Clinical Medicine and Health Research Journal (CMHRJ)
Volume 02, Issue 05, September - October, 2022
Page No. 187-190

Research Article

Postoperative Rehabilitation of Anterior Cruciate Ligament Reconstruction

Jakkula Akhil[1], Jahira Banu T[2], Yogesh Ashok Sontakke[3], Gopisankar Balaji[4]

[1]Junior Resident, Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) (An Institution of National Importance under the Ministry of Health & Family Welfare, Govt. of India), Pondicherry, 605006 India.

[2]Senior resident, Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) (An Institution of National Importance under the Ministry of Health & Family Welfare, Govt. of India), Pondicherry, 605006 India.

[3]Additional Professor, Department of Anatomy, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) (An Institution of National Importance under the Ministry of Health & Family Welfare, Govt. of India), Pondicherry, 605006 India.

[4]Additional Professor and Head of the Department, Department of Orthopedics, Jawaharlal Institute of Postgraduate Medical Education and Research (JIPMER) (An Institution of National Importance under the Ministry of Health & Family Welfare, Govt. of India), Pondicherry, 605006 India.

Received: 10 August, 2022 Accepted: 02 September, 2022 Published: 04 September 2022

Abstract:

Anterior cruciate ligament injury is commonly seen in sports-related trauma. Complete tear requires surgical reconstruction. During postoperative rehabilitation, because of arthrogenic muscle inhibition (AMI), the quadriceps muscle remains inactive and has reduced contraction. Various strategies were aimed at treating this AMI or improving quadriceps strength, such as open chain (OKC) and closed chain kinetic (CKC) exercises, blood flow resistance training (BFRT), cryotherapy, and transcutaneous nerve stimulation (TENS). Of all these, CKC was better than OKC in improving the range of movements; weight-bearing exercises provided a quicker return to physical activity. Cryotherapy was an effective way to counter AMI, improve knee function, and reduce pain. The BFRT and TENS were found to be ineffective. The single-legged hop test at six months postoperatively was found to be a reliable predictor of the quadriceps function at one year. Electromechanical dynamometry is the gold standard for assessing knee extension and providing exercise. In comparison, handheld dynamometry is easy to use. Leg press and leg extension machines are other machines used to provide exercises.

Keywords: Anterior cruciate ligament, postoperative rehabilitation, open chain kinetic exercise, closed chain kinetic exercise

Introduction

Anterior cruciate ligament (ACL) injury alters the knee kinematics, and the primary aim of ACL reconstruction is to restore the knee kinematics and quadriceps strength. However, following ACL reconstruction, a significant number of patients were found with quadriceps femoris weakness on the operated limb and poor functional capacity of the knee. Various rehabilitation protocols were followed to strengthen the quadriceps muscles. Devices came into play to augment the knee function and strength of the quadriceps. Some clinicians used the multi-modality approach to circumvent this quadriceps weakness. Since a significant number of ACL surgeries happen worldwide and much physical and economic impact is incurred on society through the treatment costs and loss of livelihood, a review of the postoperative rehabilitation techniques is of paramount importance.

Materials and methods

The data was collected through PubMed and Google scholar databases from the published articles between 2009-2022. The keywords used were 'postoperative,' 'anterior cruciate ligament,' and 'rehabilitation'. The articles in English, with full text, were included. Articles on reconstruction surgeries and articles in other languages were excluded.

Review

Quadriceps weakness after ACL injury and reconstruction

Anterior cruciate ligament tear was found to cause quadriceps weakness due to disuse atrophy and reduced quadriceps strength. The quadriceps' cross-sectional area was reduced by 4.5–13% after the ACL injury. The knee extensor strength was reduced by 8–37% following ACL injury.[1]

Even following ACL reconstruction, quadriceps weakness and poor knee joint extension were frequently encountered. The cause behind this was supposed to be arthrogenic muscle inhibition (AMI). Arthrogenic muscle inhibition is a reflex of damaged articular structures that affects the muscles around the joint. Improper sensory afferents from the damaged joint would decrease the efferent that supplies quadriceps. It resulted in a smaller number of motor units available for recruitment and the inability to activate the quadriceps muscle completely. Some patients were resistant to rehabilitative strategies, possibly due to AMI.[2]

Table 1: List of exercises

S. No.	Type of exercises	Examples
1	Open chain kinetic exercise	Knee stretch
2	Closed chain kinetic exercise	Squatting lunges, wall sits
3	Weight-bearing exercises	Stair climbing, leg press, wall squats
4	Non-weight bearing exercises	Dynamic seated knee extension, Lachman test
5	Blood flow resistance training	Cuff to occlude venous flow
6	Cryotherapy	Application of ice
7	Transcutaneous electrical nerve stimulation	

Open chain kinetic exercises vs. closed chain kinetic exercises

These exercises aim to prevent the atrophy and loss of strength of the quadriceps and to maintain knee flexion and proprioception. The list of exercises is given in table 1. Open chain kinetic (OKC) exercises are exercises in which the distal part of the leg is free, such as isotonic/isometric quadriceps exercises, knee stretching exercises, and flexor-extensor bench. In closed chain kinetic (CKC) exercises, the entire leg is fixed, such as squatting lunges, wall sits, and standing weight shifts. Both types were recommended in post-surgical rehabilitation. However, the CKC exercise improved the knee function more effectively than OKC.[3] The visual analog score was reduced more in CKC than in OKC, Lysholm score was found better improved in CKC than in the OKC group, knee flexion was better in the CKC group, and CKC better-prevented muscle atrophy than OKC. CKC is preferred for the goal of the normal range of motion and weight bearing. *Yack et al.* found more knee laxity with OKC, whereas Morrissey et al. could not find a difference in laxity in OKC and CKC.[3,4] *Bynum et al.* found patellofemoral joint pain more in OKC, whereas *Morrissey et al.* found no difference between OKC and CKC. OKC was found to provide better quadriceps strength, whereas CKC was found to provide better knee flexion.[4]

Weight-bearing exercises vs. non-weight-bearing exercises

Isometric seated knee extension with resistance, isokinetic knee extension, dynamic seated knee extension with or without resistance, and the Lachman test are examples of non-weight-bearing exercises. Weight-bearing exercises include step up, step down, forward lunge, side lunge, stair climbing, squatting, barbell squatting, leg press, and wall squat. Weight-bearing exercises showed less pain and more stable knees with a quicker return to the sport than non-weight-bearing exercises. ACL loading was found to be more with non-weight bearing than weight-bearing exercises, with a peak at 10° to 50° knee flexion in both types of exercises. Adding loads in weight-bearing exercises did not increase ACL loading, whereas increasing loads in non-weight-bearing exercises increased ACL loading.[5]

Blood flow restriction training (BFRT)

This technique aimed to provide better strength gains in quadriceps muscle by occluding venous blood from the lower limb during the exercises. The cuff was applied to the thigh, occlusion pressure was set to 80%, and the patient was instructed to perform the leg press exercise. BFRT did not significantly improve the strength, activation, or volume of the quadriceps.[6]

Transcutaneous electrical nerve stimulation (TENS)

Forogh et al. found that adding high-frequency TENS to semi-supervised exercise even up to four weeks of rehabilitation did not improve knee function or pain compared to exercise alone.[7] *Anderson et al.* also observed that the application of TENS did not improve any parameter related to performance and did not reduce the medication required for pain.[8] *Ilfeld et al.* studied percutaneous femoral nerve stimulation with the help of an implant anterior to the femoral nerve and found a downward trajectory in pain.[9]

Cryotherapy

Concerning arthrogenic muscle inhibition, cryotherapy surprisingly produced disinhibition by enhancing the availability of more motor neurons. It reduced sensory receptor discharge and slowed nerve conduction, thereby decreasing afferent signals. It was found to produce transient improvement in quadriceps, thereby providing a way for an increase in quadriceps activation and enhancing strength. Cryotherapy increased the Hoffman reflex and the quadriceps central activation ratios in patients with osteoarthritis. The risk of injury after cryotherapy is not known. The cryotherapy followed by exercises protocol was superior to the cryotherapy alone and exercise alone.[2] *Koyonos et al.* worked on preoperative cryotherapy and found it significantly reduced pain and narcotic usage postoperatively. [10]

Testing of the quadriceps strength

Clinical tests

Single-legged hop test

The single leg hop test is commonly utilized to identify the right-left asymmetry in the knee function postoperatively, typically six months after surgery. This test is also used as a predictor of outcome after reconstruction. Test conducted at six months postoperatively could predict the 1-year outcome after surgery.[11] A preoperative single leg hop test was found of no benefit in predicting knee function two years postoperatively.[12] Various types of this test were described, such as single-hop, crossover hop, triple hop, and 6-m timed hop.[11,12] Distance was measured for a single hop, crossover hop, or triple hop in the same way for one hop, three hops while crossing over a strip on the floor, and three consecutive hops, respectively. Time was measured in a 6-meter (6-m) timed hop where the patient was supposed to hop as fast as possible for a distance of 6 meters. The crossover hop and 6-metre timed hop were found to be the strongest predictors for self-reported knee function.[11]

Devices

Electromechanical dynamometry (Isometric/Isokinetic)

Quadriceps deficit was expected after the anterior cruciate ligament reconstruction, which impacts the gait, return to pre-injury activity, and athletic performance. Isometric or isokinetic electromechanical dynamometry was considered the gold standard for the same. In this technique, the patient was made to sit in the machine with hips flexed to 90° and knees flexed to 60°. The pelvis was stabilized with the help of straps. The dynamometer arm was fixed proximal to the ankle, and testing was done. The patient performed three practice trials and three maximum-force contractions for 5 seconds with a gap of one minute in between the contractions. No alternative device or technique was found superior compared to electromechanical dynamometry. The limitations of this device were the requirement of large space, and they are costly, resulting in restricted use to research settings alone.[13]

Handheld dynamometry (HHD)

Due to the prohibitive costs of electromechanical dynamometry, clinicians utilize manual testing of muscles. It had a difference in inter-rater variability. The handheld dynamometry improved the reliability and quantification of the force applied. In this technique, the patient was made to sit over the table edge; no stabilization was provided externally; instead, the patient was asked to grasp the ends of the table for stability. The dynamometer strap was fixed proximal to the ankle. The patient performed three practice trials and three maximum-force contractions for 5 seconds with a gap of 1 minute. It showed the advantage of being portable and less expensive than the gold standard dynamometer. The handheld dynamometry demonstrated a minimum intraclass correlation coefficient of 0.7 for agreement with the test. It showed good specificity and sensitivity for clinicians to decide on the return of activity. The limitations were difficulty in pelvis stabilization, the slippage of the HHD resulting in the application of force other than 90°, and discomfort due to the HHD attached to the shank.[13]

Leg press

One-repetition-maximum testing protocol for leg press was found to help assess the asymmetry of quadriceps strength, initially tested for the uninvolved limb and then for the injured limb. In this technique, the patients were reclined in a leg press machine with hip at 90° and knee in extension. Only the heel was in touch with the footplate to avoid the contraction of the triceps surae, thereby testing the quadriceps function alone. The limb not being tested was not placed in touch with the foot plate to prevent compensatory force. The test was successful if the patient could lift the weight to a defined angle and hold it for 2 seconds. The limitations were an exaggeration of the knee symmetry due to compensation by multiple muscle groups involved other than the quadriceps. Premature advice to advancing activity could be undesirable. [13]

Leg extension machine

The knee extension test (KX) was considered of two types, i.e., KX90 – 90° to 0° range of movement and KX45 – 90° to 45° range of movement. In this technique, the patients were seated in a leg extension machine with hips and knees at 90°; the resistance arm was kept proximal to the ankle joint, and the pelvis was not stabilized; instead, patients were told to grasp the handles for stability. The KX90 test was successful if the patient could lift the weight at 0° and hold it for 2 seconds. If unsuccessful, KX45 was performed.[13]

Quadriceps Index

This calculation assessed the symmetry of the quadriceps strength, i.e., the percentage of involved limb output compared to the uninvolved limb output.[13]

Radiology

T2-weighted magnetic resonance imaging

Vidmar et al. performed MRI to measure the cross-sectional area of quadriceps femoris. The images were obtained at the midpoint of a line drawn from the lesser trochanter to the lateral condyle of the femur. The cross-sectional area of each muscle of the quadriceps was measured manually, and all of them were added to obtain the cross-sectional area of the quadriceps femoris. 9–28% difference was seen between patients undergoing eccentric and traditional strength training.[14]

Conclusion

The postoperative phase of rehabilitation for the anterior cruciate ligament reconstruction is vital in the improvement of the functional capacity of the patient. The quadriceps are weak owing to arthrogenic muscle inhibition. Open chain and closed chain kinetic exercises are recommended to circumvent the weakness. Closed chain exercises were better in providing a good knee range of movements. Cryotherapy reduced AMI, improving function and reducing knee pain effectively. Blood

flow resistance training and transcutaneous nerve stimulation were not proven helpful for rehabilitation. In devices, an electromechanical dynamometer is considered the gold standard but expensive. The handheld dynamometer is easy to use and cheap. Leg press and leg extension machines were also used to improve function. Single-legged hop tests were found to be reliable as a predictor of the functional outcome.

References

1. Perry BD, Levinger P, Morris HG, Petersen AC, Garnham AP, Levinger I, et al. The effects of knee injury on skeletal muscle function, Na+, K+-ATPase content, and isoform abundance. Physiol Rep 2015;3:1–14. https://doi.org/10.14814/phy2.12294.
2. Hart JM, Kuenze CM, Diduch DR, Ingersoll CD. Quadriceps muscle function after rehabilitation with cryotherapy in patients with anterior cruciate ligament reconstruction. J Athl Train 2014;49:733–9. https://doi.org/10.4085/1062-6050-49.3.39.
3. Uçar M, Koca I, Eroglu M, Eroglu S, Sarp U, Arik HO, et al. Evaluation of open and closed kinetic chain exercises in rehabilitation following anterior cruciate ligament reconstruction. J Phys Ther Sci 2014;26:1875–8. https://doi.org/10.1589/jpts.26.1875.
4. Jewiss D, Ostman C, Smart N. Open versus Closed Kinetic Chain Exercises following an Anterior Cruciate Ligament Reconstruction: A Systematic Review and Meta-Analysis. J Sports Med 2017;2017:1–10. https://doi.org/10.1155/2017/4721548.
5. Escamilla RF, Macleod TD, Wilk KE, Paulos L, Andrews JR. Anterior cruciate ligament strain and tensile forces for weight-bearing and non-weight-bearing exercises: a guide to exercise selection. J Orthop Sports Phys Ther 2012;42:208–20. https://doi.org/10.2519/jospt.2012.3768.
6. Curran MT, Bedi A, Mendias CL, Wojtys EM, Kujawa MV, Palmieri-Smith RM. Blood Flow Restriction Training Applied With High-Intensity Exercise Does Not Improve Quadriceps Muscle Function After Anterior Cruciate Ligament Reconstruction: A Randomized Controlled Trial. Am J Sports Med 2020;48:825–37. https://doi.org/10.1177/0363546520904008.
7. Forogh B, Aslanpour H, Fallah E, Babaei-Ghazani A, Ebadi S. Adding high-frequency transcutaneous electrical nerve stimulation to the first phase of post anterior cruciate ligament reconstruction rehabilitation does not improve pain and function in young male athletes more than exercise alone: a randomized single-blind clinical trial. Disabil Rehabil 2019;41:514–22. https://doi.org/10.1080/09638288.2017.1399294.
8. Anderson AF, Lipscomb AB. Analysis of rehabilitation techniques after anterior cruciate reconstruction. Am J Sports Med 1989;17:154–60. https://doi.org/10.1177/036354658901700203.
9. Ilfeld BM, Said ET, Finneran JJ, Sztain JF, Abramson WB, Gabriel RA, et al. Ultrasound-Guided Percutaneous Peripheral Nerve Stimulation: Neuromodulation of the Femoral Nerve for Postoperative Analgesia Following Ambulatory Anterior Cruciate Ligament Reconstruction: A Proof of Concept Study. Neuromodulation J Int Neuromodulation Soc 2019;22:621–9. https://doi.org/10.1111/ner.12851.
10. Koyonos L, Owsley K, Vollmer E, Limpisvasti O, Gambardella R. Preoperative cryotherapy use in anterior cruciate ligament reconstruction. J Knee Surg 2014;27:479–84. https://doi.org/10.1055/s-0034-1367730.
11. Logerstedt D, Grindem H, Lynch A, Eitzen I, Engebretsen L, Risberg MA, et al. Single-Legged Hop Tests as Predictors of Self-Reported Knee Function After Anterior Cruciate Ligament Reconstruction: The Delaware-Oslo ACL Cohort Study. Am J Sports Med 2012;40:2348–56. https://doi.org/10.1177/0363546512457551.
12. Eitzen I, Holm I, Risberg MA. Preoperative quadriceps strength is a significant predictor of knee function two years after anterior cruciate ligament reconstruction. Br J Sports Med 2009;43:371–6. https://doi.org/10.1136/bjsm.2008.057059.
13. Sinacore JA, Evans AM, Lynch BN, Joreitz RE, Irrgang JJ, Lynch AD. Diagnostic Accuracy of Handheld Dynamometry and 1-Repetition-Maximum Tests for Identifying Meaningful Quadriceps Strength Asymmetries. J Orthop Sports Phys Ther 2017;47:97–107. https://doi.org/10.2519/jospt.2017.6651.
14. Vidmar MF, Baroni BM, Michelin AF, Mezzomo M, Lugokenski R, Pimentel GL, et al. Isokinetic eccentric training is more effective than constant load eccentric training for quadriceps rehabilitation following anterior cruciate ligament reconstruction: a randomized controlled trial. Braz J Phys Ther 2020;24:424–32. https://doi.org/10.1016/j.bjpt.2019.07.003.