confidence in limb loading.

Clinical Implications

The parallel improvements in balance and hop symmetry highlight the importance of neuromuscular stabilization in ACL rehabilitation. While traditional strengthening addresses muscle capacity exercises like wise, staggered deadlift may bridge the gap between strength and functional control in the early introduction of controlled hinge-based stabilization that appears workable and may enhance the recovery of dynamic stability.

Conclusion

This single case repeated measures study demonstrated substantial improvements in dynamic balance and functional symmetry following ACL reconstruction when standard

rehabilitation was combined with a staggered deadlift stabilization exercise introduced at week 4, m-SEBT and hop LSIs improved from asymmetrical values (63% and 57% to near normal symmetry (99% each) by six months postoperatively. These findings suggest that targeted neuromuscular stabilization exercises may accelerate restoration of sensory motor control and unilateral function after ACL reconstruction further controlled studies are warranted to confirm these effects in larger populations.

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